ORGANIZING FOR INNOVATION IN LARGE FIRMS

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ORGANIZING FOR INNOVATION:

RESOURCE ALLOCATION MECHANISMS FOR R&D IN LARGE FIRMS

ABSTRACT

Determining how a firm can best be organized to facilitate innovation is a topic of central importance to managers and academics alike and is thus the focus of this paper. Specifically, this paper focuses on two important components of organizing for innovation: design of R&D resource allocation systems and the use of external sources of technology. The study makes a theoretical contribution by developing the metaphor of the "internal market" as useful mechanism for resource allocation inside the firm. In addition, the research benefits from using a two-phase empirical approach. The first phase consists of four in-depth case studies of HP, ABB, Ericsson, and Xerox's global R&D organizations. For the second phase of the study, a questionnaire was developed to test the study's hypotheses on a sample of 103 large firms. The study's key findings are that increased use of external sources of technology results in increased efficiency, but decreased effectiveness. However, results also indicate that it is always important to perform environmental scanning activities. No strong relationships were observed between the use of internal markets as a resource allocation system and firm performance. The case studies reveal that this lack of relationship is likely because leading firms have learned to develop checks and balances to help overcome the weaknesses that their resource allocation system possesses.

Key words: Internal market, Resource allocation, Research & Development

ORGANIZING FOR INNOVATION IN LARGE FIRMS

For most large firms the link between technological innovation and competitive advantage is axiomatic. In an increasingly competitive world, it is argued, traditional sources of advantage such as distinct market positioning or access to non-imitable resources are being eroded. Instead, competitive advantage is better viewed as a *dynamic* capability – a function of the firm's ability to innovate, learn, or continuously reposition itself more effectively than its rivals (e.g., Teece, Pisano and Shuen, 1997). But while few would challenge the link between technological innovation and competitive advantage, the question of how to be consistently innovative is a matter of considerable debate. The traditional model as exemplified by firms such as IBM, Philips and AT&T was to keep everything in-house – from basic research through to product development. Today, a number of alternative models can also be identified – partnering with universities to get access to basic research, in-licensing of technologies from competitors, acquiring competitors for their emerging technologies, and using internal "contracting" relationships between business units and research labs. While the evidence is still limited, most observers argue that these alternative ways of managing innovation are on the rise (e.g., Bean, 1989; Croisier, 1998; Narula and Hagedoorn, 1999, Tidd and Trewhella, 1997; Veugelers, 1997).

The focus of the paper is on these emerging ways of organizing for technological innovation. More specifically, we focus on (1) the use of external sources of technology as a complement to the firm's own R&D and (2) the use of market-like systems inside the firm to link research more effectively with the needs of business units. We begin by considering the theoretical reasons why such resource allocation approaches might be valuable. We then describe the results of a detailed empirical investigation of this phenomenon, in terms of two questions: How are these approaches actually used inside large firms? And what, if any, is the impact of these approaches on firm performance?

The intended contribution of the paper is twofold. First, the paper is a *managerially-focused* analysis of these new approaches to R&D organization. There have been many studies in recent years about R&D in-licensing, alliances and such like, but they typically rely on secondary data and therefore they do not have detailed information about internal issues (e.g., Croisier, 1998; Narula and Hagedoorn, 1999; Veugelers, 1997). In contrast, the current paper is based on interviews with 55 managers and a questionnaire filled in by 103 different firms, and thus there is a wealth of detail that represents an important complement to the existing body of literature.

Second, the paper uses the metaphor of the "internal market" as a way of making sense of the increasing use of contract-based relationships between corporate research labs and business units. The internal market concept has been used before at a conceptual level (e.g., Halal, 1994; Reger, 1999; Williamson, 1975). Our purpose in this paper is to take it further by developing and testing specific hypotheses. This approach allows us to make a contribution to theory as well as to shed light on the phenomena described above.

The paper is in five sections. Below, we provide some background on the approaches used to organize R&D in large firms. Next, we develop specific hypotheses linking specific organizational arrangements to performance. The third and fourth sections describe the research methodology and findings. Finally, we discuss the implications of this study for the management of R&D and for the theory of the firm.

THEORETICAL BACKGROUND

A useful starting point when considering the organization of R&D activities is to view it as a resource allocation exercise. In other words, top management's task is to allocate the firm's scarce resources to certain innovation-oriented projects with a view to them providing valuable outputs in the form of new products and/or new technologies. This conceptual lens helps us to understand the choice of *where* R&D is undertaken – not just inside vs. outside the boundaries of the firm, but also the choice between different internal and external options (Teece, 1986, 1996). It also offers a way of thinking about the *process* of resource allocation in R&D and the factors that influence the process (Bower, 1970; Burgelman, 1983; 1993).

Considering the *where* question first, resource allocation in R&D has been internally focused for most of the post-war period. Two main theoretical arguments explain why this approach has dominated. One, transaction cost logic, suggests that the peculiar characteristics of technological development (uncertain outputs, tacitness, interrelatedness etc.) hinder the emergence of efficient markets in technology, and thus favour a hierarchical mode of governance between the R&D organization and the rest of the firm (Teece, 1996). A second and related argument can be traced back to Schumpeter (1934). It suggests that breakthrough technologies cannot withstand the short-termism of the marketplace because of the length of time they take to commercialize and the resistance they face from existing technologies. Schumpeter thus saw the firm as a vehicle for "protecting" new ideas in their formative stages and therefore as the principal enabler of breakthrough technological change.

