Chapter 3

Withering Core Competency for the Large Corporation in an Open Innovation World?

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1. Introduction

By the early 1990s, it had become broadly acknowledged that large technology-intensive companies, in order to achieve sustainable competitive advantage, should stick to their core technological competencies, exploit these in the development of critical components and product architectures within their core business areas, and pursue opportunities for diversification into technology-related product markets. In several ways this strategic "wisdom" represented a substantial change in the mental models and practices of corporate strategy that had prevailed during the previous decades. First, it reflected a break away from the tendencies in the 1960s and 70's towards unrelated business diversification based on portfolio thinking, particularly in the U.S. (Porter, 1987). Secondly, this new strategic perspective generally assumed a more introvert orientation than was the case in the Porterian positioning perspective that had dominated strategic theory and practice during the 1980s. In emphasizing the role of distinctive and company-wide technological competencies as the basic driver for long-term competitiveness, this strategic reorientation represented a clear inspiration from the coherent and technology-based strategies of Japanese companies of the 1970s and 80s and a critique of the fragmented strategies of divisionalized U.S. companies.

However, recent changes in the context for technological innovation have significantly contributed to undermine the validity of some of the strategy imperatives of the early 1990s. These changes are associated with increasing vertical disintegration, outsourcing, modularization, use of open standards, and the growth of the market for specialized technology. "Open Innovation" (Chesbrough, 2003) can be considered an *organizational* innovation by which large companies seek to adapt to these changes. But what has happened to the core competency perspective?

In order to better answer this question, we shall systematically apply two sets of concepts for understanding technological knowledge. The first set of concepts comprise a distinction between narrowly specialized technological capabilities, and integrative competencies, including capacities for systems integration and for reconfiguring and building internal and external capabilities to address changing environments. The second set of concepts entails the distinction, suggested by Nelson (1998), between "bodies of understanding", abstract knowledge in technical fields, and "bodies of practice", context-specific knowledge associated with the practice of product or process innovation. One important aspect of the changing environment for large companies has been the tendency for new "bodies of understanding" and specialized technological knowledge to emerge in small firms. This means that small firms often develop new agendas for technology-based business opportunities for large firms, and in order to explore and exploit these opportunities, large innovative firms must put greater emphasis on the dynamic/adaptive, open/extrovert, and systems integration sides of their competencies than what is traditionally associated with the core competency perspective.

The chapter contains three sections. Section 2 gives an outline of the dominant logics of corporate strategy and innovation in the late 1980s and early 1990s. This is done through a review of the most important literature on these matters from that period. In particular one stream of literature was associated with the emerging resource- and knowledge-based view of the firm and its strategy and focused on (core) competencies, vertical integration and technology-related diversification (e.g., Prahalad and Hamel, 1990). Introvert modes of innovation were argued to be the standards to be met for large successful companies. However, other research streams did presage the notion of open innovation and addressed issues such as absorptive capacity (Cohen & Levinthal, 1990, Rosenberg, 1990), complementary assets (Teece, 1986), and 5th generation innovation (Rothwell, 1994).

Section 3 reviews three interrelated empirical changes in the conditions for technological innovation during the last one or two decades and their likely impacts on the nature of (core) competencies for technological innovation in large companies. First, the general tendency towards vertical disintegration and the "unbundling" of the vertical corporate structure. Secondly, the tendency towards more diverse corporate technology profiles and more externally oriented and less cumulative technological competencies; and thirdly, the tendency for increasingly distributed and open modes of organizing R&D in large companies, including the increasing requirements for coordinating the innovation processes in and between large and small firms.

To illustrate the central issues raised in this chapter, section 4 presents and analyzes a case study on the current transformation in amplifier technology within the consumer electronics industry

2. Dominant logics on corporate strategy and innovation in the late 1980s and early 1990s

During the early 1990s the dominant perspectives on corporate strategy and innovation underwent significant changes that were reflected in both the management and academic literature as well as in the practices of corporate behavior. In this section, these perspectives are reviewed using the lenses of the most influential papers on these matters from the late 1980s to the early 1990s.

Perhaps most prominently these changes were featured by Prahalad and Hamel in their 1990-article in Harvard Business Review on the role of core competencies for large technology-intensive companies. They maintained that in order for such companies to perform successfully at the longer term, they would have to stick to a limited set of distinctive technological capabilities in which they could obtain specialization and synergistic economies and through which they would be able to deliver an ongoing flow of innovations to multiple product markets. The paper had a powerful impact on corporate managers' (and their consultants') general conception of what constituted the foundation for sustainable competitive advantage in large corporations. But it was also part of a broader wave of strategy literature that surfaced in the late 1980s and early 1990s, under the common term Resource-Based View (RBV). This literature provided theoretical and empirical support for the basic idea that competitive advantage stems from imperfectly imitable, imperfectly substitutable and imperfectly tradable, and valuable assets (Barney, 1986 and 1991; Dierickx and Cool, 1989; Grant, 1991; Peteraf, 1993). It formed a comprehensive critique of the two hitherto dominant perspectives in corporate strategy, portfolio-based strategy that flourished in the 1960s and 1970s, and the Porterian positioning view that prospered during the 1980s. The RBV was inconsistent with unrelated diversification strategies while providing support for competence-based strategies associated with related diversification strategies (Markides and Williamson, 1994). Likewise, much of the RBV literature criticized the predominant multidivisional mode of organizing the large company (the M-form), especially in its decentralized (Williamsonian) version, which was argued to lead to corporate fragmentation and short-termism and to undermine the capacity for developing core competencies and radical innovations (Chandler, 1991; Hedlund, 1994; Pavitt, 1991; Prahalad and Hamel, 1990; Teece et al., 1994; Christensen and Foss, 1997). Some level of central planning was needed to identify and build company-wide core competencies and to overcome the “tyranny of the SBU” (strategic business unit) (Prahalad and Hamel, 1990).

As Porter already in 1991 observed, much of the RBV literature shared an introvert inclination: *Your* company is, or should be, the best in what *your* company is doing, an inclination stimulating not only a high achievement spirit but also (potentially) a Not Invented Here arrogance.[1] That also accounted for the way technological innovation in large corporation was generally perceived, although Prahalad and Hamel (and many others) explicitly referred to the effectiveness with which Japanese firms during the 1970s and 80s acquired external knowledge as an important means of building core competencies.

While Prahalad and Hamel and much of the other RBV literature made strategic arguments for nurturing core competencies in order to leverage long-term innovative, hence competitive, performance, Henderson and Clark’s paper on Architectural Innovation from the same year (1990) addressed the more downstream issues of managing and organizing innovation in large companies. The paper obtained lasting impacts on the theory and practice of management of technological innovation, and in particular brought the issue of modularity and systems integration out of the narrow confines of design and engineering disciplines and into the broader strategy and management fields.

Henderson and Clark proposed a distinction between two levels of innovation, the component (or module) level and the architectural (or systemic level). This allowed them a more nuanced perspective on technological innovation by better specifying the well-established distinction between incremental and radical innovation and to add two new categories: modular and architectural innovation. Their empirical case studies pointed to particular difficulties for large companies in dealing with not only radical innovation (which is not surprising) but also architectural innovations that involve substantial systemic changes but no dramatic technical changes. Their explanation for the difficulties in managing architectural innovation was that existing product architectures tend to become ingrained in organizational routines and division of labor, the inertia of which provides a substantial barrier to architectural innovation – even when the cognitive barrier associated with the technological change is low. Accordingly, large companies would have to explicitly engage in organizational adaptations in dealing with such innovations, and this would require some element of centralized planning.

