

**THE DYNAMICS OF THE DIVERSIFIED CORPORATION AND THE
ROLE OF CENTRAL MANAGEMENT OF TECHNOLOGY**

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1. INTRODUCTION

During recent years there has been widespread "downsizing" efforts within headquarters of large multi-divisional corporations. This tendency has also involved downgrading of corporate R&D (i.e. in the form of corporate labs), decentralization of R&D to divisional or business unit levels, and increasing use of external suppliers of technology. To the extent that downsizing of central R&D has not lead to overall downsizing of internal R&D, these dynamics have probably contributed to stimulate motivation and entrepreneurship at decentral levels and a stronger market-orientation in technological innovation.

However, a likely negative implication of downsizing central R&D may be increasing corporate fragmentation which may contribute to undermine core competences, reduce inter-divisional synergy and increase duplication of innovative efforts. Moreover, technological innovation may become biased towards incrementalism and short-termism at the expense of long-term exploration of new oportunities.

This paper discusses 1) generic forces of diversified corporations and their implications for the corporate technology base, 2) the changing role of the central R&D lab in the context of these forces, and 3) the (potential) role of management of technology in promoting dynamic coherence in diversified - and highly decentralized - corporations. Dynamic corporate coherence is here defined as the corporate capacity to exploit and explore synergies from a diversity of capabilities, competences and other resources (Christensen and Foss, 1996).

Management of technology may operate at different levels: It may be concerned with the management of specific innovative projects, the management of R&D in a central lab or in a one-business firm, division or SBU, or it may be concerned with the management of the overall corporate technology base in a diversified corporation. This paper deals with the latter. The notion of corporate technology base refers to the corporation's total portfolio of technical capabilities and managerial competences in developing new technologies, products and processes¹. In the diversified and transnational corporation the corporate technology base is not a unified base with a central organizational and geographical locus. On the contrary, it has increasingly become dispersed in different parts of the corporation (i.e. the central R&D labs, divisional R&D centres, engineering and manufacturing departments or design centres or teams in business units and even in network relations with firms and institutions outside the corporation).

¹ The notion of "technology base" is discussed more in-depth in Christensen (1996a) in which a conceptual distinction between capability and competence is suggested: A capability signifies lower-order functional or technical capacities to mobilize resources for productive activities, while a competence signifies a higher-order managerial capacity of the firm to mobilize, harmonize and develop resources and capabilities to create value and competitive advantage. In this paper, however, the distinction is not critical, and I systematically use the term competence when referring both to technical and managerial capacities.

In section 2 the Chandler/Williamson strategy-structure issue is revisited and four generic forces characterizing the growth of the multi-divisional corporation are identified: 1) Diversification, 2) increasing division of labour, 3) decentralization, and 4) internationalization. The implications of these dynamics for the structure and profile of the corporate technology base is discussed. It is argued that combined these dynamics have promoted an inherent movement towards fragmentation of the corporate technology base and more short-termism and risk-aversion in R&D-investments. However these dynamics have also given rise to a stronger market-orientation in innovative efforts, and better possibilities to promote inter-functional integration in innovative efforts. These implications primarily hold for the "traditional" Williamsonian M-form. Section 3 takes a look at different M-form variants which provide a more differentiated picture.

In section 4 and 5 the focus is narrowed from the overall corporate level to the specific level of central R&D and corporate management of technology. Section 4 attempts to give a broad outline of important changes in the role and organization of the central R&D lab, and section 5 focuses on the options for managing the corporate technology base in technology-intensive corporations. Four objectives for the management of the corporate technology base that may contribute to strengthen the dynamic corporate coherence are briefly discussed:

- Providing overall strategic guidance of the corporate technology base and innovative efforts,
- providing "parenting value"² to divisions and business units in their innovative efforts,
- assuring a proper balance and alignment between short-term, incremental innovative efforts (exploitation) and long-term explorative efforts,
- increasing horizontal technology transfer and sharing, as well as synergy and coordination in research and technological innovation between divisions and business units.

The line of argument in the paper is illustrated by different case material, especially material from an in-depth case-study of Danfoss, a Danish multi-divisional corporation operating primarily within mechatronical, industrial product markets (Iversen & Christensen, 1996). The case-study is based on both a comprehensive written material on Danfoss and interviews especially with corporate research manager Hans J. Pedersen and technology manager Vibeke Gustafsson.

² This term is borrowed from Goold, Campbell and Alexander (1994)

2. DYNAMICS OF THE DIVERSIFIED CORPORATION AND IMPLICATIONS FOR THE TECHNOLOGY BASE

Since the work of Chandler (1962) the relationship between the strategy and the organizational structure of diversified large corporations has been subject of intensive research and debate. Research by among others Hill and Hoskisson (1987) and Goold and Campbel (1987) have focused attention on the significance of different variants of the M-form corporation. Others have argued that the increasing complexity in the wake of globalization stimulates the emergence of new organizational network structures that transcend the M-form (Prahalad and Doz, 1987, Bartlett & Ghoshal, 1989, 1993, Hedlund, 1994). From a competence-based perspective Prahalad and Hamel (1990) have argued that the "strategic business unit" paradigm of the conventional M-form has contributed to fragment the diversified corporation and undermine its core competences. Recent discussions on the diversified corporation have focused on the coherence of the corporation (Teece et al., 1994, Christensen and Foss, 1996) and the "parenting" roles of the corporate headquarters (Chandler, 1994, Ferlie and Pettigrew, 1996, Goold, Campbell and Alexander, 1994).

Below, I shall focus attention on the implications for the corporate technology base of some generic tendencies in the strategy-structure dynamics of diversified corporations.

2.1 General dynamics of M-form corporations and their implications for the corporate technology base

Following Chandler (1962) and Williamson (1975) it became conventional wisdom that the decentralized multi-divisional (M-form) structure - as compared to the functional structure (U-form) - provided a more adequate way of dealing with administrative and operational problems of managing the multi-product corporation.