While these arguments are still highly relevant, there is evidence that this historical model is beginning to break down (Leonard-Barton, 1995: 144). The reasons for this shift, at a conceptual level, are as follows:

- End products embody an increasingly broad set of technologies (e.g., electronics in cars) so firms can no longer hope to do everything in-house. Thus, certain technologies and particularly those that are deemed to be non-core are bought (Iansiti, 1998).

- The existence of increasing returns to scale in certain industries (Arthur, 1996) provides an incentive for firms to conform to existing technological standards rather than develop their own proprietary standards.

- The ability to evaluate technologies has increased, through such techniques as portfolio analysis and real options pricing. This reduces transaction costs and makes it easier for firms to trade technology (Narula, 1999).

- Basic research is increasingly seen by firms as an expensive luxury – nice to have, but frequently benefiting their competitors as much as themselves. Notwithstanding Schumpeter’s (1934) argument that breakthrough technology occurs most effectively in large firms, the reality is that many such firms are moving downstream and leaving basic research to universities and other government-funded programs.

All of these changes, then, point to a qualitative shift in the way that large firms are thinking about R&D resource allocation. Part of this shift is an *increasing openness to external sources of technology*, through in-licensing on an open market, relationships with universities, alliances with competitors and a number of other techniques (Doz and Hamel, 1998; Eisenhardt and Tabrizi, 1995; Iansiti, 1998; Leonard-Barton, 1995; MacCormack, 1998; Veugelers, 1997). The other part of this shift is an *increasing interest in market-like systems for allocating resources inside the firm*. For example, many firms have moved R&D into business units where it is closer to customers, while others have created "contract" funding systems to link R&D more explicitly with the perceived needs of business units (Bean, 1989; Halal et al, 1996; Leonard Barton, 1995; Peters, 1994; Reger, 1999; Roussel et al, 1991). In both cases, this represents a move away from a traditional hierarchical mode of governance and towards various hybrid modes such as alliances and internal markets (Williamson, 1975, 1991). Before getting into specific hypotheses associated with each one, it is therefore valuable to consider the markets-hierarchies framework in greater detail.

Hybrid Modes of Governance

Hennart (1993), Williamson (1991), and many others have argued that most transactions occur under hybrid modes of governance that lie in the "swollen middle" between pure market and pure hierarchy. In considering the nature of such hybrid modes of governance, Hennart (1993) makes the important distinction between organizing methods (hierarchy and price) and institutions (firms and markets). This distinction suggests two different forms of hybrid – (1) market-based transactions that incorporate elements of hierarchy such as trust, forbearance, and identity; and (2) firm-based transactions that are organized through the price system. The former, as manifest in strategic alliances, joint ventures, outsourcing relationships, franchise arrangements and so on, has received considerable research attention in recent years (e.g, Jarillo, 1988; Kogut, 1988; Thorelli, 1987). The latter form of hybrid, which we broadly refer to as an "internal market", has been studied sporadically over the years (Arrow, 1959; Buckley and Carter, 1997; Halal, 1994; March and Simon, 1958; Williamson, 1975) but without ever developing as a subject for research in its own right.

Why should such hybrid modes of governance be attractive? The simple answer is that they can provide many of the benefits of hierarchy *and* market without some of their inherent weaknesses. Hennart (1993) argues that the price system encourages cheating and hierarchy encourages shirking, thus to minimize total organizing costs (costs of shirking plus cheating) most transactions embody elements of both market and hierarchy. This is an attractive logic, but it does not help to choose *between* the two different hybrids. Here, the issue is essentially one of ownership and control. Thus, alliances are often formed as a means of gaining accesses to resources that cannot be controlled by the firm, whereas internal markets are formed in cases where the firm is reluctant to lose possession of the resource in question.

Our argument, in essence, is that the concept of hybrid modes of governance is a very useful way of looking at the phenomenon of R&D resource allocation, because the changes described above represent a shift in governance mode from pure hierarchy to the two hybrid modes, and perhaps even to the pure market in some instances. Exactly why one mode is chosen over another is a complex issue, thus it will be discussed after the empirical evidence has been set out. For the moment, it is important simply to recognize that the increased use of external sources of technology and the increased use of market-like systems inside the firm are really two sides of the same coin.

To pick up one more thread from the earlier argument, it is important to remember that R&D resource allocation is also a *process*, and as such it is steered as much by contextual factors within the organization and individual preferences as it is by efficiency criteria of the type described above (Bower, 1970; Burgelman, 1983). While the process issues will not be developed in any great depth, it would be wrong to neglect them. Thus, in the findings from the first phase of research, we explicitly consider both the where and the how of resource allocation and the interlinkages between them.

Use of External Sources of Technology

When considering the literature on external sourcing of technology, two distinct strands of thinking can be identified. One is concerned with the specific decision to *substitute* in-house R&D with technology sourced from the outside. The second concerns the process of tapping into the knowledge bases of partner firms through, e.g., learning in alliances, environmental scanning, and direct observation.

The former line of thinking has focused primarily on the reasons why firms source technology from external parties. Studies have discovered that there are many factors at work here, including aspects of the corporate strategy, the industry, the technology, and the internal preferences of management (Atuahene-Gima, 1992; Croisier, 1998; Granstrand et al, 1992; Hagedoorn, 1993; Hauschildt, 1992; Reger, 1999; Tidd and Trewhella, 1997). They have also shown that external sourcing of R&D is more effective when done in combination with in-house R&D (Gambardella, 1992; Rothwell, 1992; Veugelers, 1997).