When scrutinizing Prahalad and Hamel’s(1990) paper, a duality emerges in their use of the term core competencies. Sometimes, core competencies are associated with company-wide and integrative competencies needed for developing architectural and radical innovations. Sometimes, they are associated with deep and narrowly specialized technological capabilities needed to develop core components. Henderson and Clark’s analysis makes it clear that there is no identity between the two categories. The distinction between the two corresponds to Christensen’s (1996, 2000) distinction between, on the one hand, a specialized, technical capability that reflects a team-based

[1] The relative introvertnes in much of the RBV-literature can be ascribed to its emphasis on criticising the strong extrovert bias of the positioning strategy school. This latter extrovertnes, however, was predominantly occupied with the external competitive environment, not the (potential) cooperative environment which later came strongly onto the agenda of both the strategy and innovation literature.

capacity to mobilize resources for particular productive activities, and, on the other hand, an (integrative) competence that reflect a higher-order managerial capacity of the firm to mobilize, harmonize and develop a diverse set of (tradable) resources and team-based capabilities to create value and competitive advantage at the systems level (e.g. in systemic products). We shall henceforth (in later sections) apply this analytical distinction as signifying two qualitatively different sets of (potentially) core capacities (capabilities and/or competencies).

Prior to Prahalad and Hamel's "embracing" of the integrative core competency perspective, Prahalad and Bettis (1986) wrote a paper on the dominant logics of companies. Here they raised the concern that the dominant logic might filter out important knowledge when that knowledge is not well-integrated into the corporate logic. In my parlance above, that sort of knowledge would exactly be the new, specialized and narrow capabilities emerging under the radar of the existing dominant logic, and eventually emerging to become a critical technology that will have to be aligned with existing or new integrative competencies. These concerns vanished in Prahalad and Hamel's later notion of (integrative) core competency, which was considered an unambiguously positive asset, but were later qualified by Leonard-Barton (1992) who argued that core competencies may turn into core rigidities, and indeed mostly do.[2]

Other concerns have later been raised by Williamson (1999) who states that the concept of core competency is expansive, elastic, and tends to be identified as an ex post "good" asset: "There being no apparatus by which to advise firms on when and how to reconfigure their core competencies, the arguments relies on ex post rationalization: show me a success story and I will show you (uncover) a core competence." (1093)

Despite variations, and some critical concerns among scholars in corporate strategy and management of innovation as well as among business consultants and analysts, there was a broadly shared view in the late 1980s and early 90s that the ideal large R&D-intensive company should incarnate a core competency view, control both the systemic and the most critical parts of the component level of innovation (the more simple parts should be outsourced), and be occupied with the need for ongoing organizational adaptation. That would imply a more coherent and synergistic organization than the one accounted for in the strictly multi-divisional structure (see also Christensen, 2000, Hedlund, 1994, and Markides and Williamson, 1994). Pavitt (2003) precisely points to the continuing importance of " …[d]ealing with an inevitably imperfect M-form organization, given the impossibility of neatly decomposing technological activities with pervasive applications into specific product divisions…" (p. 105). A focus on core competencies, technology-related diversification and fairly introvert modes of innovation seemed to be the standards to be met for the large company, and among the successful benchmark cases frequently mentioned in the literature at the time were companies such as IBM (prior to the crisis and strategic turnaround in the early 1990s), Intel, Texas Instruments, Ericsson, 3M, Philips, Siemens and large Japanese players such as Canon, Casio, Honda, NEC, Matsushita, Sharp and Sony.

This is not to say that there was no sense, during this period, of the need for external relations in corporate innovation. Two seminal papers, Teece's 1986-paper on Complementary Assets, and Levinthal and Cohen's 1990-paper on Absorptive Capacity, clearly precipitated later more open innovation perspectives. Teece (1986) made a distinction between technological innovation (per se) and the complementary assets required to commercialize the innovation. While he seems to assume

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[2] Thanks to Henry Chesbrough for suggesting these points.

that technological innovation is the outcome of R&D conducted by one firm, he develops a contingency framework, combining insights from resource-based and transaction cost theory, for determining whether complementary assets should be outsourced, accessed through alliances or licensing agreements, or developed in-house. The well-known phenomenon that many pioneers of technological innovation never capture a significant share of the rents from their innovations, is explained by these pioneers' tendency to overrate the strength of the appropriability regimes surrounding their innovations and to underestimate the strategic importance of complementary assets. Even if Teece gives examples of owners of complementary assets (mostly large companies) capturing the major rents from innovations pioneered by other firms, he takes the view of the pioneer, whether small or large, and doesn't expand his framework into a strategic analysis of large owners of complementary assets in search of (possibly) external technological innovation ideas, projects and technology entrepreneurs. This latter perspective has only more recently become a central part of an Open Innovation perspective.[3]

In their opening statement, Cohen and Levinthal (1990) placed Open Innovation (without using the term) as an upcoming agenda: "Outside sources of knowledge are often critical to the innovation process, whatever the organizational level at which the innovating unit is defined" (p. 128). The central idea in their paper is that internal R&D investment plays two functions, to provide improved and new technologies and innovations and to provide a capacity to absorb relevant knowledge emerging in the external environment. Hence, absorptive capacity is primarily seen as a byproduct of a firm's R&D investment. In the same vein, Rosenberg (1990) argues that an important reason why (some) large firms spend their own money on basic research, despite it having no or very little value as direct input to ongoing innovation, is that it positively impacts their capacity to integrate relevant, external science-based knowledge. Basic research may be thought of as "a ticket of admission to an information network" (p. 170) and "…a basic research capability is often indispensable in order to monitor and to evaluate research being conducted elsewhere" (p. 171). Both Cohen and Levinthal's and Rosenberg's arguments are grounded in the fundamental insight that R&D processes, and especially research processes, are inevitably associated with spillovers, and to build absorptive capacity through in-house R&D is one way of capturing spillovers from external R&D. Moreover, as argued by Rosenberg, large multi-business companies can better than small firms make internal use of spillovers from in-house research. Both papers show a certain bias in their discussion towards internal mechanisms that influence an organization's absorptive capacity, and Cohen and Levinthal articulate a skepticism towards more "open" forms of absorptive capacity: "The discussion thus far has focused on internal mechanisms that influence the organization's absorptive capacity. A question remains as to whether absorptive capacity needs to be internally developed or to what extent a firm may simply buy it via, for example, hiring new personnel, contracting for consulting services, or even through corporate acquisitions. We suggest that the effectiveness of such options is somewhat limited when the absorptive capacity in question is to be integrated with the firm's other activities. A critical component of the requisite absorptive capacity for certain types of information, such as those associated with product and process

[3] Christensen (1995, 1996) takes this discussion one step further by arguing that technological innovation (per se) is not just the outcome of some unitary R&D function, but the outcome of the mobilization of a specific constellation of innovative assets. Four generic innovative assets are delineated from Pavitt's (1984) taxonomy of firm-based technological trajectories: scientific research assets, process innovative assets, product innovative application assets, and aesthetic design assets. Most innovations involve more than one type of innovative assets (just like most innovations require more than one type of complementary asset for their commercialization), and firms may access some of these innovative assets externally. Likewise, most innovation requires the mobilization and integration of various specialized technological capabilities. Although the main focus of the papers is on firms' innovative asset profiles, the papers clearly precipitate a more explicitly Open Innovation perspective.

innovation, is often firm-specific and therefore cannot be bought and quickly integrated into the firm" (p. 135).