Chandler (1962) and Williamson (1975) argued that headquarters in M-form firms should: 1) take responsibility for the overall strategic boundaries and direction of the corporation (notably for acquisitions, divestures, and long-term investments), 2) monitor and audit the affairs and performances of the divisions (which may require specialized corporate staff), 3) reallocate resources generated by divisions on the basis of relative yields rather than returning them to their source division, 4) use corporate incentives to promote profit seeking behavior in the divisions (i.e. compensation schemes, promotion incentives). On the other hand, divisional management should have full functional autonomy in operational matters.

According to Williamson such M-form structures are more likely to favour goal pursuit and least-cost behavior in line with neoclassical maximization behavior than are functionally organized corporations.

At least five overall tendencies have characterized the development of the large multi-business corporation:

- 1) Diversification into a) new business areas or product markets, and b) new technologies,
- 2) increasing division of labour (for example with respect to organizing the corporate technology base, or with respect to the focus of individual business units or functional departments),
- 3) increasing organizational decentralization implying increasing scope for autonomy at lower levels (i.e. the divisions, business units or profit centers), not only in operational matters but also in strategic matters, and
- 4) internationalization into still new geographical areas and globalization of management and production structures,

These generic dynamics³ of the modern multi-business corporation all contribute to increasing differentiation, diversity and complexity, and - to the extent interdependencies exist between divisions and businesses in the corporation - they call for measures to assure integration or coherence. This section focuses on the implications of these tendencies - individually and as a whole - on the overall corporate approach to R&D and technological innovation (the organization of the corporate technology base, the profile of innovative competences and the focus of innovative efforts). However, while this section does not take account of potential coordination mechanisms, the subsequent section discusses M-form variants with coordinative planning mechanisms that seek to exploit synergies and scope economies and counter the inherent fragmentation tendencies of the "classical" Williamsonian M-form.

Ad. The dynamics of diversification.

Diversification has been the subject of systematic research by economists and strategy researchers for many years. Mostly this research has focused on product or business diversification, while the dynamics of technology diversification, i.e. the firm's expansion of its innovative and technological asset base, has attracted much less attention (among the exceptions, see Pavitt et al., 1989, Granstrand et al., 1990, Oskarsson, 1993). The trend for technology diversification seems to have been even more pronounced - at least within technology-intensive firms - than product diversification (Pavitt et al., 1989). This tendency for increasing diversity of the technology base has been a central factor stimulating the rising managerial (as well as academic) attention to technology management and strategy in recent years.

If technological diversification is exclusively linked to product-market strategies at divisional

³ These dynamics are certainly not considered to be all-inclusive. At least one more generic force should be mentioned, the increasing tendency for outsourcing or joint knowledge accumulation with external parties. However, the scope of this paper does not allow a specific treatment of this issue.

or business unit levels, and no corporate or inter-divisional coordination is taking place, the corporate technology base will tend to become not only increasingly complex, but also increasingly fragmented in the sense that there is no attempt to coordinate efforts to assure best possible corporate-wide use of the technology base. This is not, however, a serious problem if technological innovation is not important for the competition in the product-markets of the business units.

The path-dependent pattern of evolution and branching of technological development underlies the notion of "technological trajectories" (Dosi, 1982; Nelson and Winter, 1977). Some technological trajectories evolve over time into many derived technologies and provide a platform for many product applications and market opportunities, while others are linked to specific applications in specific products and processes, and thus, are dead-ends with respect to both technical and product market opportunities (Kim and Kogut, 1996). Without coordinated or corporate level R&D and management of technology substantial growth prospects may be lost if the individual divisions/business units do not have the financial resources and competences to make the transition from increasingly obsolete or dead-end trajectories to new prospective platform trajectories.

Ad. Increasing division of labour

As technology-intensive firms grow larger and diversify into new product markets and new technologies the functional and managerial organization of the technology base becomes increasingly specialized. Product development becomes separated from manufacturing, long-term R&D becomes separated from short-term development activities, R&D activities in one technical field is separated from R&D in another field, etc. This increasing specialization is caused by the generic dynamics of increasing returns to differentiation, but the process is also stimulated by the above mentioned "diversity dynamics" of diversification and internationalization. As firms grow into diversified corporations this process of increasing division of labour increases compartmentalization, cultural segregation and political rivalry over resources between various parts of the corporate technology base.

In large corporations operating in high-technology markets there is no longer one R&D department that comprises the total corporate portfolio of innovative and technological assets. Rather, different parts of the technology base are spread all over the corporation, from central science laboratories to product development, engineering and design departments (or individuals/groups) in product divisions, subsidiaries, or joint ventures.

Hitachi Ltd - one of the world's leading electronic companies - is spending around 5 billion dollars on R&D, more than any other company in the world. Hitachi has 33 R&D laboratories, nine of which are directly under the corporate headquarters, two are located in Europe, and two others in the US. These laboratories can be classified in six categories (Bowonder & Miyake, 1994, p.66):

- Laboratories with short-term research focus for quick commercialization of innovations

originating from various product groups (Central Research Labs).

- Specific divisional R&D laboratories dealing with short-time horizon innovation projects (Semiconductor Design and Development Centre).
- Highly specialized laboratories with core competence as the focus (VLSI Lab).
- Laboratories with multi-disciplinary expertise with focus on generic competence in one application segment (for example, Space Systems Labs).
- Laboratories that specifically focus on long-term projects in emerging technologies (for example, Advanced Research Lab).
- Laboratories which act as interfaces for new projects, user-supplier interaction, and technology scanning (for example, System Development Lab).

Unless met by countervailing coordination and integration measures this division of labour dynamic promotes a fragmented competence building at the level of the specialized competence categories and the individual business units. Paradoxically, while this specialization process reflects the accumulation of knowledge and capabilities, the same process may contribute to the undermining of core competences (and corporate coherence) and make it difficult to build synergies between different assets (Prahalad and Hamel, 1990).