But in all the aforementioned research, there is little direct consideration given to the impact of external sourcing of technology on firm performance. To some extent one can predict that external sourcing must be beneficial because its use continues to rise, but it is important be clear on a theoretical basis what effect one would expect it to have on performance. This is where the market-hierarchy framework, and the bodies of theory discussed earlier, come in useful. Our argument, in simple terms, is that external sourcing of technology will be *more efficient* than sourcing from inside the firm, but that it will be *less effective*. Efficiency here is the extent to which production of required output at a perceived minimum cost is achieved (Schmidt and Finningan, 1992: 347). Effectiveness refers to how closely an organization's output meets its goal and/or the customer requirements (Schmidt and Finningan, 1992: 347). Thus, if the technology in question meets a short-term or well-defined need, efficiency is likely to be the key performance indicator, whereas if the technology is long-term in scope or vague in definition, effectiveness is more important.

The theoretical logic for this assertion can be traced back to Hayek (1945), who argued that markets are very efficient in terms of their ability to adapt autonomously to changes in supply or demand. However, this efficiency comes at a price because investments that offer uncertain or distant returns are hard for the market to evaluate and are thus "driven out" by short-term considerations. Hence, Schumpeter's (1934) argument that firms offer an important benefit to society to the extent that they nurture investments of a long-term and indeterminate nature. Hierarchy, in other words, is a mode of governance that offers the potential for greater R&D effectiveness, e.g., in terms of breakthrough technologies, but without the same efficiency of the market (Williamson, 1991: 280). Stated more formally:

> Hypothesis 1. The more firms use external sources of technology, the higher performing they will be on measures of efficiency.

> Hypothesis 2. The more firms use external sources of technology, the lower performing they

will be on measures of effectiveness.

As noted above, there is a related strand of thinking that is concerned with how firms tap into the knowledge base of partner firms. It includes research on knowledge imitation between competitors (Mansfield, 1985; Zander, 1991; von Hippel, 1987) the process of environmental scanning in general (Aguilar, 1971; Ghoshal and Westney, 1991; Hambrick, 1982), learning in joint ventures (Hamel, 1991; Inkpen, 1992; Kogut, 1988; Mowery et al., 1995), and knowledge spillovers in industry clusters (Malmberg et al., 1995; Saxenian, 1995; Frost, 1998). Without getting into a long discussion on the nature of knowledge, an important distinction between knowledge as used in this literature and technology as used earlier is that that knowledge can be imparted to the recipient without loss to the source, whereas technology sourcing involves a shift in property rights. Thus, the cost-benefit equation for external sourcing of knowledge is likely to be rather different from that put forward for external sourcing of technology. Our argument here is that the more firms use external sources of knowledge, the higher performing they will on measures of efficiency *and* effectiveness. There is, in other words, no trade-off between efficiency and effectiveness. This is because the cost of tapping into knowledge from outside the firm is low. It is achieved through openness to new ideas, rather than through costly systems or programs. More formally, then, we suggest an elaboration of Hypothesis 2, as follows:

Hypothesis 2a. The more firms use external sources of *knowledge*, the higher performing they will be on measures of effectiveness.

Use of Market-like Systems Inside the Firm

The use of market-like systems inside the firm is far less developed in the literature. As noted above, the term internal market is used occasionally in the academic literature and primarily with regard to the idea of an internal capital market (Williamson, 1975). However, the underlying notion that market-like systems of resource allocation pricing and competition exist within the boundaries of the firm is an old one. One line of thinking examines the use of transfer pricing within the firm as a market-like control system (Cook, 1955; Eccles, 1982; Hirschleifer, 1956). A second body of literature looks explicitly at the multinational corporation and the systems of interaction between HQ and affiliates (Birkinshaw, 1999; Buckley and Carter, 1997; Ghoshal and Bartlett, 1990). There is also a more practically-oriented body of literature concerned with how such systems are applied in large firms (Halal, 1994; Peters, 1994).

The use of market-like systems in *R&D organizations* is, however, given almost no consideration in the extant literature (small exceptions are Halal, 1994, and Reger, 1999). Thus, we have to be very clear on what the concept refers to. Figure 1 provides a simplified illustration. Under the traditional model, corporate research groups were responsible for coming up with new technologies, which were then picked up by the business units and turned into commercial products. To simplify considerably, the emphasis was on technology "push" and on basic research. Under the internal-market system, the power lies primarily with the business units, who contract with the corporate research group to undertake research in a specified area in return for funding. Here, the emphasis is on market "pull" and on applied research that is directed towards commercial ends. Of course the reality in most companies is a blend of the two approaches described here. The essential point is that as one moves from the traditional model towards the internal-market model the "commercial" pressures of the market are brought more to bear on the work undertaken by the research department.

On the basis of this description, it is quite straightforward to hypothesize about the likely impact of market-like systems on firm performance. As before, such systems are likely to increase efficiency e.g., by making R&D activities more cost-efficient, but with a concomitant reduction in effectiveness, because business units are by nature more short-term oriented than research departments. However, it is also reasonable to speculate that these effects will be weaker than for hypotheses 1 and 2 above, because the resource allocation processes in question are still occurring within the boundaries of the firm.

> Hypothesis 3. The more firms use market-like systems inside the firm for R&D, the higher performing they will be on measures of efficiency.
>
> Hypothesis 4. The more firms use market-like systems inside the firm for R&D, the lower performing they will be on measures of effectiveness.