From the secure position of the hindsight, it is clear that Cohen and Levinthal underestimated the extent to which such more "open" mechanisms would come to penetrate many companies' mode of innovating and developing their absorptive capacity. Thus, for example, Lane and Lubatkin (1999) find that alliances can also develop absorptive capacity, and Mayer and Kenney (2004) demonstrate how Cisco since the early 1990s has successfully used acquisitions as a form of absorptive capacity, and, at least partially, a substitute for internal R&D. Cohen and Levinthal's concept of absorptive capacity is also limited to cover only knowledge areas related to or overlapping with those targeted by the firm's general R&D investments. If the firm wishes to acquire and use external knowledge that is unrelated to its current R&D activities, it must dedicate efforts exclusively to creating absorptive capacity, and Cohen and Levinthal state that firms are likely to underinvest in such areas (p. 149-50). In somewhat a contrast to this position, however, they also predict a need for companies in the future to expand the diversity of their absorptive capacity: "We also suggest… that as the fields underlying technical advance within an industry become more diverse, we may expect firms to increase their R&D as they develop absorptive capacity in each of the relevant fields. For example, as automobile manufacturing comes to draw more heavily on newer fields such as microelectronics and ceramics, we expect that manufacturers will expand their basic and applied research efforts to better evaluate and exploit new findings in these areas." (p. 148). As we shall see in section 3.2, this prediction has later been verified by empirical research.

More explicitly open innovation perspectives that treat spillovers as potential resources to be managed either by bringing in external spillovers (in the Cohen and Levinthal mode) or by fostering external utilization of internal spillovers through licensing, spinnoffs, etc., had to await yet another decade.

That external relations are needed in technological innovation, has for long been reflected in both the practice and theory of management of innovation (dealing with innovation at the project level and in the context of an R&D organization). Since the 1970s, much of the management of innovation literature has addressed the interactive, cross-disciplinary and (mostly) inter-organizational nature of innovative learning and searching (Rosenberg, 1982; Rothwell et al.,1974; von Hippel, 1988; Lundvall, 1992; Pavitt, 1998), and in his excellent review of generations of (somewhat different) modes of managing innovation, Rothwell (1994) clearly presages the notion of Open Innovation when, in the early 1990s, seeking to identify prevalent features in current streams of innovation practices (termed Fifth-Generation Innovation Process).

However, even if the importance of external relations were increasingly acknowledged, the predominant logic of innovation in especially large high-tech companies was introvert and proprietary (the technologically complex parts of innovation should be done in-house, while the simpler parts could be outsourced). In the following section, I shall argue that the emergence of increasingly open modes of managing technological innovation in large companies reflects substantial changes in the external conditions for conducting technological innovation.

3. Empirical insights on innovative dynamics since early 1990s

In the years since the papers by Prahalad and Hamel and Henderson and Clark appeared, much seems to have changed. Below, we shall address three interrelated aspects of these changes: First, the general tendency towards vertical disintegration (section 3.1), secondly, the tendencies in the proliferation of technology bases of large R&D-intensive companies (section 3.2), and thirdly, the changes in the mode of organizing R&D in large companies (section 3.3).

3.1 The general tendency towards vertical disintegration

> *It has become exceedingly clear that the late twentieth (and now early twenty-first) centuries are witnessing a revolution at least as important as, but quite different from, the one Chandler described. Strikingly, the animating principle of this new revolution is precisely the unmaking of Chandler's revolution. Rather than seeing the continued dominance of multi-unit firms in which managerial control spans a large number of vertical stages, we are seeing a dramatic increase in vertical specialization – a thoroughgoing 'de-verticalization' that is affecting the traditional Chandlerian industries as much as the high-tech firms of the late twentieth century.*
> (Langlois, 2003, p. 352)

Likewise, Sturgeon (2002) argues that a new mode of industrial organization, characterized by increasing modularity, specialization, outsourcing and networking, has been driving American industrial capitalism (and probably most other parts of modern capitalism) since the 1990s. Two interrelated economic and institutional dynamics seem to underly this change: First, in recent decades the world has seen dramatic increases in population and income as well as reductions of barriers to trade implying increasing division of labor and increased coordination through "the market".[4] Secondly, an important aspect of this development has been the emergence of market-supporting institutions (North, 1990) reducing the costs of coordinating through the market. The powerful trend in recent years for open market standards (Steinmueller, 2003) to penetrate former domains of proprietary company-based standards is one example of the emergence of such a market-supporting institution. The rise and diffusion of the venture capital institution to promote technological entrepreneurship represent another important case. In combination with the increasing scope for secure and alienable intellectual property rights, these institutional dynamics have undoubtedly been critical drivers in the enhanced effectiveness of markets for specialized technological knowledge, whether this knowledge takes the form of a patent, an intangible asset (e.g. a software program), or a component to fit into an end-product (Arora et al., 2001, 2001a ??). In any case, the shaping of (much more) well-functioning markets for technology has fuelled the generation of small technology entrepreneurs dedicated to the development of and commercial exploitation of highly specialized technological capabilities. Their "core competency" (cf. previous discussion in section 2) thus only reflects the specialized and deep side of Prahalad and Hamel's double-sided concept of core competency.

Also the very nature of technological change seems to have reinforced vertical disintegration in the sense, as argued by Langlois (2003), that technical change generally tends to reduce (minimum efficient) scale, making it possible and profitable for small firms to drive technological innovations in many areas and thereby "unbundle" the vertical corporate structure.[5]

[4] Langlois (2003) uses the term market in a broad sense encompassing "… a wide range of forms many of which are not anonymous spot contracts but rather have 'firm-like' characteristics of duration, trust, and the transfer of rich information (p. 351).

[5] Moreover, some have argued that while coordination technologies (associated with information processing, communication, and transportation) previously tended to favor internal organization, they have more recently favored market dynamics (Malone and Laubacher, 1998): "The coordination technologies of the industrial area – the train and the telegraph, the automobile and the telephone, the mainframe computer – made internal transactions not only possible but advantageous" (p. 147). With more recent information and communication technologies, most notably the Internet,

The tendency towards vertical disintegration, modularization, outsourcing and networking gives rise to more rich and open innovation models: ”Rather than being limited to the internal capabilities of even the most capable Chandlerian corporation, a modular system can benefit from the *external capabilities* of the entire economy” (Langlois, 2003: 375). It can generate external *economies* of scope (Langlois and Robertson, 1995), thus allow more entry points for innovation.

These overall tendencies have implied that large companies have had to give way to specialized suppliers (often independent start-ups, sometimes later to be acquired by large companies) at the level of component-based innovation and beyond (sub-components or knowledge or service inputs in intangible form). If this also implies giving up front positions in an increasing array of relevant technological specialty fields, one can ask whether large incumbents may still be able to maintain the other side of the classical notion of core competency, those stemming from interaction and interfaces across components and their underlying capabilities? Or to use the concepts of Henderson and Clark, can incumbents maintain superior abilities to innovate at the architectural level when they, at least partially, have had to surrender at the component level? In order to come closer to answering this question, we shall take a look at what we know about the proliferation of corporate technology bases.

3.2 Tendencies in the proliferation of corporate technology bases

As stated above, the nature of technological change in recent decades seems to have favored vertical disintegration and market dynamics. But two other aspects in the accumulation of technological knowledge have, in combination, given rise to non-trivial challenges in the technology strategies of large firms. The growth in global R&D investment (Kodamoa, 1992) leads to an increasing number of technical fields providing new opportunities for problem solving, and moreover, a tendency for specialized knowledge in each field to deepen leading to ongoing enhancement of the opportunities for performance improvements in problem solving. Altogether, we witness an expansion in the global technological opportunity set, an expansion most likely to be exponential in times of global market expansion and improved effectiveness of markets for specialized technology, as witnessed since the 1980s as the Asian Tigers, China and Eastern Europe have become strongly enrolled in the global market economy, and as institutions for supporting technology markets have been strengthened.