Ad. Decentralization

The processes of diversification, internationalization and increasing division of labour has made large multibusiness corporations so complex that centralized planning has given way to delegation and decentralization to lower organizational levels. But decentralization is also a consequence of the principles of economic organization (as formulated by Williamson, 1975) for controlling the efficiency of divisions, and achieving efficient allocation of capital resources: First, the separation of strategic and operating functions, secondly, the implementation of functional autonomy of divisions, and thirdly, the establishing of a top-down financial control of divisional profit performance.

Decentralization in the form of divisionalization⁴ has also involved decentralization of R&D and management of technology in large diversified corporations (Coombs and Richards, 1991, Coombs, 1996, Whittington, 1990). Loescher (1984) argues that the tendency for tight, top-down financial control may lead to risk-avoidance by divisional managers. Hill (1985) hypothesizes that M-form efficiency focus is linked to short-termism and low R&D commitment, that is, "static efficiency" (or operational efficiency and exploitation of existing

⁴ The term divisionalization here refers to decentralization of some previously centrally managed activities to either product divisions or more decentral levels (business units or profit centres within the business units).

competences and resources) at the expense of "dynamic efficiency" (or innovative and explorative efforts that provide opportunities for value creation at the longer term). But divisionalization of innovative investments also leads to stronger market orientation, better inter-functional integration between R&D, marketing, manufacturing, etc. (Coombs, 1996) and a focus on incremental innovation. In short, the decentralization dynamics tend to promote both short-termism in innovative efforts and a strong, but risk-averse, market-orientation.

Ad. internationalization and globalization

The dynamics of internationalization has implied a need for the corporation to be present in an increasing number of countries or regions. This presence may involve sales agencies in all countries in which the corporation has or goes for a market position; or it may involve a global regionalization of manufacturing or R&D facilities. Like business diversification, internationalization contributes to increase complexity in managing the corporation: Balancing the difficult and ever-changing trade-off between global coordination and concern for local/national requirements⁵.

While the international distribution of corporate manufacturing facilities tends to reflect different factor market endowments of special relevance for manufacturing costs and quality, the international distribution of facilities for the corporations' technical research and innovation facilities cannot be reduced to "factor market" advantages. Internationalization of industrial R&D is a fairly recent phenomenon and has not progressed as far as the internationalization of corporate manufacturing (Granstrand, Håkanson and Sjölander, 1993). Granstrand and his colleagues find that the forces for geographical decentralization to some extent is retarded due to countervailing forces for centralization (such as scale economies in R&D, need to protect technical know how from leaking, wish to minimize costs of coordination, historical path-dependency). The forces for geographical decentralization may either be associated with the objective of better serving foreign national markets or enhancing the efficiency of R&D. With respect to the former objective national R&D laboratories may be established to provide product differentiation for specific national requirements. Sometimes national laboratories that were set up to provide technical support services for national manufacturing subsidiaries gradually evolve into proper product and process development departments focusing on adaptation of products and processes to local circumstances. With respect to the objective of enhancing R&D efficiency foreign national R&D may also be involved in more the profound development of new technological capabilities. This objective is reflected in two categories of foreign R&D units. First, the R&D of foreign acquisitions, in which the R&D competences may constitute the primary reason for the acquisition. Secondly, the "monitoring R&D unit" that is set up with the primary objective of "tapping into" a foreign scientific infrastructure (Granstrand et al, 1993, p. 416f.).

⁵ The so-called multi-domestic matrix organization of for example ABB is a reflection of the need to balance this trade-off (Taylor, 1991, Bartlett and Ghoshal, 1993).

The combined effects on the corporate technology base

Taken together, the four tendencies provide incentives for changes in innovative efforts and innovative competence profiles. There may be a general pressure to downgrade total R&D or innovative investments. Hoskisson and Hitt (1988) provide moderate (although not statistically significant) support for the hypothesis that M-form firms invest relatively less in R&D than functionally organized (U-form) firms. However, rather than an overall downgrading of R&D, the decentralized (Williamsonian) M-form may induce incentives for changes in the innovative asset profile that will tend to 1) fragment or weaken the internal coherence of the corporate technology base (implying a potential failure to explore and exploit cross-divisional synergies, as well as risk of duplication of innovative efforts), 2) favour short-termism and incrementalism in innovative efforts such as line extensions and suppress more radical innovation, thus moving the balance between incremental and explorative efforts in favour of the former. This move towards incrementalism may moreover favour process, product and design innovative competences relative to science-based competences (Christensen, 1995). Such changing balance of the innovative competence profile may underlie the tendencies to reduce the role and autonomy of central science laboratories and to induce a stronger "internal market mechanism", that is, guiding and funding from divisional levels (see section 4).

In sum, when the dominant dynamics of the corporation are based on strategies and trajectories at divisional and national levels rather than strategies and visions at corporate level, the outcome is likely to be increasing inter-divisional and corporate-wide fragmentation of the corporate technology base despite possibly increasing intra-divisional coherence. So far, this discussion has taken the conventional williamsonian M-form as given. In this form divisional autonomy in operational and functional matters is considered decisive, since top management intervention in these matters will reduce efficiency by weakening incentives. However, this focus on incentives has led to a theoretical neglect of coordination issues in the multibusiness firm. M-form theory has overlooked, as Argyres (1995) maintains "...the condition of complementarity, under which intervention may produce coordination gains which offset these incentive losses".

Today most diversified firms are multidivisionals (Hill and Pickering, 1986). However, as Hill and Hoskisson (1987) and Goold and Campbell (1987) have pointed out, M-form structures are not homogeneous, and many M-form firms vary in substantial ways from the ideal form suggested by Williamson.