-------------------- Insert Figure 1 about here --------------------

RESEARCH METHODOLOGY

This research was conducted in two phases. Phase one involved in-depth interviews with 55 executives in four firms. Phase two was a mail questionnaire that yielded 103 responses from R&D –intensive firms in Sweden and Great Britain. Before getting into the details of the methodology, it is important to emphasize that the clinical phase of research provided the insights into the resource allocation processes in R&D that allowed us to operationalize the constructs and put together the questionnaire. We have chosen to write up the study in a more deductive style by organizing the text around the main constructs, but this is for expositional reasons only.

In phase one of the research we undertook comparative case studies of four firms operating in the electronic-electrical engineering sector. Since this sector clearly is undergoing considerable technological changes and is global, it represented a suitable arena in which to investigate the changes outlined above. The sample firms had to meet a number of criteria including size (greater than $10 billion sales) and geographical diversity (R&D activities in at least four countries). We also chose to approach firms that were commonly thought to be reasonably successful and appeared to be working close to the "best practise" boundary.

The four firms studied were ABB, Ericsson, HP, and Xerox. Ericsson, HP and Xerox are remarkably similar in their R&D profiles in that they are all working with electronics, hardware, and software. ABB is somewhat broader in scope with operations in power generation and transmission, industrial systems, and a number of other industries. However, even in ABB the importance of software and electronics R&D is increasing. Thus, during the research we focused on the software-intensive parts of ABB to facilitate comparisons. Table 1 provides an overview of the four firms' R&D organizations, in terms of where their R&D activities are located and how they are structured.

--------------------- Insert Table 1 about here ---------------------

Data in these four companies were collected between December 1997 and April 1999. We conducted a total of 55 interviews (each one to two hours in length) with R&D vice presidents, lab managers, and business unit managers (see table 1). These interviews were semi-structured around issues of resource allocation. Questions were gradually refined as the research progressed and we began to get a more detailed understanding of each firm. We also conducted a questionnaire survey in the companies. It was put together as the interview stage neared completion, and it was then mailed to all the interview subjects. 43 of the 55 questionnaires were returned. The questionnaire aimed to provide quantitative verification for our qualitative findings. We developed multi-item scales for what appeared to be the main constructs emerging from the interviews. These scales were examined for reliability using the 43 responses and refined accordingly. The analysis then consisted of a series of Kruskal Wallis ANOVA models to identify differences in mean levels between the four firms.

The second phase of data collection was a large sample survey using the questionnaire that was developed in the four-company study. For practical reasons this survey was undertaken in Sweden and Great Britain. In Sweden, we assembled a database of R&D-intensive firms using the sources *Hugin* (owned by magazine Veckans Affärer) and by using the Swedish Institute of Statistical Information's (SCB) database. Foreign-owned firms were excluded from this database, as were holding companies. The questionnaire was sent to 160 companies. In Great Britain we used the Financial Times list of the largest 500 R&D intensive firms in the country, which after removing foreign-owned companies resulted in a database of 220 firms. In both countries, we phoned each of these firms to get the name of the R&D director. The questionnaire was then mailed to that individual, and after a follow-up mailing we ended up with 50 responding firms in Sweden (31%) and 53 responding firms in Great Britain (24% response rate).

Construct Operationalization

The constructs were operationalized in the course of the first phase of research. This section describes how they were measured on the questionnaire and, where relevant, how they were identified as important characteristics.

Use of external sources of technology. We developed three operational measures. First we asked respondents to indicate the percentage of technology they bought or in-licensed (as opposed to being developed in-house). The second measure was an aggregate assessment of how important a variety of external sources of R&D expertise were. Third we asked how open people in the organization were to knowledge from other sources. The latter measure was developed to tap into the issue of external *knowledge* acquisition developed above. More specifically:

1. Percentage of technology bought or in-licensed. What percentage of the firm's technology capability is bought or in-sourced from other companies?

2. Use of external sources. How valuable are the following as sources of R&D expertise: (a) universities located close to the R&D sites, (b) universities located elsewhere, (c) alliance or joint venture partners, (d) supplier firms, (e) customers. 1= not important, 7= extremely important. Cronbach's Alpha = 0.68.

3. Openness to outside knowledge. Indicate the extent to which you agree with the following statements about your company: (a) In this company there is a great openness to picking up ideas from outside. (b) The "not invented here" syndrome is a real problem here (reverse coded). 1=totally disagree, 7=totally agree. Cronbach's Alpha=0.73.

Use of Market-Like Systems Inside the Firm. We developed three operational measures, which together provide a fairly comprehensive indication of the extent to which market-like systems of resource allocation are used inside the firm. The first was concerned with the *locus of control* of pure and applied research, from being a corporate responsibility to being activity controlled by individual business units. The second focused on the *system for funding research.* At one extreme, a firm would fund research purely through a corporate "tax" on the business units. At the other extreme, all research would be funded through project-based contracts, in which business units would specify exactly what they expect to get in return for funding. The third measure was the extent to which R&D *resource allocation decisions were driven by commercial vs. technical managers*, to give a qualitative sense of the influence of market considerations on R&D decisions. Wording for these questions is as follows.

1. Business unit control of research activities. How is (a) pure research, (b) applied research split in your firm? 1 = done at a corporate level, 2 = split between corporate and divisions, and 3 = done by the divisions. Inter-item correlation = 0.79.

2. Use of "contract" system for funding corporate research. Which of the following systems are used for funding research? (a) Projects are contracted by divisions; (b) a fixed tax paid by

divisions (reverse coded). 1=not used at all to 7 = used to a great extent. Cronbach's Alpha = 0.80.