However, companies can generally not (at least not on an enduring basis) expand their R&D investments at the same rate due to budgetary constraints and limited organizational capacity of firms to absorb, “digest” and integrate new knowledge. With R&D funding in large incumbents being constant (or slowly growing) and the global technology base rapidly expanding, incumbents must acknowledge that an increasing share of relevant technological knowledge is being accumulated externally, and they will have to chose between (at the extremes) whether they strive for world-leading positions within in one or a few fields or wish to obtain some (fairly superficial) level of knowledge in many areas.

How have large R&D-intensive companies responded to these strategic dilemmas? Are they sticking to a few core areas in accordance with a core competency perspective, or do they try to follow suite into a broader array of technologies more in accordance with an architectural view and

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the value of centralized decision making has decreased. While these arguments seem intriguing, only a more profound comparative analysis could discern whether external markets are indeed favored over internal coordination by these technologies.

the proposition of increasing diversity of technical change, as predicted by Cohen and Levinthal (1990) (cf. section 2). Several empirical studies based primarily on patent data (covering especially the 1980s and early 1990s) have shown that within large technology-intensive companies, technology diversification has been more pronounced than product diversification (Granstrand, 1982; Granstrand and Sjölander, 1990; Granstrand et al, 1997; Gambardella and Torrisi, 1998; Patel and Pavitt, 1997; Pavitt et al., 1989). While their technological diversity has tended to increase, their product range has typically become narrower. Among the world's largest technology-intensive companies, by far the most had expanded the number of technical fields in which they are active from the early 1970s to the late 1980s and have significant competencies outside their distinctive technologies (Granstrand et al., 1997).

In interpreting their empirical data (both patent statistics and case studies), Granstrand et al. (1997:13) state the following: "Large firms built up and maintained a broad technology base in order to explore and experiment with new technologies for possible deployment in the future. The creation of corporate competencies in new fields was a dynamic process of learning, often requiring a combination of external technology acquisition and in-house technological activities and usually resulting in an increase in R&D expenditures. While technology sourcing was rarely a substitute for in-house R&D, it was an important complement to it." Large companies clearly also had a focus on a number of "core" technological competencies[6], as recommended by Prahalad and Hamel, but in addition they sustained an increasing and broader (if less deep) set of technological capabilities, what Granstrand et al. (1997) term background competence enabling the company to coordinate and benefit from technical change (and exchange) in its supply chain, and moreover explored new opportunities emerging from scientific and technological breakthroughs. In short, they had become Multi-Technology firms (Granstrand et al, 1997, Patel and Pavitt, 1997).

The studies furthermore show that firms producing similar products tended to master similar technologies. These results are contemplated by Patel and Pavitt (1997) as follows: "[G]iven that some technologies underpin a range of competing and differentiated product configurations, product variety in an industry is compatible with technological homogeneity" (p. 154). This interpretation, they further argue, "…is compatible in the sphere of product development with variety, experimentation, social shaping, and trade-offs at the margin, but in the sphere of technology, it is underpinned by quite rigid one-to-one technological imperatives" (p. 155). Pavitt (1998) further elaborates on this interpretation by relating to Nelson's (1998) distinction between two complementary forms of knowledge, "bodies of understanding", abstract knowledge underlying technological fields and giving rise to patenting and publishing, and "bodies of practice", context-specific knowledge related to engineers' experience and firms' practices in product and process development. The former is reflected in the technology profiles as indicated by the patent studies, while the latter is interpreted as "organizational knowledge", and Pavitt more broadly concludes that competitive advantage is primarily based on *organizational* characteristics of the firm (e.g. interactions between different functional departments) rather than on distinctive technological competencies. This interpretation is contested by Nesta and Dibiaggio (2003) who make an empirical account of Nelson's analytical distinction in their study of the dynamics of technology profiles in biotech firms. They find that even if these firms also tend to develop similar profiles in terms of technical disciplines (bodies of understanding), they diverge in terms of the particularities of their technology combinations which are used as indicators of application- and experience-based competencies (bodies of practice). While this analysis specifies the role of (hence saves *some* role

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[6] Indicated as being technical fields in which the firm has a relatively high share of its patenting plus a relatively high share of total (global) patenting (p. 14).

for) technology as a source of competitive advantage, it does not contest the proposition that organizational characteristics are also important. Generally, the results of the studies discussed above support the resource-based and Smithian proposition that firms specialize in given activities, but they do not support the stronger proposition that successful firms primarily tend to focus on a few distinctive "core technologies" as would be expected following the more narrow conception of core competency (cf. the discussion in section 2). "Core technologies" play a significant but relatively decreasing role in the technology profiles (bodies of understanding) of large companies, while they show increasing involvement in non-core technology areas, "background competencies" and emerging areas of knowledge. Most of these studies, however, deal with industry averages and mask inter-industry differences between firms[7], and they cannot say much about the possible role of (core) competencies in the broad sense of being (more or less) company-wide integrative competencies.

A richer picture of innovative and technological competencies of large firms has been emerging from a number of detailed case studies (Brusoni et al., 2001; Chesbrough, 2003; Ernst, 2003; Gawer and Cusumano, 2002; Iansiti, 1998; Prencipe, 1997 and 2000). Generally, these studies have addressed the increasingly important role of large companies as system integrators, innovation architects, platform leaders, standards creators, or in short, market coordinators of increasingly distributed and vertically disintegrated value chains. Prencipe (1997, 2000) found that aircraft engine manufacturers retain knowledge about components whose production is outsourced. Thus, one engine maker developed capabilities to specify and test externally produced components, and to coordinate the integration of new technologies. Brusoni et al. (2001), who further explore the development of the aircraft engine control systems, find evidence that such development requires the mobilization and maintenance of a loosely coupled network organization: "A key characteristic of a loosely coupled network organization is the presence of a systems integrator firm that outsources detailed design and manufacturing to specialized suppliers while maintaining in house concept design and systems integration capabilities to coordinate the work (R&D, design, and manufacturing) of suppliers" (p. 617-18).

The nature of this "modern" concept of integrative competencies differs in two respects from that of Prahalad and Hamel's (1990) company-wide core competencies. First, from the technology side, integrative competencies are not as strongly associated with particular areas of technological knowledge ("bodies of understanding") as the case is with Prahalad and Hamel's core competencies. Integrative competencies rather relate to application-specific knowledge ("bodies of practice") engaged in product design (both of components and architectures), including the processes by which firms synthesize and acquire knowledge resources and transform these resources into applications (Kogut and Zander, 1992). Secondly, from the managerial and organizational side, the integrative competencies need to be responsive and adaptive to changing external contingencies (e.g. changes in component markets, the emergence of new external technologies), while "core competencies" are usually assumed to be subject to long-term strategies for cumulative competence building and improvement. While the former side relates well to recent research into systems integration competencies (Prencipe et al., 2003), the latter side is much closer to the concept of dynamic capabilities (Teece et al., 1997, Eisenhardt and Martin, 2000) by which firm managers "integrate, build, and reconfigure internal and external competencies to address rapidly changing environments" (Teece et al., 1997: 516). And more generally, this notion of

[7] Thanks to Connie Helfat for pointing to this issue.

integrative competencies is better aligned with Open Innovation strategies than the core competency notion is.