2.2 Variants of the M-form and the management of the corporate technology base

Hill and Hoskisson (1987) identify three main strategies that firms use to become multi-product companies: vertical integration, related diversification, and unrelated diversification. Each of these strategies is associated with a specific type of economic objective: Vertical integration strategies seek to exploit "vertical economies" that arise from scale or integration economies, from increase in control over resources or outlets, or from elimination of the

transaction costs of using the market. Related diversification strategies seek to benefit from "synergistic economies" (synergies or scope economies between resources and competences). Finally, unrelated diversification strategies seek to exploit financial economies (by reducing risk, applying portfolio management, and overcoming external capital market failures).

To each of these three strategies corresponds a set of planning and control arrangements within the basic M-form framework (Hill and Hoskisson, 1987, p.333): The "pure" williamsonian M-form is consistent with a strategy of unrelated diversification in order to realize financial economies, but not consistent with either vertical integration or related diversification strategies. Both of these latter strategies require a degree of central coordination and interdivisional cooperation. Moreover, Hill and Hoskisson maintain that it is difficult for a firm to go for both financial economies on the one hand, and synergistic or vertical economies on the other, while they find similarities between the systems necessary to realize vertical and synergistic economies and, thus, suggest that these are more compatible (Hill and Hoskisson, 1987, p. 335).

If we now introduce the corporate technology base perspective, it seems obvious that the "pure" M-form (to realize a strategy of financial economies) will tend to "balkanize" the corporate technology base along the lines discussed above. This may not cause any problems as long as the technology base consists of generic technologies that are not proprietary to the firm and do not have strong systemic features. In contrast, the "synergistic" M-form structures (to realize vertical or synergistic economies) are more likely to promote coherence both in terms of relatedness of the business fields of the corporation (as suggested by Teece et al., 1994) and in terms of the couplings and synergies between different parts of the corporate technology base (Christensen, 1997) - to the extent that technology base synergies come to the attention of the corporate strategy agenda.

Based on case-studies of 16 British diversified corporations, Goold and Campbell (1987) find three major types of management styles used by senior management at corporate headquarters: Strategic planning, strategic control, and financial control. These management styles are defined in terms of two dimensions of the centre's influence, planning influence and control influence. Planning influence concerns the centre's contribution to the strategy process in the business units. Control influence concerns the centre's way of reacting to results achieved. Strategic planning corporations have a high level of central planning influence, while the centre's control influence is flexible and focused more on strategic targets than on annual budgets. Strategic control corporations exert a more moderate level of planning influence, while control measures are stricter and cover both financial and strategic targets. Financial control companies have a low level of central planning influence, while the centre focuses on tight financial control.

In a recent paper Chandler (1994) reviews both his own and Goold and Campbell's work on the functions of headquarters in multibusiness companies. Like Goold and Campbell he finds that strategic planning and strategic control companies are generally smaller and less

diversified than financial control companies. While strategic planning and strategic control companies tend to operate in relatively high technology industries, have relatively large R&D departments, and exploit interbusiness and interdivisional opportunities, financial control companies tend to operate in service industries and in industries involving relatively inexpensive production facilities and small R&D expenditures. Moreover, financial control companies show a low level of interbusiness and interdivisional interdependencies.

Combining the classifications of Hill and Hoskisson (1987) and Goold and Campbell (1987) some tentative implications concerning the management of the corporate technology base may be drawn. The "pure" Williamsonian M-form structure may favour unrelated diversification and the exploitation of financial economies. This corresponds to the financial control type of corporations which are mostly prevalent in relatively low technology areas, and subsequently no efforts, whatsoever, are mobilized to manage the overall corporate technology base. On the other hand corporations which pursue strategies of related diversification or vertical integration in order to exploit synergistic or vertical economies will tend to use some kind of either strategic planning or strategic control style which may very well include some level of centralized R&D as well as efforts to promote dynamic coherence of the corporate technology base. It is, however, likely that the problems of short-termism in innovative efforts and fragmentation of the corporate technology base, are not exclusively associated with the "pure" M-form, but are also present or inherently creeping into the more "synergistic" M-form corporations as they diversify into still new business areas and the technology base grows more complex⁶.

2.3 Danfoss - a "synergistic" M-form corporation

Since its establishment in 1933 Danfoss has been one of the most successful Danish manufacturing companies. Every single year since 1933 Danfoss has shown a positive profit. In 1995 Danfoss reached a turnover of around 2 billion dollars. and had about 17.000 employees. Danfoss manufactures thousands of different products (particularly mechatronical products for industrial markets), has manufacturing facilities in 11 countries and a sales presence in more than 100 countries. The products can be classified into 13 broad product lines, among others thermostats for cooling and freezing equipment, comfort automatics (products for temperature control, radiator thermostats, etc.), cooling and airconditioning automatics, hydraulic components and industrial instrumentation (i.e. electronic flow meters). In the early 1970's Danfoss transformed its organization from a highly centralized U-form company to a more decentralized M-form company. The number of product divisions have grown from four in 1971 to ten today. Moreover, two sales divisions are responsible sales in different geographical regions. In april 1996 the product divisions became part of one of three new divisional groups (product families): Refrigeration Controls, Heating Controls and Motion Controls. This organizational restructuring also implied that the four general

⁶ Coombs and Richards (1991 a+b) provide some illustrative evidence on the complexity of promoting strategic technology base coherence in large diversified companies.

managers not any longer also were divisional managers - a double task that tended to overload the managers in question. Thus one purpose was to release managerial capacity in the organization; another purpose was to focus synergy attention to inter-divisional relations within the product family group.

Most of the Danfoss products have one thing in common: They are located in technical equipment and systems to control dynamic processes. Danfoss has technological leadership within several of its product areas (e.g. some types of hydraulic equipment, intelligent cooling systems, radiator thermostats, non-CFC compressors and thermostats for refrigerators and freezers).