3. Commercial input into R&D resource allocation decisions. Assess the relative input of commercial and technical managers into the following decisions: (a) overall funding levels, (b) definition of specific projects, (c) definition of long-term research trajectories, (d) identification of new research opportunities, (e) "killing" a project that is delayed or in difficulties, (f) paying additional costs when projects are delayed. 1 = decided by technical managers, 5 = decided by commercial managers. Cronbach's Alpha = 0.76.

Measures of Performance. As discussed, it is important in this research to distinguish between the efficiency and effectiveness dimensions of performance. We asked respondents to self-rate their performance on specific aspects of efficiency and effectiveness. This approach was chosen since we wanted to get as precise measures of efficiency and effectiveness as possible.

Respondents indicated their firm's overall performance over the last three years, in comparison to competitor firms in the industry, in terms of (1) getting new products to market quickly, (2) making efficient use of R&D expenditure, (3) coming up with radical / breakthrough technologies, and (4) bringing breakthrough technologies to market. The first two measures are measures of efficiency and the last two measures are measures of effectiveness.

FINDINGS

There are two sets of findings from this study, corresponding to the two phases of research. The first set of findings will describe how R&D resource allocation works in the four companies, focusing on the core constructs identified above, and on some of the process issues that cannot be ascertained from a questionnaire. The second set of findings will draw from the questionnaire and will address the hypotheses about performance.

Findings from the Four-Company Study

Use of external sources of technology. All four firms make considerable use of external sources of technology for many of the reasons that were put forward earlier. But there is also considerable variation in the extent to which external sources are used and the policies (usually implicit) around external sourcing. As shown in table 2, HP makes the greatest use of external sourcing with only 70% of the technology in products created in-house. Ericsson is at the other extreme with 88% in-house, while ABB and Xerox are at 76% and 78% respectively. Key to understanding these differences, though, is the insight that *it is not so much the percentage of technology brought in from external sources that matters, but the extent to which business unit managers are free to choose between external and internal sources.* On this issue there are again differences between the four firms, and it is informative to briefly consider how each operates.

- In ABB business units are free to decide whether to source technological inputs from corporate research centres (inside the firm) or from external sources, though with a strong expectation that the former will be prioritized if they have the relevant capabilities. Corporate research centre managers are comfortable with this situation, and it provides an incentive for them to demonstrate their ability to add value to the business units.

- Ericsson uses relatively little externally-sourced technology, because its core technology is a proprietary mobile communication system which makes it both technically difficult to integrate external technologies and emotionally difficult to "open its doors" to outside technologies. As a result, business units have no choice but to source internally for the proprietary technology, but as open standards are embraced by the firm, more and more technology will be sourced from the outside, or from a combination of the two.

- HP has strong business units that are free to source technology from wherever they choose. However, they pay a fixed "tax" to fund the corporate labs so there is a strong incentive to make use of that resource. The result is a hybrid system with considerable freedom to use external sources of technology, but a preference to make use of the corporate labs if possible.

- In Xerox the business units used to have very little choice, in that their role was to commercialize the technologies generated in the corporate research labs. This approach has changed in recent years, resulting in a higher level of external sourcing and more discretion on the part of business units in their choice (internal or external) of where to source from.

In terms of the use of outside sources of R&D expertise, table 2 suggests little difference between the four firms. Closer scrutiny of the individual questions underlying this construct, however, reveals some significant differences – notably that ABB regards customers' R&D expertise to be particularly valuable whereas Xerox perceives greater value (in comparison to the others) in the R&D expertise of alliance and JV partners and suppliers.

But more important than the specific differences between firms is the question of how valuable these external sources of R&D expertise are. In all four firms, respondents argued that external sources are becoming increasingly important. In particular, the importance of strong relationships with universities was highlighted, as corporate funding for basic research goes down. However, it emerged during several interviews that simply sponsoring research programs at universities had little bearing on the ability of the firm to use the technology they had supported. Ericsson, for example, has now moved to a more structured model whereby the Ericsson liaison manager designs a program with the university professor that is then reviewed on a quarterly basis. While still a pilot program, they believe that this approach creates more accountability on both sides and results in a stronger personal relationship between the liaison manager and the professor.

Use of market-like systems inside the firm. There are very large differences among the four firms in the extent to which they use market-like systems for resource allocation. Table 2 shows the mean scores on the three constructs defined above, but it is also important to describe the differences in qualitative terms.

- Research in ABB is split, with some taking place in the ten corporate research centres and the rest taking place in specific business units. Moreover, funding for corporate research centres comes primarily from the business units, the result being a system in which research expenditure is essentially the decision of the business units. The influence of commercial managers in R&D decisions is, accordingly, the highest of the four firms (table 2). However, to ensure that the resource allocation system does not become too short-term focused, there are a number of corporate funding vehicles for high-impact and high-risk projects.

- Ericsson has no corporate research as such, in that all R&D activities are held at the business unit level. There is, however, a vice president responsible for corporate research, and his job is to integrate the research activities of the three business units to ensure that technology is shared and new projects are coordinated. In terms of funding mechanisms, R&D budgets are defined at a business unit level. A contracting system exists, however, because the individual development centres (of which there are more than 40) are operated as profit centres. Thus, Ericsson ends up with a mixed fuding system, less contract-based than ABB, but more so than HP. Finally, the lack of corporate research, and indeed the absence of any "pure" research per se, means that commercial input to R&D decisions is strong.