3.3 The organization of corporate R&D and the coordination with technology specialists
"Open Innovation" (Chesbrough, 2003) can be conceived as an *organizational* innovation in the way large companies try to come to grips with the changes in the context for technological innovation that have been outlined above.[8] This organizational innovation is partially overlapping with and extending the scope of earlier organizational changes since the 1980s from the "central R&D lab" mode that became prevalent in large high-tech companies after World War II to an increasingly distributed mode through a wave of downsizing of central labs and delegation of responsibility for technical innovation to product divisions and subsidiaries (Christensen, 2002; Coombs and Richards, 1993). A particular feature of this transformation has been the tendency, although somewhat reluctantly, towards internationalization of corporate R&D (Boutellier et al., 2000; Gerybadze and Reger, 1999; Kuemmerle, 1998; Kim et al., 2003).

Neither in the case of increasingly distributed corporate innovation nor the case of open innovation, are we dealing with one paradigm replacing another. While the overall trend in the 1980s seems to have involved a predominant process of decentralization of R&D to lower levels in the corporate structure, hence a weakening (at times a full elimination) of the previously dominant position of the central lab, there are no evidence that this trend has continued to create a dominant model of fully decentralized and distributed R&D. Rather, according to two surveys of R&D-intensive companies in 1994 and 2001 by Industrial Research Institute (here referred from Argyres and Silverman, 2004), the largest group of the surveyed companies (about 60 percent) in both years reported hybrid structures, while only a small minority (about 10 percent) reported a decentralized structure and a larger group (about 30 percent) a centralized structure. Thus, many corporations still maintain quite powerful central labs and experiment with different ways of coordinating R&D at the central and decentral levels (Argyres, 1995; Argyres and Silverman, 2004; Coombs and Richards, 1993; Christensen, 2002; Tidd et al., 2005).

Likewise, corporations do not externalize all research and innovation in the transition from relatively more closed to more open innovation. A recent study by Laursen and Salter (2004) indicates that while external relations are critical for successful management of innovation, there are limits to the scope of external relations that companies can effectively manage in innovation projects. Furthermore, neither the distributed nor the open paradigm of innovation should lead to the interpretation that all companies act according to herd behavior and practice identical or very similar strategies for and modes of governing innovation. Huge variation exists across as well as within industries and companies are not only moving in a one-way direction towards delegation and externalization, but may, under various contingencies, also change the direction and partially recentralize and internalize.

[8] Organizational innovation is here defined in a broad sense as comprising a general set of organizational features that emerge as a response, among an increasing and eventually substantial part of a given population of organizations, to the emergence of either external or internal incongruities (Christensen, 2002). A well-researched other example of the same kind of organizational innovation, is the innovation, in the early twentieth century, of the multidivisional organization (Chandler, 1962). In other words, I do not by the term organizational innovation adhere to more specific organizational changes such as those taking place on a more regular basis within, for instance, an Open Innovation model, or a multidivisional form.

An important premise for large high-tech companies in an increasingly Open Innovation world is that superior technological capabilities are increasingly emerging outside the confines of large companies, in particular in specialized suppliers of IP, components or parts of components. As markets for technology have improved, we increasingly witness a division of labor between, on the one hand, technology entrepreneurs, often in collaboration with universities and other research institutions, providing emergent, deep technological knowledge and capabilities, and, on the other hand, large companies providing integrative, and dynamic competencies, as well as complementary operational assets for large-scale production, distribution, sales and services within their industries. While the advanced technology entrepreneurs develop the technologies in their more abstract form ("bodies of understanding") and experiment with early adaptation of the knowledge to practical applications (e.g. prototypes, early products/components for high-end markets), the large companies further transform the technology into application-specific use ("bodies of practice") which, among other things, imply the use of modularity tools for systems integration and the experience-based maturing of the technology for large-scale through-put. The strength of large firms, however, often extends beyond the scope of their innovative assets (Christensen, 1995, 1996) and capacities for systems integration. As has been well-established knowledge since Teece's 1986-paper, large companies also tend to be endowed with powerful complementary assets for large-scale commercialization of innovation, even if these more operational types of assets (in particularly manufacturing assets) are also increasingly being subject to "de-verticalization". Thus, from an innovative asset perspective, large companies will have to look out for external (as well as internal) innovative ideas, new technologies, concepts or IPs to align with and integrate into new or improved product architectures. And from a complementary asset perspective, large companies will have to look out for external (and internal) innovations in search of, and sometimes in exchange for, complementary assets.[9]

4. Open Innovation: The case of the digital amplifier in consumer electronics[10]

The industrial and strategic dynamics underlying the recent breakthrough of a new amplification technology, termed Class D or switched amplification, can provide us with an improved empirical understanding of the critical issues discussed in this chapter. More specifically, the case can illustrate

- the way knowledge for leveraging a new, complex technology can be decomposed into a set of specialized and deep capabilities, on the one hand, and particular forms of integrative competencies, on the other hand;
- how the division of knowledge between small technology-based firms and large incumbents involve a division of labor in terms of the roles in developing, maturing and commercializing the new technology; and
- the diversity of more or less open innovation strategies conducted by large incumbents engaged in the development of the same new technology.

[9] According to Teece (1986), complementary assets are required in weak appropriablity regimes, when strong they are not required. Most technology entrepreneurs have limited access to complementary assets and limited resources (financially and competence-wise) for building complementary assets. In cases of tight appropriability regimes, which are rare, the technology provider may gain a good return on its technology from a licensing contract with little risk of having the technology expropriated by the licensee (and by others). Still a good return may also accrue to the licensee, due to synergistic economies from integrating the technology into a complex system of other technologies and complementary assets.

[10] This case is based on a more detailed account of the innovation dynamics of switched/digital amplification technology in Christensen et al. (2005).

4.1 Specifics about Class D technology and its market prospects
Since the mid-1990s a radically different approach to amplification, class D or switched amplification, has been subject to a major scientific, technological and commercial breakthrough.[11] "*It marks a clear break with tradition, and incidentally demands an almost entirely different set of design skills than those we are used to seeing in analog electronics generally*" (Sweeney, 2004, p. 5). While known at least in conceptual form for more than 40 years, class D amplifiers had never been successfully applied in an audio context. Even if early class D amplifiers offered big advantages as compared to conventional class A/B amplifiers in terms of space efficiency, energy efficiency, and low heat dissipation, they also suffered from severe fidelity and reliability problems and tended to burn up due to overload or radiate unacceptable amounts of interference (Sweeney, 2004, p. 7). However, as these problems have recently been overcome, we are currently witnessing a technological transformation comparable with the solid state revolution in amplification some 50 years ago. In less than ten years, since the mid 1990s, this technology has undergone a condensed cycle from a stage of embryonic experimentation pioneered by university scientists and small startups, to a fairly mature stage characterized by chips-based technology and mass production controlled, to a great extent, by large incumbents (Christensen et al., 2005).

Class D amplifiers can be embedded in either discrete modules (based on discrete standard components) or in chip-based modules (based on integrated components). The former are high-cost/performance amplifiers which have since the late 1990s penetrated parts of the high-end niche markets, while the latter have since 2000 penetrated the mid-level mass markets, in particular the DVD receiver market, and increasingly are moving down towards the lower-end markets. The large audio product markets are generally still clearly dominated by conventional technology. Rodman & Renshaw Equity Research estimates the size of the analog amplifier market between $2.1 billion to 3.0 billion as of 2003 and the size of the digital amplifier market between $80 to $100 million, or only 2-3% of the total amplifier market (Rodman & Renshaw, 2003). This level is expected to increase to $515 million, or 15% of the total amplifier market by 2006. Forward Concept (Sweeney, 2004) estimates the total class D amplifier 2003-market at $84 million, and forecasts steep growth rates as cell phones, automotive audio and other markets are expected to kick in. By 2008, the market is expected to be above $800 million.