The evolutionary growth of Danfoss has been based on the continuously launching of new or improved products and expansion into still new geographic markets and customer segments. The nearly persistent success of Danfoss can to a large extent be explained by its ability to identify and exploit new market opportunities through innovative application and combination of different assets in the corporate technology base and through the ability (and luck) to build new technological competences that align well with the existing ones and provide new commercial opportunities. Scale economies, effective and high-quality manufacturing and "design for manufacturability" are critical competitive advantages of Danfoss' most important products - certainly of the most successful of them all: the radiator thermostat. Growth has from the end of the 1930's and up until the mid 1970's been focused on internally generated growth based on mass production. Not until the 1980's did Danfoss begin to expand through acquisitions, and in the 1990's acquisitions have become a vital part of Danfoss' strategy for growth and globalization. In Europe acquisition options are sought among firms with products that are complementary to Danfoss products. In the rest of the world Danfoss is seeking to acquire firms not only for the sake of their products but also their distribution system.

Danfoss has been marked by all the generic forces discussed in section 2.1. The dynamics of diversification has involved not only product market diversification but also technology diversification. Thus, for example the primarily mechanical engineering base of the early Danfoss has been supplemented by electronic competence since the 1950's⁷. Hydraulics

⁷ The founder of Danfoss, Mads Clausen, hired an electronics engineer in 1953 and in the beginning of the 60's the newly established Danfoss Electronics manufactured customized electrical rectifiers. When this production stopped in 1965 due to poor commercial results the department was turned into a Technical Research Center with 20 employees. This center has given the task to identify a promising area for Danfoss within electronics. Out of this searching and R&D effort grew the frequency control - the first successful electronics product in Danfoss. The frequency control provides continuous regulation of alternating-current motors and today Danfoss is among the international leaders within the field. Electronics is, however, not only linked to this specific field within Danfoss but has gradually diffused into most of the product lines and been aligned with mechanical engineering, hydraulics and other technical fields of expertise in Danfoss.

competence has become a decisive asset in the technology base from the 1960's and onwards⁸. Other more specific technical competences (i.e. stainless steel technology, computational fluid dynamics) have been developed in the context of the expanding product portfolio. The dynamics of increasing division of labour, decentralization and internationalization have been very profound in Danfoss with respect to the organization and specialization of the technology base (see section section 4 and 5).

Referring to the strategy categories of Hill and Hoskisson (1987) (see section 2.2) Danfoss has primarily become a multi-product company by pursuing a strategy of related diversification rather than unrelated diversification and vertical integration, even if the two latter also to some extent have been followed, especially in the early history of Danfoss. The attempts to exploit "synergistic economies" through some degree of central coordination and inter-divisional cooperation have been significant even if decentralization has also implied tendencies for divisional autonomy and corporate fragmentation. In the terminology of Goold and Campbell (1987) Danfoss' planning and control systems seem more in accordance with the strategic control type than with both the financial control type and the strategic planning type although there are some elements that bring Danfoss closer to the latter. This is also reflected in the organization of the corporate technology base to which I shall return in section 4 and 5.

The following sections will only deal with the more "synergistic", technology-intensive M-form corporations and penetrate somewhat deeper into the role of the central R&D lab and the potential role for management of the corporate technology base in a context of predominantly decentral R&D.

4. THE CHANGING ORGANIZATION OF THE CENTRAL R&D LAB

The conventional role of the central R&D laboratory is to provide long-term research and development of new technological capacities and trajectories that may feed into new ventures, product or process development either within the central lab itself or in engineering, manufacturing or product development departments of divisions and business units.

From World War II and the following decades the large central laboratory emerged as the leading institution for industrial R&D (Whittington, 1990). Some of the main advantages of centralized R&D organizationally as well as geographically can be summarized as follows:

⁸ This asset was also initiated by the founder of Danfoss as he in 1959 decided to go into partnership production of harvester threshers (combines) - a quite unrelated product market diversification. The production was stopped in 1962 after significant loss. However, Danfoss continued to produce hydraulic components for combines and gradually hydraulics became one of the most important product areas and high-level competence area in Danfoss.

- Concentration of R&D within a single organization on the same location facilitates coordination of projects and reduces the risk of redundancies (Twiss, 1986).
- Integration of multidisciplinary and tacit knowledge is a decisive part of most technological innovation, and this integration tends to be facilitated by physical proximity (Patel and Pavitt, 1991)
- R&D is subject to economies of scale: One single laboratory is more likely than a diversity of small R&D departments to achieve "critical mass", attract talented engineers, and mobilize resources for complex R&D problems.
- By locating R&D personnel in laboratories distant from operational activities they can concentrate on long-term R&D and avoid getting distracted from daily operational problems (Twiss, 1986).

Some of these advantages, however, have not materialized in practice or have become less obvious as some typical weaknesses associated with centralized R&D have become visible in the context of the growing complexity of the diversified corporation. To the extent that product divisions become involved in innovative activities themselves, there will tend to arise coordination and communication problems in the relations between central R&D and divisional R&D. To the extent that the central R&D lab has authority to interfere in divisional R&D affairs, incentive problems will occur at divisional levels. As divisions grow larger, divisional R&D may surmount the "critical mass" threshold for effective R&D and make one of the basic rationales for central R&D, economies of scale, less adequate. Thus, as divisions grow larger (and more autonomous) and as the corporation grows more diversified (and increasingly difficult to assist from central R&D) the central R&D lab tends to become decoupled - not only from the divisions' operational affairs, but also from their innovative activities. This may result in 1) a bad fit between the supply of "high brow" knowledge from the lab and the practical requirements of the business units, 2) poor technology transfer mechanisms due to the distance in skills and priorities between the two parties, and 3) undermining of the legitimacy and authority of the central lab from the perspective of the increasingly powerful divisions. Thus, while isolation from the operating divisions originally was an advantage, it has tended to become a disadvantage.

