Between Autonomy and Control:

The role of industrial researchers' decision-making

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WP 11/99

Oktober 1999

MPP Working Paper No. 11/99 ©
Oktober 1999
Print: Handelshøjskolens Reproduktionsafdeling
ISBN: 87-90403-64-9
ISSN: 1396-2817

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Paper presented to the CISTEMA Conference on Mobilizing Knowledge in Technology Management, Copenhagen, October 24-27, 1999

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Abstract

This paper deals with issues related to management of industrial research. The overall research question is how industrial researchers can be managed to increase the company's benefits. The relevance of this question is put into perspective by two main considerations. On the one hand, it is widely recognized that individual researchers should possess a high level of autonomy to preserve the ability of research to renew itself. On the other hand, companies need to maintain control over that freedom to develop their research activities in a long-term company perspective.

The paper contributes to a deeper understanding of the management of industrial research by moving the focus from risk management and portfolio planning (decision and control based management) to management in situations marked by high uncertainty and asymmetric distribution of information (management of self-governing systems). More specifically, the evolutionary perspective on individual adaptation is used in combination with evolutionary economics to create an analytical framework for understanding managerial action in industrial research. This framework, is used to explain how managers can try to increase the probability that individual research processes create results, which eventually increase the fit of the company to its environment. It is argued that research managers can, to a certain extent, influence the complex processes of individual adaptation by influencing individual decision making through a) setting and communicating research specific goals and b) creating and maintaining shared cognitive frames.

Introduction

Research based companies have for long recognized the need for managerial influence on the research process. Since the decline of the linear growth model in the late 1960s (Coombs 1996, Hounshell 1996) various models for allocating limited resources to create most value for the company have been developed and tested. In the 1970s and 1980s the linear growth model was succeeded by a management approach with emphasis on risk reduction through strong management influence on the research process and orientation toward the needs of today's customers (Hounshell 1996, Roussel et al. 1991, Rosenbloom and Spencer 1996). Although the project portfolio planning approach proofs to be efficient in delivering results according to time-schedules, it also suffers from serious shortcomings; the focus on reaching predictable ends pushes industrial research toward low risk incremental projects. In this case the results primarily support the short-term activities but hardly have a strategic impact and value for the firm. The main concern in the research management literature in the 1990s is to balance the two considerations (Randle and Currie 1996, Rostrup-Nielsen et al. 1997, Husted 1998). On the one hand, it is widely recognized that individual researchers should possess a high level of autonomy to preserve the ability of research to renew itself. On the other hand, companies need to maintain control over that freedom to develop their research activities in a long-term company perspective.

This paper argues that besides creativity also other factors like complexity, rate of change, uncertainty combined with an asymmetric distribution of knowledge between research management and researchers make it necessary to allow for a high degree of autonomy in research. However, autonomy does not inevitably imply that individual research processes and decisions are beyond managerial influence. Drawing upon an evolutionary perspective on individual adaptation in a nested hierarchy this paper develops an analytical framework for understanding the role of research management in a largely self-governing autonomous system.

The paper first treats the subject of the simultaneous need for control and autonomy in research. It then briefly introduces the evolutionary perspective on adaptation in a nested hierarchy and the following management understanding. Based on this the paper develops a framework for analyzing managerial action in self-governing system as industrial research. Within this framework, the paper suggests that management has to deal with following three issues when designing organizations or processes within organizations as adaptive systems: 1) influence individual decisions, 2) selecting and rewarding among contributions and giving feedback from the selection process and 3) designing the internal research environment. The focus then narrows to discussing the first of the proposed design parameters - how management can influence individual decision-making with the aim of increasing the corporate value of sponsoring research.

The stage for institutional control and individual autonomy

High uncertainty is a basic condition for decision-making in research. The processes of science, technology and innovation are interacting and iterative processes embedded in multidimensional uncertainty (Kline and Rosenberg 1986; Vincenti 1990). The uncertainty concerns 1) the character of output from the knowledge creating process (research often answers other questions than intended (Stephan 1996)), 2) timing in terms of when the results might come, 3) what benefit/value creation they might give rise to. Serious decisions often have to be made at an early stage of R&D projects where uncertainty is especially high and the possibility of obtaining relevant information for making decisions is limited. Decision-making in research is, moreover, characterized by a two-way asymmetric distribution of knowledge between individual researchers and management.

On the one hand, the individual researcher knows more about the potential of his or her field than managers do. This means that the researcher is better prepared for making decisions on a continuos basis about what activities to take up, what methods to apply, how to interpret the results in the research process, what new opportunities should be pursued, when and how to disclose results and to who etc. On the other hand, research managers often possess a more detailed understanding of the company's needs and competitive environment. Under these basic conditions of uncertainty and asymmetric distribution of knowledge and information, decision-making in research has to reflect a wide range of considerations, sometimes acting in opposite directions.