- HP operates a pure (and some would say old-fashioned) model in which research is done in four corporate labs and funded entirely through a corporate "tax" that is paid by the business units. Business units in turn are responsible for doing all development work. As a result, HP scores significantly lower than the other three firms on all three measures of market-like systems (table 2). There is a risk with this model that research becomes divorced from the needs of the business units, but respondents felt that this was not a problem because the relationships between individuals in corporate labs and business units were typically very strong. We will return to this issue later.

- Xerox operates a mixed system. Research is conducted primarily (but not exclusively) at a corporate level, and is funded through a combination of (a) straight "tax" on business units based on their revenues, (b) negotiated tax on business units, and (c) specific contracts with business units. This system is intended to generate business unit commitment to research projects at early stages while not making the system too short-term focused. As a result, Xerox ends up placed between ABB and HP on the extent to which it uses market-like systems.

These findings illustrate the variety of approaches large firms use to manage the internal resource allocation process in R&D. But while ABB clearly operates a more market-like system than HP, with the other two lying somewhere in between, it would be wrong simply to conclude that ABB should score higher on measures of efficiency and HP higher on measures of effectiveness. The reason for this is that managers in these firms are aware of the potential dangers in the different models, so they have typically developed systems to alleviate the greatest weaknesses in their chosen approach. For example, since ABB has the most market-like system, funding vehicles have been established to promote long-term or high-risk projects that would otherwise not get funded. HP uses a very traditional model, but lab managers are aware of the risk of getting cut off from the needs of the business units, and thus they work hard to build relationships with business unit managers. The important insight from this analysis, then, is that *regardless of the resource allocation system the firm uses, it is possible to create checks and balances to guard against the worst drawbacks of the chosen system*. This does not mean, however, that such systems are irrelevant to performance because there are likely to be some firms that have not put the necessary checks and balances in place.

Performance. While the hypotheses linking resource allocation systems to performance will be formally tested in the next section, it is worth looking at the performance of the four companies on the same measures. As shown in table 3, all four are very successful (indeed, they were selected in part on this criterion). Average operating margins over the last five years vary from 11.0% in ABB to 18.4% in Xerox. Sales growth over the last five years has been spectacularly high in Ericsson and HP, and modest but positive in Xerox and ABB. And the subjective performance measures all fall in the average to above-average range, with no statistically significant differences between firms.

We will not dwell on this data at the moment. As noted above, well-managed companies can put checks and balances in place to counteract the deficiencies of any resource allocation system, and there are of course many factors at work in determining the performance of a large firm. Once the large-sample data have been presented the performance question will be given further consideration.

-------------- Insert Tables 2 and 3 about here --------------

Findings from the Questionnaire Survey

Table 4 lists the mean and standard deviation for all constructs, and the correlation matrix for the whole sample. Worthy of note, before moving onto the specific hypotheses, is that the correlations between conceptually-related constructs are often low. Thus, for example, the four measures of the use of external sources of technology are correlated between .106 and .250. This is not surprising as such, given that each is clearly tapping into a different construct, but it is indicative of the fact that these systems are very complex –as the previous section showed.

Hypotheses 1 and 2 linked the use of external sources of technology to performance. We begin examining hypothesis 1 and 2 by looking at the first three rows of the correlation matrix presented in table 4. We see that the more technology is obtained from outside, and the less conducted in-house, the greater the *efficiency* and the less the *effectiveness* of the firm. For example, the percent of technology bought/in-sourced and the value of outside sources of R&D are negatively correlated with our two measures of efficiency (getting products to market rapidly and making efficient use of R&D expenditure) and positively correlated with our two measures of effectiveness (creating breakthrough technologies and bringing breakthrough technologies to market). Thus, a firm which in-sources much technology is likely more efficient at doing R&D, but they achieve this increased efficiency at the price of decreased effectiveness.

Openness to external knowledge, in contrast, is positively associated with all measures of firm performance (both efficiency and effectiveness measures), as predicted in hypothesis 2a. Thus, environmental scanning for interesting ideas is useful for both efficiency and effectiveness as long as it can be contained such that it does not become a largely cost and time-driven battle as discussed above. Both hypotheses 1 and 2 are supported by the correlations.

Table 5 presents several regression models, which are also useful for investigating our hypothses. Models 1 and 2 have measures of efficiency as dependent variables and models 3 and 4 have measures of effectiveness. Several control variables are included in the regression equations. A dummy for parent firm country (UK=1, Sweden=2) is included and results indicate that in some cases the Swedish firms slightly outperform the UK firms. Parent firm size is also controlled for with smaller firms slightly outperforming larger firms in some cases.

The key finding our regression models reveal is that it is important to conduct environmental scanning activities for useful external ideas (hypothesis 2a supported). This can be seen since the "openness to external knowledge" relationship is clearly what drives the regression equations. Our regression equations also provides limited support for hypothesis 1 which states that firms which use more external sources of technology will experience higher efficiency and hypothesis 2 which suggests that increased use of external sources of technology will result in decreased effectiveness. The signs of all of the coefficients are in the correct direction to support hypotheses 1 and 2, however only some of the coefficients are significant. Never-the-less, the clear difference in signs for the use of external sources of technology variables (variables 4 and 5 in table 5) in the regressions on efficiency and the regressions on effectiveness lend support to hypotheses 1 and 2.

Hypotheses 3 and 4 are not supported at all. Indeed, if one considers the correlation matrix in table 4, what emerges most clearly is the complete lack of relationship (positive *or* negative) between the use of market-like systems for allocating resources and performance. Likewise "funding system type" the proxy for market like systems we use in the regression equations also exhibits not significant results. We only include one of the three market-like systems proxies in the regression models since all of them are insignificantly related to performance, there are some potential multicollinearity issues, and degrees of freedom need to be preserved. The reason for the observed lack of relationship between the use of market-like systems and performance is partly explained by the four company cases described above. Firms appear to be good at putting in checks and balances to counteract the deficiencies of any given resource allocation system. As a result, when one measures specific attributes such as the funding mechanism or input of commercial managers into R&D decisions, it is perhaps not surprising that they have no performance effect.