A typical way of handling this problem in the 1970's and 1980's was to increase divisional power over the central R&D implying that divisional managers became directly involved in the steering committees of central labs, and that a larger share of central R&D should be ordered and financed by the divisions. This has generally provided a better link between the central and divisional R&D efforts. However, in many cases the transmission of funding and power from corporate to divisional level has led directly to downsizing of central R&D and/or creeping short-termism in the form of smaller ad hoc projects at the cost of the visionary long-term projects. These changes in the economic organization of the central R&D have been accompanied by a change in the terms of cooperation: Increasingly the "transfer

logic" implying that new discoveries were "thrown over the wall" to the design and engineering departments has been replaced by a "teamworking logic" in which the corporate lab is part of teams operating on conditions that are very much specified at the level of the business unit (Edelheit, 1995).

Few companies seem to have gone so far as Siemens - the German electrical engineering group - in putting the idea of an internal market for R&D into practice (Wagstyl, 1996). Siemens, has - next to Hitachi - the world's largest corporate R&D budget (around 4,8 billion dollars)⁹. Until 1994 Siemens' central laboratories secured two-thirds of their finance from the group headquarters, which charged the money as a "tax" on the divisions. The rest was funded directly from the divisions or from government research programmes. The divisions resented paying this "tax", so central funding was reduced to one-third and the amount contributed directly by divisions was increased to one-half. Moreover, the divisions were given the freedom to contract their R&D to outside organizations. Thus, the divisions are not obliged to use the services of the research centre. The laboratories not only had to orient their work to the needs of their customers in the divisions. They also had to advertise their services using lectures and demonstrations. "The "buyers" from the operating divisions choose the programmes they want to fund and then negotiate the details, including price, with the laboratory managers (Wagstyl, 1996).

Central R&D in Danfoss

The changing organization of R&D in Danfoss seems quite typical of the described tendencies in the evolution of R&D in the multi-divisional corporation (Iversen & Christensen, 1996). In the 1960's Danfoss was a quickly growing functionally organized company with a conventional R&D lab, Corporate Technology and Research. However, up through the 1970's the newly established and rapidly expanding product divisions gained growing control over resource allocation decisions in the R&D lab. This resulted in increasing numbers of small projects without much coherence and overall guidance. In the 1980's, under the direction of Jørgen M. Clausen, son of the founder of Danfoss, CTR regained significant autonomy and began to focus on a more limited number of strategic R&D and venturing projects. Gradually the product divisions, of which there are 10 to day, have grown so large that they increasingly have become capable of managing their own R&D within their respective business domains and to some extent also ventures for business diversification. This has resulted in a substantial transformation of CTR from a R&D lab to center for corporate technology management that transcends the traditional role of the corporate R&D lab even if R&D still plays an important role. While most of R&D in Danfoss was carried out in CTR in 1960's and early 70's the CTR-based R&D today only covers about 20% of total R&D in Danfoss. Around one fourth of total costs in CTR is financed by the divisions.

⁹ Some 44,800 people work in R&D in Siemens. Far the most of these work in the operating divisions, and about 1,700 are assigned to the central laboratories where the mainpart of the longer-range research takes place (Wagstyl, 1996).

In the subsequent section I shall explore the potential roles of such corporate technology management and provide further illustration from the Danfoss case.

5. THE ROLE OF CORPORATE MANAGEMENT OF TECHNOLOGY IN PURSUING DYNAMIC COHERENCE

While the conventional central R&D lab has come under severe strain as the corporation has diversified and divisional R&D has been strengthened, there seems to be a growing demand for corporate-level management of technology. However, this does not imply a reversal of the general tendency to decentralize innovative efforts. A "back to centralism" in the management of the corporate technology base would impose dramatic bureaucratic costs and incentive problems, and undermine the advantages that the decentralized M-form has demonstrated with respect to the organization and functions of the technology base:

- A stronger market-orientation (including responsiveness to national or local requirements) in technological development and innovative efforts,
- less bureaucracy and fewer vertical levels involved in decisions concerning the allocation of R&D resources between alternative projects,
- greater motivation and entrepreneurial spirit as a consequence of a situation in which local operations and initiatives are not constantly disturbed or overruled from higher levels, and
- better potential for intimate inter-functional arrangements between R&D, marketing and other functional areas in the pursuit of product or process development (Coombs, 1996).

What is called for, is a balanced perspective on corporate management of technology, in which there is still a role to play at the corporate level, even if the larger part of R&D and the management of technology take place at the more decentral levels and even in collaboration with external parties. This implies that the "pure" williamsonian M-form has to be counterbalanced by some elements of central coordination and inter-divisional cooperation, and generally by loosening the rigidity of organizational structures and creating elements of flexibility and variety in exploring opportunities. Pavitt (1991) argues that an essential dimension of successful large firm's managerial competence is the ability to combine the differentiated technological competencies into effective units for identifying and developing innovations.

This section discusses the options for managing the corporate technology base in technology-intensive corporations with the purpose of increasing dynamic corporate coherence.

5.1. Pursuing dynamic coherence of the corporate technology base

Dynamic corporate coherence is defined as the corporate capacity to exploit and explore synergies from a diversity of capabilities, competences and other resources (Christensen and Foss, 1996). In high technology corporations coherence of the corporate technology base is a critical aspect of the overall corporate coherence¹⁰.

The coherence of the technology base signifies the degree of coordination and interrelatedness within the technology base between the different technological and innovative competences. A high level of coherence reflects a technology base comprising a diverse portfolio of innovative competences, and characterized by the exploitation and exploration of a high level of communication, knowledge exchange, synergy and coordination in innovative efforts - not only in horizontal relations (between divisions and business units) but also in vertical relations (between the corporate centre of R&D and technology management and divisional innovative efforts), as well as in external relations.

Below I shall briefly discuss the following objectives of a corporate centre of technology management:

- Providing overall strategic guidance of the corporate technology base and innovative efforts.
- providing "parenting value" to divisions and business units in their innovative efforts,
- assuring a proper balance and alignment between short-term, incremental innovative efforts (exploitation) and long-term explorative efforts,
- increasing horizontal technology transfer and sharing, as well as synergy and coordination in research and technological innovation between divisions and business units.