Another important aspect of research and similar knowledge creating activities in both private and public R&D organisations is that they increasingly take place in and are shaped by close interactions with their environment. Gibbons et al. (1994) label this "Mode II" and point out that besides being increasingly interdisciplinary in nature, the knowledge creating process is to a greater extent shaped through the interaction with both upstream and downstream users and the political level. This issue is also addressed by the so-called "triple helix" concept (Etzkowitz and Leydesdorff, 1998).

Industrial research is expected to create innovative and relevant knowledge for the firm's future ability for adapting to its business environment. Decisions made in research are often decisive for the future of research based companies since they form the basis for the companies' future competitiveness and set the agenda for future corporate interpretation of the environment and the possible actions. Because of the vital role in designing the future ground for the company's competitiveness, industrial research is more than other corporate activities about preparing for, reckoning with and building futures (van Lente 1994). In order to meet this responsibility decision-making in research must depend on and be guided through anticipation of changes in the complex and dynamic environment e.g. progress or setbacks in competing and complementary external research activities, government regulation, and changes in customers' preferences and needs in the market.

Research not only builds up competencies for the future but is also partly responsible for harvesting from these competencies by constantly monitoring the business environment for imminent changes to which research can mount an adaptive response (Mort 1994). Results from research is often related with considerable scope advantages (Cristensen 1998, Henderson and Cockburn 1993), where knowledge developed with a specific purpose in mind opens up for a wide range of unexpected applications in e.g. new product or processes. An asymmetric distribution of knowledge between top-management, market oriented staff and research management on the one side and the researchers who create the knowledge on the other side implies that these unexpected opportunities cannot be detected by other than the researchers themselves. Besides participating in identification of possible application areas, the difficulties and cost of transferring knowledge from research to development force industrial researchers to put a considerable effort in the dissemination and application of knowledge in development of new or improved products and processes.

Lately, the importance of access to external knowledge has achieved increased attention mainly because of the accelerating need for applying multidisciplinary approaches in industrial research. Cohen and Levinthal (1990) suggest that the ability of a firm to recognise the value of new, external knowledge, to assimilate it, and to apply it to internal purposes is one of the most important benefits from funding internal research. However, it is far from sufficient to posses the needed absorptive capacity in order to create value from new external knowledge. The value for the company of accessing external knowledge is highly dependent on:

a) that the relevant external knowledge can be access as early as possible preferably before it is disclosed for wider audience and

b) access to the related often tacit knowledge directly from the source.

This kind of access to knowledge works on quid pro quit basis (Hicks 1995), which implies that industrial research must besides being willing to share its knowledge, produce competitive new knowledge and hence coordinate the choice of activities with the priorities of the network it wants to access. All decisions have to be based on the insights of individual researchers because research management:

1) does not possess the needed very detailed knowledge about the progress in specific scientific fields that only can be obtained through ongoing and deep involvement in field, and

2) might have the formal authority to decide what results to disclose when, but lacks the needed access to and background for moving the knowledge from the private domain of individual researchers to a form where it can be shared.

As argued above, factors like complexity, rate of change and uncertainty combined with a asymmetric distribution of knowledge between research management and researchers make it necessary to allow for a high degree of autonomy in research. On the other side, decisions in research often have a decisive influence on the future of the company and depend on internal systemic

mechanisms of the company e.g. the actions of suppliers of complementary competencies (Teece 1988). In other words, companies need to maintain kind of influence on individual researchers in order to develop their research activities in a long-term company perspective. The challenge for research management is to organize autonomous individuals often from different disciplines into a cohesive group that will meet the company's objectives.

In the search for an approach suitable for analyzing research management under these conditions, we can find useful inspiration from scholars working with the emerging fields of competence and evolutionary theory. They promote the view that strategic management in firms operating in rapidly changing environments should be considered as a process of designing organizations as adaptive systems. Sanches (1997) specifies the objective of this mode of strategic management as follows: "*the objective is creating and supporting self-managing organizational processes that enables better interpretation of and faster response to complex, dynamic environments and their attendant uncertainties.*"

The following section provides an evolutionary perspective on adaptation in a nested hierarchy and the role of management. The perspective will be related to the unique features of decision-making in research with the aim of developing a framework for analyzing management of research as creating and supporting self-organizing processes.

Adaptation in a nested hierarchy of evolutionary processes

Dating back to the seminal work of Simon (1962) and Campbell (1960) evolutionary economists have promoted the idea that the internal flow of information, interpretation of the business-environment and adaptation take place in an internal hierarchy of nested evolutionary processes (Aldrich 1979, Miner 1994, Metcalfe and Calerini 1997, Nelson 1991).