-------------------- Insert Tables 4 and 5 about here ---------------------

DISCUSSION AND CONCLUSIONS

This is a multi-faceted study, and thus before discussing some of the broader issues that arise from the research, it is worth just summarizing what emerged from the empirical analysis.

- A high degree of variation in the use of external sources of technology and market-like systems exists inside the firm, even between four successful firms operating in the same industry sector.
- The key managerial variable, when considering these processes, appears to be the amount of choice business unit managers have over the where and the how of R&D resource allocation.
- In successful firms, checks and balances are in place to guard against the major weaknesses of any given resource allocation system. These are often hard to detect in a questionnaire study.
- Over a large sample of firms, the use of external sources of technology is positively related to efficiency measures of performance and negatively related to effectiveness.
- It is important to differentiate between systems clearly linked to the use of external sources of technology and more loose systems encouraging environmental scanning. The former method can result in such a strong focus on development time and cost that effectiveness may be impaired. However, the latter case helps both efficiency and effectiveness.
- The use of market-like systems inside the firm has no overall effect on firm performance.

What are the implications of these findings? Since the managerial implications are quite straightforward, we will consider them first. External sourcing of technology has a demonstrable but double-edged impact on performance, in that it increases efficiency and decreases effectiveness. This suggests that the commonly-used approach of retaining core R&D activities in-house and outsourcing non-core activities is probably sound. It also helps us to distinguish between core activities (those that lead to radical or breakthrough technologies) and non-core activities (those that focus on speed to market or efficiency), a distinction that few companies appear to have mastered.

In terms of the use of market-like systems inside the firm, the evidence is more equivocal. Such systems can apparently be very valuable (e.g., in ABB) but they need to be considered in the context of the firm's entire organization structure, not as isolated approaches. Overall then, while these hybrid approaches to R&D resource allocation appear to be on the rise, they should definitely be handled with care because their effect on firm performance is not clear.

At a theoretical level, the paper's findings are more complex. The first important issue to address is: do organizational hybrids really lie between the pure forms of market and hierarchy? The case of ABB shows that such hybrids do exist – ABB allows business units a high level of choice in their use of external sources of technology, and it makes good use of market-like internal systems. However, the other three case studies suggest that ABB may be a fairly unusual case, in that they were far closer to the traditional hierarchical model. Overall, though, the trend would appear to be towards a greater openness to different approaches to sourcing technology. In Ericsson, for example, internal development units often compete against one another for the right to undertake development projects, which is a way of enhancing their efficiency and increasing the business unit's sourcing options.

An issue that arose in the theory development section was how a firm chooses between the two different hybrids – the use of an external alliance vs. the use of a market-like system inside the firm. Based on the evidence collected here, it seems that these are complementary rather than alternative approaches. For example, an ABB business unit manager will typically consider external *and* internal options for a given technology. Thus, while the two hybrids are conceptually distinct, they are in practical terms simply part of the "swollen middle" described by Hennart (1993).

A third theoretical issue that emerges from the paper is whether the "internal market" can end up being *too efficient?* In other words, if resource allocation decisions are pushed too far towards commercial or short-term needs, is it possible that effectiveness will be sacrificed? Or are there systems in place to deliberately make resource allocation decisions that are *not* efficient in the local domain or on a short-term basis, because they have the promise to offer longer term effectiveness. Williamson (1991) refers to this as coordinated (C) adaptation, and much of the contemporary writings on the theory of the firm (Kogut and Zander, 1996; Moran and Ghoshal, 1996) as well as earlier work (Barnard, 1938; Schumpeter, 1934) recognizes its importance. Evidence from this study suggests that the internal market, to the extent that it exists, does not suffer from being too efficient. Again, taking ABB as the standard bearer of the internal market, evidently many checks and balances are in place to guard against decisions that are made for efficiency-only reasons. For example, all R&D unit managers report to both their country manager and the global head of R&D, and research "programs" that are the vehicle for allocating central funding have review boards with representative from many different parts of the company. These systems appear to provide sufficient counterweight to the customer-driven demands of the business units to safeguard ABB's long term technological development. Several stories were recounted to us (in ABB and the other firms) of top management over-ruling the decision of a business unit in order to protect the broader interests of the corporation. Of course, such decisions cannot be taken lightly, because they are perceived by business unit managers as "meddling" by top management, but it is evident that they have to be taken now and then to ensure that long-term effectiveness is not unduly compromised. Again, the extent to which this balance is achieved is an important issue but one which we cannot shed light on in this study.

A number of directions are suggested for future research in this area. There appear to be some country and size effects in the regression analysis, and these could be usefully examined in greater detail. Other characteristics of the internal market also need exploring – for example the role of entrepreneurship in making the market work efficiently and the use of real prices as a coordination mechanism. Finally, it is also important to understand the dynamics of these issues – for example, how these approaches to sourcing R&D are changing.

To conclude, the purpose of this paper was to study the resource allocation systems used in large R&D organizations, with a view to understanding how they are actually used, and their impact –-if any—on firm performance. By pursuing a two-phase study we ended up with a complex set of findings that confirm to some degree our hypotheses, but which leave us with more questions than answers. The overall conclusion is that these emerging approaches to R&D resource allocation appear to offer considerable benefits, but they need to be handled with great caution.