These objectives reflect different (although overlapping) dimensions of pursuing dynamic coherence of the corporate technology base. Strengthening the corporate coherence of the technology base should not, of course, be the only strategic concern for corporate

¹⁰ The notion of coherence of the technology base may apply to three dimensions as discussed in Christensen (1997): 1. The external coherence (or "fit") reflects the degree to which the competences constituting the technology base match the requirements of the competition. 2. The contextual coherence reflects correspondance between the technology base and the broader firm or corporate context (the complementary assets, the operational and infrastructural firm context, the company's strategy and culture. 3. The local coherence signifies the degree to which there are interdependencies and synergies between different parts of the technology base. This section exclusively deals with this latter dimension of coherence of the technology base.

management in diversified corporations. But it should certainly be of central concern to the corporation that seeks synergistic and vertical economies.

Providing overall strategic guidance

One overall objective for the corporate management of technology would be the provision of long-term perspectives and guidelines for the rate and direction of the corporate technology base as well as for the overall strategic direction of the corporation.

In their study of 24 diversified companies with significant R&D performance, Coombs and Richards (1993) found..."that some companies are creating small units at the centre of the corporate structure (which may or may not be within the R&D function), the purposes of which include the following:

- analyzing the structure of the overall technology portfolio;
- ensuring that a technological competence in one business is known to and available to other potential user businesses in the group;
- identifying technical competencies which straddle businesses, in order to take steps to strengthen them through 'horizontal' organizational links and through small special budgets;
- considering the overall technology portfolio and injecting an appreciation of this portfolio into the broader strategic management processes of the company" (p.390).

Thus, such a corporate centre of strategic technology management could be a vital vehicle in promoting a coherent technology base "from above": A forum for reflection, coordination and strategic guidance on the one hand, and a window for making the different facets of the corporate technology base visible and accessible for divisions and business units on the other hand. These roles can only be performed effectively if a close and ongoing dialogue exists between the centre and the divisions and business units.

Providing direct "parenting value" to the business units

While this broad strategic guidance role - if successful - provides "parenting value" of an indirect kind, direct "parenting value" implies the provision of specific inputs to the value generating processes in the divisions and business units. The role of the conventional R&D lab was in fact to supply R&D-inputs into the product and process development projects of the business units. As outlined in section 4 this role has been increasingly difficult to realize in the context of the isolated lab in the ivory tower and the growing complexity of the divisional setting. The objective to improve the direct parenting value of the central lab underlies the increasing efforts in diversified corporations to tie the central lab in to the direct interests of the divisions by a) increasing divisional funding of the lab, b) increasing divisional political influence on resource allocation in the lab, and c) by replacing the "transfer logic" by a

"teamwork logic" (cf. section 4),

It should be added, however, that central R&D and technology management may not only produce technical knowledge but also - and perhaps increasingly so - inputs to the development of organizational or managerial competences (such as procedures and standards for project management, quality management or user-producer relations in product development).

Assuring a balance and alignment between exploitation and exploration

Balancing the trade-off between the reproductive and explorative dimensions of the technology base is a highly complex task in the large diversified corporation. Within the conventional conception of the large corporation with a central lab this balance was handled by a simple division of labour: The lab was responsible for the explorative efforts, while the operating divisions were responsible for the efficient exploitation and commercialization of inventions and discoveries generated in the lab.

Centralized R&D may play a role in countervailing the tendency in the wake of decentralization and internationalization towards compromising exploration and risky R&D investments in favour of exploitation (and short-termism). Thus, some degree of centralized control over and impetus in the strategic development of the technology base may be required to assure a coherence of the corporate technology base that balance the trade-off between short-term incremental and longer-term explorative efforts.

This objective may be difficult to reach if the R&D lab is exclusively locked-in to serve the immediate requirements of the divisions. The answer is not, however, to go back to the "ivory tower" model of the lab; this model may very well assure a remarkable exploratory capacity, but it does not assure a fit between the exploratory outputs and the operational competences of the divisions. A very critical aspect of the balance between exploration and exploitation is that the new technologies developed can be aligned with the "old" operating technologies and that requires a cooperative relation between the lab and the divisions and a recognition that sometimes explorative efforts that go beyond the scope of the individual divisions is necessary¹¹.

Strengthening horizontal linkages and coordination

Strengthening horizontal linkages and coordination seems an increasingly important, although highly difficult, objective for diversified corporations in which fragmentation of the corporate technology base is creeping in.

Two types of horizontal issues should be addressed: First, providing channels and incentives for inter-divisional communication, asset sharing and transfer; secondly, providing means to

¹¹ Barpal (1990) illustrates how Westinghouse has organized its central R&D in order both to assure direct parenting value to the divisions, and assure proper concern for explorative efforts.

assure inter-divisional coordination when technological interdependencies exist.

Promoting inter-divisional communication and exchange would involve both some channels (an infrastructure) and some incentives. Examples of channels could be a) coordination groups and committees that cut across the interest of individual businesses and divisions; b) rotation programs among divisions for the younger personnel; c) cross-divisional project teams for diffusing core competencies and for loosening the bonds that might tie an individual to one business (Prahalad and Hamel, 1990, p. 91), d) implementing the "merchandiser" concept (Collinson, 1993) as developed by Sony¹². Moreover, an efficient and sophisticated corporate-wide IT infrastructure is a basic precondition for any effort to expand inter-divisional communication.

Incentives are probably more difficult to assure. While the economic incentives for divisional management in the conventional M-form is focused exclusively on the economic performance of the individual division, incentives in the synergy-oriented corporation should (also) emphasize inter-divisional cooperation (for example, profit bonus for divisional managers may be linked to inter-divisional or corporate rather than exclusively divisional profitability) (Hill, 1994)¹³. The complexity and stability of such integrating mechanisms can vary, depending on the degree of interdependence, and the uncertainty and durability of the relations (Hill, 1994).