4.2 Competence requirements for Class D innovation
Even if the traditional class A/B amplifiers and the new class D amplifiers share some components, such as power supplies, filters and semiconductors, the knowledge underlying their respective core components and systemic interdependencies differ in fundamental ways. Thus, despite some technological heredity (Metcalfe and Gibbons, 1989) in peripheral parts of the amplifier, this new technology reflects a radical competence-destroying discontinuity signifying substantial cognitive barriers (Tushman and Anderson, 1986) to overcome for amplifier incumbents.

During the embryonic stage of this technology (mid- to late 1990s), successful innovation in class D technology required the alignment not only of three complementary types of innovative assets: science-based assets, high-tech product design assets, and lead-user assets (Christensen, 1995; von

[11] Class D amplifiers produce a power output by modulating a carrier frequency with an audio signal through a technical principle termed Pulse Width Modulation (PWM). A conventional class D amplifier is not digital, because the width of the pulses is continuously variable rather than variable according to some given number of discrete values. However, through various modifications (in which so-called Pulse Code Modulated input signals are transformed into the PWM format), it is possible to make class D amplifiers truly digital. In the final stage of the audio signal path, a passive low-pass filter transforms the PWM signal into an analog power signal that can drive a speaker.

Hippel, 1988), but also the alignment of operational types of complementary assets such as manufacturing, distribution and marketing (Teece, 1986). The knowledge base necessary for leveraging the functionalities of class D technology to acceptable performance standards was (and still is) highly complex. To design a full amplifier system, including integrating a class D amplifier chip with high-power transistors and other components, requires capabilities in fields such as signal modulation, electro magnetic compatibility (EMC), error correction and electric power engineering, chip design as well as competencies in optimizing and integrating the components associated with the new technology into a complete amplifier module, and the integration of this module into the particular end-product system (Lammers and Ohr, 2003). These requirements thus involve both deep, specialized capabilities in numerous technical fields with a bias towards "bodies of understanding", and complex system integration competencies with a bias towards "bodies of practice" – and both are very different from those at work in traditional amplification technology. Hence, the digital amplifier represented an engineering challenge beyond the existing capacities of most amplifier incumbents.

4.3 The pioneering role of technology entrepreneurs

The breakthrough in Class D amplification occurred as a result of basic university research, and at the frontier of this breakthrough was a research community lead by Professor Michael A.E. Andersen at Institute of Electric Power Engineering at the Technical University of Denmark, where the research culminated in two spin-off ventures: Toccata Technology and ICEpower. Both ventures were founded on a strong IP base of patents reflecting the technical novelties obtained through the founders' previous PhD-projects at Technical University of Denmark. Together with the US-based startup, Tripath, and Dutch Philips, Toccata and ICEpower (owned by Bang & Olufsen) were the early pioneers of class D amplifiers, launching products in 1998 and 1999.

Figure 2 shows the cumulative number of firms' first launches over the period 1997-2004. By early 2004, 25 firms with at least some activity in the area have been registered. They can be divided into three groups: First, a number of small startup ventures, including, beyond the previously mentioned early pioneers, Apogee (USA), JAM Technologies (USA), and NeoFidelity (Korea); Second, a group of large vendors of semiconductors and digital signal processing chips, for example National Semiconductor, STMicroelectronics and Texas Instruments; and third, a few large-scale Audio-Visual (AV) OEMs, including first of all Philips and Sony.

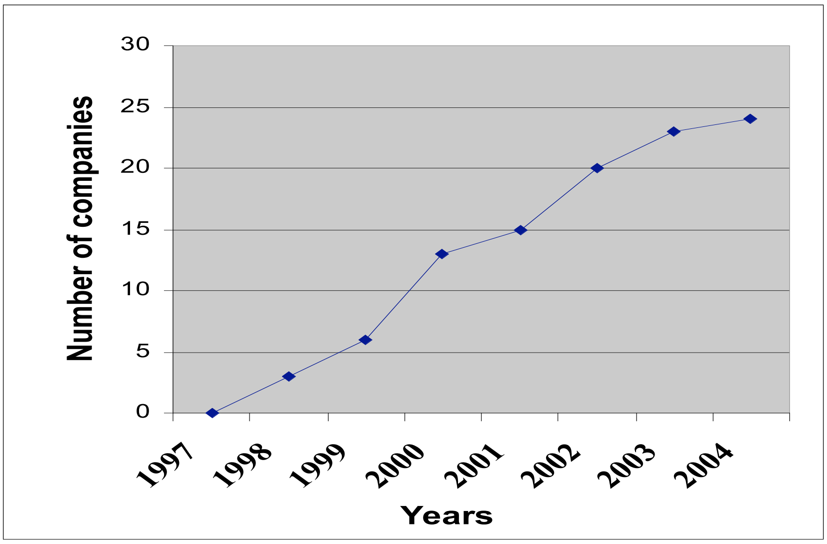

Figure 4.1. Accumulated number of firms' first product launches within class D amplification

Small technology-based firms have been able to set the agenda for this upcoming technological innovation founded on a core of highly specialized and deep technical knowledge. Several of the startups did not provide any amplifier products but only IP assets covering part of the class D value chain. Hence, in order to become technologically mature and commercially viable, the innovation process has required complementary contributions from different types of players. In the early stage of the technology cycle, the major challenge to small high-tech startups was twofold. First, to establish a deep technology base that could be well-protected from quick imitation or replication. Secondly, through codification, documentation and communication to make this technology base attractive in the eyes of one or more complementary players and try to persuade them to engage in cooperative efforts to create functional solutions and to test market potentials. Such partnership may form the beginning of an interactive and evolving learning process based on a mutual recognition of the opportunities for innovative synergies between the two parties. This is exemplified by Apogee's partnership with STMicroelectronics. Alternatively, the partnership may be the first step towards a takeover of the technology entrepreneur by a larger incumbent as the case was with Texas Instrument's takeover of Toccata. The most successful of these technology entrepreneurs were able to establish a fairly strong regime of appropriability around their technological knowledge due to a combination of patents, a high level of complexity of the knowledge base, and the fact that this knowledge was generally unrelated to the relevant knowledge bases of the prospective large competitors. They were moreover able to access complementary assets (both innovative and operational) through partnerships with (or eventually takeovers by) large incumbents.

These kinds of early-stage dynamics dominated by technology entrepreneurs have been well documented in the literature (for a recent case, see Giarranta, 2004), but less attention has been addressed to the particularities of the "core competencies" of these firms and especially the fact that their innovative practices not only require deep and specialized technological capabilities, but *also* managerial and organizational capabilities to link up with owners of critical complementary assets *without* loosing out of their capacity to capture rents from their technological knowledge. In other words, small high-tech startups are bound to embrace some form of open innovation involving in-depth technological knowledge *and* skills in managing external relations (for an extended analysis, see Christensen et al., 2005).

Next we shall more closely address the particularities of the "core competencies" of the large incumbents that eventually engaged in innovative endeavors in class D amplification, and how these competencies were associated with (more or less) open innovation procedures.

4.4 Modes of (more or less) Open Innovation response from large incumbents
For the large players with strong engagements in class A/B amplification, there were good reasons to expect that they would aggressively try to take control over this new technology. The conventional amplifier represented a critical module in any AV product,[12] hence to give up on the new amplifier paradigm would not only imply the loss of control over a critical module, but also the loss of a potentially large source of revenue and profits.