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Figure 1. The "traditional" and "internal market" models of R&D organization

Table 1. Characteristics of sample firms and data collected

Dimension	ABB	Ericsson	HP	Xerox
Total sales revenues 1997	$31.3 billion	168 SEK	$43.2 billion	$19 billion
R&D headquarters	Zurich	Stockholm	Palo Alto, CA	Rochester, NY
R&D expenditure 1997	$2.6 billion	21b SEK	$3.1 billion	$1.1 billion
Amount of total R&D done at Corporate level	$300m	0**	$250m	$345m
Major R&D locations	Switzerland, Sweden, US, Germany, Finland, Italy, Norway	Stockholm, US, Germany, UK, Canada, smaller sites in another 40 countries	US, Japan, UK, France	US, Japan (Fuji Xerox), UK, France
Interviews				
Senior managers in R&D organization	5	7	3	7
Technical people & lab managers	3	11	3	6
Managers in business units	3	4	6	4
Locations for interviews	Sweden, Germany, Finland, US	Sweden, US, Japan, Canada, UK	US, UK, Canada	US, Japan, Canada
Questionnaires returned	10	12	11	10

** R&D in Ericsson is all conducted either at the business area or business unit level, rather than through corporate research labs.

Table 2. Mean responses from four companies to resource allocation questions

	ABB	Ericsson	HP	Xerox	Kruskal-Wallis Chi Square (sig.)
Percent technology conducted in-house	76%	**88**%	<u>70</u>%	78%	2.0 (.09)
Percent technology bought / in-licensed	8%	5%	**20**%	10%	3.2 (.07)
Use of outside sources of R&D expertise (1=not important, 7=extremely important)	4.0	3.7	3.9	4.2	1.41 ns
Extent research is conducted at divisional level (1=corporate, 2=split, 3=division)	1.5	**1.75**	<u>1.37</u>	<u>1.20</u>	7.96 (.047)
Use of "contract" system for funding corporate research (1=corporate tax, 7=contracted with business units)	**5.37**	**3.53**	<u>1.42</u>	**3.56**	20.91 (.000)
Commercial input into R&D decisions (1=technical managers, 5 = commercial managers)	**2.64**	2.50	<u>1.73</u>	2.17	9.78 (.02)

Note: Bold indicates significantly higher, underline significantly lower in Kruskal-Wallis test

Table 3. Mean responses from four companies to performance questions

Performance	ABB	Ericsson	HP	Xerox	Kruskal-Wallis Chi Square (sig.)
Getting products to market rapidly	4.60	4.75	4.18	3.50	5.2
Creating radical or breakthrough technologies	5.10	5.33	5.09	4.80	1.1
Making efficient use of R&D expenditure	4.40	4.75	4.73	3.90	2.2
Average operating margins 1993-1997*	11.0	12.2	13.9	18.4	N/A
Total sales growth 1993-1997**	14%	266%	208%	27.7	N/A

*Taken from Value Line financial reporting service

**Taken from annual reports

Table 4. Pearson correlation coefficients (n=103)

Variable	Mean	SD	2	3	4	5	6	7	8	9	10	11	12
1. Openness to outside knowledge	4.73	1.18	.106	.250*	.095	-.073	-.010	.341**	.431**	.292	.349**	-.346**	.064
2. Percent technology bought/in-licensed	14.5%	3.9		.147	-.090	-.067	.103	.119	.115	-.329**	-.140	.230	.013
3. Value of outside sources of R&D expertise	4.28	1.08			-.095	-.033	.021	.200*	.214*	-.077	.088	.057	.307**
4. Extent research is conducted at divisional (not corporate level)	1.98	.85				.216	-.013	-.046	-.059	.018	.022	.088	-.094
5. Commercial (vs. technical) input into R&D decisions	2.80	.60					-.151	-.001	-.118	-.119	-.058	-.185	-.141
6. Use of "contract" system for funding corporate research	3.77	1.58						.076	-.095	-.005	.154	.345	-.065
7. Getting products to market rapidly	4.42	1.25							.430**	.323**	.458**	-.255	.153
8. Making efficient use of R&D expenditure	4.44	1.15								.053	.162	.061	.080
9. Creating radical or breakthrough technologies	4.47	1.39									.671**	.207	.132
10. Bringing breakthrough technologies to market	4.28	1.45										-.056	.253*
11. Size (sales in 0000 pounds)	193015	578074											-.107
12. Country (England=1, Sweden=2)	1.56	.632											

* p <.05

** p < .01

Table 5. OLS Regression models. Predictors of performance (n = 103)

Model:	1	2	3	4
Dependent variable:	Getting products to market rapidly	Making efficient use of R&D expenditure	Creating radical or breakthrough technologies	Bringing breakthrough technologies to market
1. Parent firm country	-.074	.226	.216^{+}	.268*
2. Size (sales)	-.069	.218	-.231^{+}	-.225^{+}
3. Funding System	.118	-.082	-022	-.006
4. Percent technology bought/in-licensed	.131	.001	-.163	-.211^{+}
5. Value of outside sources of R&D expertise	.092	.215^{+}	-.305*	-.159
6. Openness to outside knowledge	.371***	.408***	.429***	.480***
R-squared	.237	.252	.402	.433
F	2.071*	2.249*	4.475****	4.965****

Numbers are standardized Beta coefficients

† p < .10
* p < .05
** p < .01
*** p < .005
**** p < .001