When strong technological interdependencies exist between divisions in a corporation coordination on a set of standards for technology adoption decisions may yield significant benefits. And that may be difficult, if there is no hierarchical authority to assure that this will happen: "If potential adopters make decisions independently, however, only weak incentives may exist for them to invest in technologies which meet a common standard, since net gains from such investment to the individual adopter may be small or even negative, even if net gains to the group are large. The externalities are positive" (Argyres, 1995, p. 338-39). IBM had until recently a series of formal procedures for coordinating the strategies of the divisions. "Foremost among these was the so-called 'right of review'. If any division 'nonconcurred' with a strategic decision made by another division, it could demand that the decision be 'escalated'

¹² "Merchandisers" are individuals with a cross-divisional perspective. They are freed from routine tasks and given the authority to act as internal entrepreneurs.

¹³ IBM was in the 1970's and 1980's a "benchmarking" case of strategic planning style corporation pursuing corporate coherence (Goold and Campbel, 1987). As one IBM executive commented: "IBM is a very big organisation, distinctive in how tightly we link everything together. We want to integrate as much as possible and maintain control through centralised planning and tracking, but we also want to decentralise implementation and operating decisions. There are no major strategic decisions that are delegated" (Goold and Campbel, 1987, p. 261). The incentive and bonus system for division managers in IBM reflected this corporate style. Following Argyres (1995) "Division managers' bonuses were said to depend heavily on corporate performance...Promotions of these managers were widely believed to depend on both the performance of their divisions and on subjective evaluations of their decision-making abilities. Those earning promotion were often seen as, in the words of one manager 'good team players, good IBMers' (p.349).

to the next level in the hierarchy" (Argyres, 1995, p. 349). Mostly, however, the threat of intervention from corporate management implied that most of these disagreements were resolved bilaterally (Goold and Campbell, 1987, p. 264).

5.2 Corporate management of technology in Danfoss

During the first half of the 1990's Corporate Technology and Research Center in Danfoss has focused strongly on the creation of synergy between the product lines in the corporation. One organizational means of promoting synergy is the so-called technology pyramid. The "technology pyramid" is a strategic posture of the corporate technology base. It contains a selection of technologies used in (or to be developed and used in) Danfoss. These technologies have significant value for more than one division¹⁴. Two sub-categories of technologies in the pyramid are distinguished: 1) Technologies that are considered "key competences" implying that Danfoss is or strives to be at the global forefront in R&D, and 2) technologies considered "key disciplines" implying a position among the leading competitors. To provide support for both a central and inter-divisional development of these high-priority technologies committees have been formed, each responsible for one technology. Apart from competent members from different divisions and CTR, each committee has an appointed gatekeeper who is directly responsible for the development and monitoring of the technology, and a sponsor who has responsibility for budgets and for assuring proper linkages and coordination between the committees and gatekeepers. The technology pyramid is not static but regularly subject to consideration and changes.

Danfoss has moreover an elaborate network of inter-divisional committees and groups for among other things standardization, quality management and information technology. Both the "technology pyramid" and the other networking efforts have been established to strengthen corporate coherence and synergy.

Both corporate technology management and central R&D is localized in CTR with 150 employed. Apart from quality and technology management (including property rights services) CTR is involved in R&D that can either be directly used in one or more of the product divisions or provide options for new ventures. While the divisions' R&D for the most part has a time horizon of 1-3 years, CTR R&D takes care of projects with a horizon of 4-5 years and a higher level of uncertainty.

6. CONCLUSION

This paper has discussed 1) generic forces of diversified corporations and their implications for the corporate technology base, 2) the changing role of the central R&D lab in the context

¹⁴ For technologies that are only important to one division the division in question is expected to take full responsibility.

of these forces, and 3) the (potential) role of management of technology in promoting dynamic coherence in diversified - and highly decentralized - corporations.

Four overall tendencies in the growth of the multi-divisional corporation have been identified: 1) Diversification, 2) increasing division of labour, 3) decentralization, and 4) internationalization. It is argued that combined these dynamics have promoted an inherent movement towards fragmentation of the corporate technology base and more short-termism and risk-aversion in R&D-investments. However these dynamics have also given rise to a stronger market-orientation in innovative efforts, and better possibilities to promote inter-functional integration in innovative efforts. These implications primarily hold for the "traditional" Williamsonian M-form and not to the same extent within corporation that actively pursue inter-divisional synergy and corporate coherence which is mostly the case with technology intensive corporations.

In the context of these corporate forces for increasing diversity and complexity the role of the central R&D lab has undergone significant changes. As divisions grow larger and more autonomous with respect to R&D, and as the corporation grows more diversified the central R&D lab has tended to become decoupled from the divisions' operational as well as innovative affairs. The response to this problem has been either to close or downsize central R&D or to make the central R&D activities dependent of divisional funding and strategic influence, and to replace the traditional "transfer logic" by a "teamworking logic".

While the heyday of the conventional central R&D lab is over - at least in the large diversified corporation - the paper argues that management of the corporate technology base has an important and growing role to play in technology-intensive diversified corporations. Exactly the same forces that have contributed to increasing corporate diversity and undermined the central lab's corporate monopoly on R&D, have created the need for an overall corporate management of technology to pursue synergy and corporate coherence.

Four objectives for the management of the corporate technology base that may contribute to strengthen the dynamic corporate coherence were identified and shortly discussed: 1) Providing overall strategic guidance of the corporate technology base and innovative efforts, 2) providing parenting value to divisions and business units in their innovative efforts, 3) assuring a proper balance and alignment between exploitation and exploration in innovative efforts, and 4) increasing horizontal technology exchange coordination between divisions and business units.

If dynamic coherence of the technology base becomes a corporate strategic objective, then corporate centre must take (at least part of the) responsibility for promoting synergy, balancing exploitation and exploration, and assuring that the logic of technology diversification is subject to strategic analysis in terms of technology base coherence, and not exclusively the reflection of the business strategies of the divisions.

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