Table 4.1. shows the response (registered by mid 2004) to the new amplifier technology from three categories of large incumbents: Large-scale semiconductor firms with strong positions in conventional A/B amplifiers, large-scale AV OEMs likewise with strong positions in A/B amplifiers, and finally large-scale AV OEMs with no or weak positions in A/B amplifiers.

Table 4.1. The Response of categories of incumbents to the challenge of switched amplification technology

Category of firms	**Firms**	**Response to Class D amplification technology**
Semiconductor companies with a strong position in AB amplifier technology	National Semiconductor	Slow response – few products
	STMicroelectronics	Strong position with Apogee and Tripath in chip-based amplifiers
	Texas Instruments	Strong position in chip-based amplifiers
AV OEMs with a strong position in AB amplifier technology	Philips	Internal technology – few products
	Sanyo	Slow response/partnership with ICEpower
	Toshiba	No digital amplification technology
Large AV OEMs without a strong position in AB amplifier technology	LG Electronics	External technology – e.g. Pulsus
	Matsushita	External technology – e.g. Tripath
	Samsung	External technology – e.g. NeoFidelity
	Sharp	Internal 1-bit technology
	Sony	Internal module – external chips

[12] The amplifier module would typically account for about 20-30% of the total sales price of a traditional home stereo system.

The two former categories comprise those firms with the strongest incentives to jump unto the new paradigm and indeed, with the exception of Toshiba, they have all engaged in development activities in class D technology. Toshiba's reluctance may be explained by the fact that Toshiba is operating in the low-price AV markets which has not yet faced any competitive threat from class D technology. The firms in the last category had already (at least to a large extent) outsourced traditional A/B amplifiers, and have, with the exception of Sony, so far also primarily been using external class D technology.[13]

Table 4.2. shows the substantial variety of innovation strategies pursued by the five AV and semiconductor incumbents involved in class D innovation. In terms of timing, we can identify three early, dedicated movers (Texas Instruments, STMicroelectronics and Sony), one early but slow mover (Philips), and one late mover (Sanyo). In terms of external/internal orientation, three of the firms (Texas Instruments, STMicroelectronics and Sanyo) have demonstrated a strong external orientation (acquisition-based, partnership or licensing oriented), while two firms (Sony and Philips) have exerted a more internal approach.

Table 4.2. Innovation strategies of incumbents engaging in class D development.

Timing	External Focus		Internal Focus	
	Acquisition-based	Partnership/ Licensing-based	Tight system Integration	Closed style
Early/dedicated movers	Texas Instruments	STMicroelectronics/ Apogee	Sony	
Early/slow mover				Philips
Late mover		Sanyo		

As of early 2005, the commercial leaders are Texas Instruments and STMicroelectronics, the semiconductor firms that were early movers *and* strongly externally focused. Below, we shall especially address the particular strategies pursued by each of these companies, in particular TI.

STMicroelectronics and Texas Instruments (henceforth TI), have managed to establish dominant positions in the chip-based digital amplification markets. Prior to entering the class D market, both companies were heavily embedded in the old solid state amplification paradigm and witnessed small high-tech frontrunners such as ICEpower and Toccata Technology leverage the new technology and offer class D IP and early products to the high-end market niches. They were early movers in the sense that they fully engaged in catch-up efforts as soon as the small pioneers had demonstrated the viability of the new technology by the end of the 1990s and *before* any substantial

[13] Interestingly, Sony developed an early Class D amplifier already in the 1970s. However, due to gaps in technical know-how, which have only been filled during the 1990s, this amplifier was error prone and failed to meet the market requirements.

market inroads had been obtained. Both companies used open innovation strategies, STMicroelectronics based its strategy around a long-term alliance with the technology specialist Apogee, while TI demonstrated a concerted set of actions to get access to complementary, innovative assets through acquisitions (it already possessed innovative assets in chip design and the necessary operational complementary assets). First, TI acquired Unitrode, a major supplier of power management components and thereby obtained a strong position in catalog analog semiconductors for power management. Secondly, TI acquired Power Trends, a leading supplier in the fast-growing market for point-of-use power solutions. In part through these acquisitions, TI found that it had obtained key components and knowledge necessary for transferring fully digital class D amplification into chip design. Both in the area of chip design and chip manufacturing, TI was recognized as one of the world's leading companies, but it lacked key knowledge associated with digital/class D amplification. This knowledge was initially sought acquired through a licensing contract in 1999 with the technology entrepreneur, Toccata (one year exclusivity and to IC manufacturing only). However, in March 2000, following a mutual recognition that the technology transfer and the related chip design project was proving more complex than expected, TI came up with an acquisition offer and, after some negotiations, acquired Toccata. Through the acquisition, TI reduced the vulnerability and uncertainty of being dependent on critical capabilities located in an independent firm, and eliminated further contracting issues as well as royalty outlays. TI moved quickly to integrate all R&D activities in and related to digital amplification in order to ensure a more effective design process, and later in 2000, TI was able to launch its first generation of digital amplifier chips. By late 2003, TI was producing its fourth generation chipsets in millions.

TI has clearly exercised dynamic capabilities (Teece et al., 1997; Eisenhardt and Martin, 2000), that is, organizational and strategic capacity to alter its resource base, through combining in-house R&D with timely licensing and acquisition policies. In particular, TI managed to orchestrate various sets of complementary innovative assets (Christensen, 1995) through a succession of three acquisitions followed by organizational integration of the class D-relevant R&D of the various parties. This made it possible for TI to take the lead in transforming the technology into amplifier chips and to use its powerful operational complementary assets (in manufacturing, marketing, distribution) to create a first-mover spearhead for mass-produced digital amplifier chips in the expansive market for DVD receivers.

At about the same time during the late 1990s, Sony engaged in establishing a proprietary module system, the S-master technology, which seems dedicated to its captive product markets in order to seek differentiation gains. However, the core components of this module, the amplifier chips, were from the early start provided by Mitsubishi and more recently by other class D chips vendors. Sony has shown a strong commitment to S-Master as a brand and an in-house technology that has become an integrated part of many Sony products and the system is offered on a licensing basis to other AV OEMs. Sony was an early mover incumbent as were TI and STMicroelectronics but decided for a system integration strategy allowing for external chips suppliers willing to adapt to the particular system requirements of Sony's S-master system. Hence, even if Sony has exerted a more internal and proprietary systems orientation than TI and STMicroelectronics, with respect to the core component, the amplifier chipset, Sony has been using external suppliers. Sony's strategy can be seen as an attempt to set the standards for a dominant design in digital amplifiers and has been pushing the system into a large array of its audio products. It is too early to judge the broader success of this strategy, but so far, Sony has refrained from in-house development the heart of the digital amplifier, the amplifier chipset.

Philips was probably the only company which already by the late 1990s possessed a fairly complete endowment of innovative assets and specialized technological capabilities (in both power and front-end technologies) necessary for leveraging class D amplifiers as well as the complementary assets for commercialization. Philips could therefore pursue a more introvert mode of innovation and provide one of the first class D products to the market. What seems more surprising is that Philips, despite its in-house technological strengths and early product launch, has not so far (by early 2005) demonstrated a capacity (or willingness) to commercialize class D products more broadly into its products. This may be due to missing corporate commitment to do what Sony has apparently done, namely to force the end-product divisions to adopt the new technology. Hence, Philips may be a case of not only fairly closed innovation but also of the "tyranny of divisions" in decentralized multi-divisional companies (Prahalad and Hamel, 1990).

Sanyo combines a strong position in traditional analog amplifier and chip production with a position as large AV OEM. Sanyo has shown a strong commitment to ongoing optimization of its conventional module technology and manufacturing capabilities, and when the paradigmatic shift in sound amplification emerged, Sanyo was ill prepared. Around the time when TI and STMicroelectronics launched their first amplifier chips (2002), Sanyo established a royalty-based licensing contract with the technology entrepreneur ICEpower to develop its own amplifier chipsets. In this way Sanyo seeks to combine ICEpower's technology with Sanyo's chip manufacturing and miniaturization capabilities and distribution network. The downside for Sanyo is that ICEpower controls the new technology and that Sanyo will have to pay a royalty for each amplifier chip sold. By the end of 2004, as TI and STMicroelectronics seem to have consolidated their leading market position in amplifier chips, Sanyo has just begun to ship its first licensed amplifier chipsets. Sanyo combines a slow response with an active catch-up effort based on external technology.

The large incumbents have, with the possible exception of Philips, applied elements of open innovation, and since small technology startups pioneered the embryonic stage of the technology cycle, even the strategies of the early moving incumbents have implied some kind of reactive rather than proactive response to the challenge of the new technology. An interesting inherent paradox of a strongly acquisition-based way of practicing open innovation, the case of TI, is that it leads to vertical integration. Hence, after an innovative entry involving a highly extrovert strategy that is considered necessary for managing and controlling a technological discontinuity, the company can internalize the next rounds of follow-up innovations, much more in accordance with the closed model. This points to the significance in some cases of non-regular cyclical changes from a relatively more open style of innovation associated with a company's attempt to realign a company's resource base in the face of radical (competence-destroying) and architectural innovation, and subsequently to a more closed style of innovation as the technology matures and incremental change and technical upgrading come to prevail. This cycle may eventually, as suggested by Chesbrough and Kusunoki (2001) create the basis for re-externalization of increasing parts of the components as the technology and the associated interfaces become commoditized and standardized. Thus, we do not necessarily see a once-and-for-all replacement of closed innovation by open innovation. This shows that companies cannot freeze their modes of managing innovation into one particular set of routines.

The case has illustrated the key analytical perspectives and issues discussed in this chapter. First, it has shown that the development of new complex technologies can fruitfully by analyzed using the distinction between specialized technical capabilities, possibly, but not necessarily, with a bias towards “bodies of understanding”, and integrative competencies, mostly with a bias towards “bodies of practice”. Secondly, the case has illustrated the new division of knowledge and labor between small technology specialists and large incumbents emanating from the dynamics of vertical disintegration. Accordingly, technology-based startups will tend to have an advantage in the embryonic stages of a radically new technology requiring deep and specialized knowledge unrelated to the knowledge of conventional technology possessed by incumbents. By contrast, incumbents with strong incentives to capture commercial value from the new new technology, will be better situated to mobilize the integrative competencies needed to provide the appropriate systemic/architectural innovation and large-scale commercialization. Critical features of such integrative competencies are the capacities for technical systems integration, for coordination with technology-based specialists, for reconfiguring the knowledge base (dynamic capability), and for mobilizing complementary assets.

Finally, the case has demonstrated that different incumbents engaging in the development of the same technology and associated products apply different innovation strategies. The most successful incumbents involved in class D development have been the two early movers dedicated to open innovation strategies (TI and STMicroelectronics). The outline of TI’s strategy has indicated that system integration competencies may have to be closely aligned with capacities to reconfigure the existing knowledge base – in this case through acquisitions followed by R&D integration – *and* the mobilization of critical complementary innovative assets (such as chip design) and complementary operational assets (such as manufacturing and marketing). The more closed strategies of Sony and Philips have not so far proven as successful. Sony has followed a tight system integration strategy trying to establish a dominant systems architecture based on external amplifier chips, while Philips seems to have possessed the in-house knowledge assets to provide most elements of a class D amplifier, including the chipsets, but not the corporate commitment to commercialize the amplifier at large scale. This seems to indicate that the core competency strategy with a strong introvert orientation cannot adequately meet the challenges of increasing vertical disintegration and improved markets for technology.

5. Concluding remarks

What has happened to the core competency perspective in corporate strategy and innovation that in the early 1990s was generally praised as *the* strategy for achieving sustainable competitive advantage among large technology-intensive companies? To what extent is this perspective at odds with the empirical tendencies towards vertical disintegration, enhanced markets for advanced technology, and increasingly open innovation? No doubt, companies will still have to develop or maintain in-house core competencies and innovative assets that are unique, complex and difficult-to-imitate in order to obtain competitive advantage. However, in a world of increasing vertical disintegration and expanding technological opportunities in many industries, large incumbents have had to accept, more or less voluntarily, to give up full control and ownership over increasing parts of the value chain within their product markets and instead leave the provision of these parts to external suppliers with highly specialized expertise. This development has had numerous implications for the conception of “core competencies” and associated innovation strategies in large companies. First, as has been demonstrated in several empirical studies, large companies have expanded the diversity of their technology profiles (technical fields in they have at least a fairly deep level of generic/abstract knowledge – “bodies of understanding”) putting relatively increasing emphasis on developing “background competencies”, a sort of absorptive capacity enabling the firm to coordinate and benefit from external technical development in the supply chain, and to explore new opportunities emerging from scientific and technological breakthroughs outside the firm. This is not to say that the large firms (should) give up developing deep core technologies, but these seem to play a relatively decreasing role in the overall technology profiles. Secondly, as large firms increasingly take on the role as innovation architect and market coordinator of increasingly distributed value chains, they have to develop integrative competencies for systems integration. involving a experience-based and firm-specific architectural knowledge ("bodies of practice"). Thirdly, as an increasing share of relevant innovative knowledge and component development takes place outside the large firm, dynamic capabilities, the capacity for reconfiguring the firm's knowledge and resource base, become a central asset which is strongly related to competencies for systems integration. The diverse and highly dynamic nature of integrative competencies cannot in a stable way be contained in either a central lab or "imprisoned" in isolated business units – but must be reflected in ongoing (sometimes erratic) changes in the organization and delegation of tasks and the mobilization of external relations (Galunic and Eisenhardt, 2001; Brown and Eisenhardt, 1997).

Open Innovation is premised on the presence of widespread useful knowledge, such that even the biggest and most knowledgeable companies cannot develop all of the important technologies they require on their own. This indeed seems to have been the case in the digital amplifier technology. While it has proven to be a highly useful technology that is gaining market acceptance rapidly, it emerged from a Danish university, not from any of the leading consumer electronics firms. And it has diffused very unevenly into the consumer electronics market, as different firms with different innovation strategies varied in their competence to absorb this innovation into their own systems. While TI's discovery of the digital amplifier technology was almost accidental, to its credit, it rapidly developed a working relationship with the inventor, and though it struggled initially to successfully transfer the technology into its own development organization, it has successfully created new systems and chips that benefit from the technology. This exemplifies the increased importance of architectural competence build through dynamic reconfiguring of the parts of the firm's knowledge base. By contrast, Sony perhaps overestimated its own ex ante systems integration competence and underemphasized the requirements for the development of the core component technology. This may have left Sony a difficult bargaining position vis-à-vis the increasingly strong suppliers of amplifier chipsets.

In a world of widely available knowledge, there are virtues in seeking external technologies, and hazards in ignoring them in favor of one's own technologies. Indeed, Chesbrough (2003) argues that architectural knowledge will be increasingly important when knowledge is widely available. We appear to see that supported in this instance. But that doesn't mean that architectural knowledge is the only asset that matters for large firms. "Old style" core competencies will most likely still be needed, but the dark side of core competencies, when they turn into core rigidities, has become increasingly prevalent as the technological opportunity set expands and as the external knowledge expands more than the internal knowledge. Hence, companies cannot any longer base themselves on a few deep core competencies that are cumulated over decades.

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