The hierarchy ranges from customers' decision about buying the product at the top of the hierarchy to individuals considering the value of their ideas at the bottom of the hierarchy (Randle and Currie 1996). Each level in the hierarchy constitutes an evolutionary process with selection, variation and rentention. The hierarchy is nested in the sense that selection criteria on one level in the hierarchy are subject for selection on a higher level in the hierarchy. From the adaptation point of view this implies that variants created and selected on one level are expected to be adapted to higher-level selection criteria and ultimately to the market. The adaptation on all levels involves a high degree of uncertainty and is thus far from perfect. Variation on one level does not necessarily correspond with variation on another level. For example, Gambardella and Torrisi (1998) found that those electronic firms that simultaneously broaden their technology base and narrowed their product focus performed better than average in the industry over the past ten years.

Evolutionary theory deals with the interplay between variety creation and selection by focusing on changes in variety over time (Frenken et al. 1999). In

biology, variety is defined as the number of species in a given population. This narrow definition of variety does not serve the purpose in dealing with knowledge creation. In knowledge creation every contribution per definition should be distinguishable from former contributions and represent a new species itself. A strict biological analogy would imply a simplistic conceptualization of the relation between knowledge creation and variety. Following the biological definition of variety, the variety in the knowledge base will increase every time new knowledge is created. In the present paper variety is perceived as variation in relation to trajectories of knowledge.

Following this definition, individual adaptation to a shared environment will result in a high variation in the created knowledge, because of the diversity in individual interpretation of the environment. According to Dosi and Marengo 1994; Marengo 1992; Metcalfe and Boden 1991 and Witt 1995, the needed coordination of the individual knowledge creation is achieved by assigning managers the task of observe and monitor the environment and to communicate their interpretation to the other members of the organization.

The literature dealing with management from an evolutionary perspective is mainly focused on strategic issues. Its key concern is the discussion of how to achieve a suitable alignment between the external selection process at the market and the internal strategic process that determines which product and processes the company chooses to compete with on the market. In this perspective the managerial task is to increase the likelihood that internal processes create variants adapted to the environment (Metcalfe and Boden 1991, 1993; Meyer 1994, Miner 1994 and Saviotti 1996).

In the core of this evolutionary perspective on management is the assumption that adaptation is a top-down process. Top management is expected to monitor the business environment and to foreclose potential directions of development. When adaptive initiatives are required, the need and conditions are articulated and communicated through the internal selection environment (Metcalfe and Boden 1993). Adaptation in a hierarchy takes the form of acceptances of goals, subgoals, subsubgoals etc. as defined by organizations (Meyer 1994).

Reflecting the general tendency in evolutionary economics the management understanding suffers from two general problems. First, it is highly focused on the hierarchical dimension and second, it does not explicitely include perspectives on management on lower levers in the hierarchy. The issue concerning a narrow hierarchical focus is thoroughly addressed by Pavitt (1998). According to him, evolutionary economists put too much emphasis on the interface between the company and its selection environment through focus on explaining the economic benefits of technological diversity, on the frequency and causes of creative destruction expressed in new products and implications of change in technological paradigms. In order to avoid that evolutionary theory ends up in the same dead-end as the theories it claims to replace, Pavitt (1998) invites evolutionary economists to take up the challenge of improving the understanding of the organizational process of coordination and control of the

simultaneous, interacting processes of development and application of technological and scientific knowledge on one hand and commercially successful working artifacts on the other.

The horizontal dimension is especially important in managing research. Capturing value from research is highly dependent on the coordination with interacting and simultaneous processes within the company. As pointed out by e.g. Metcalfe and Boden (1991), the limits within which a firm can handle variation as input from research are set by two systemic factors. The first is the presence or the willingness in the organization to develop the needed complementary assets for appropriating the rents from the research results (Helfat 1994 and Teece 1988). Teece suggests that in order to increase the likelihood that the organization is able to harvest the economical benefits from its research the research goals should reflect the development in the complementary assets of the hosting organization. The second is the development in co-evolutionary processes both internal and external to the hosting organization. Research and similar knowledge creating activities in both private and public research organizations increasingly take place in and are shaped by close interaction with their environment. The dependency of other external knowledge creation processes is a crucial part of the uncertainty of the decision-makers in research.

Another weakness of the strategic focus is that it only vaguely indicates how managerial action on a higher level in the hierarchy is related to managerial action on lower levels in the hierarchy. Miner (1994) provides an exception by suggesting that the two primary managerial roles are to 1) adjust the department's relationship to higher level evolutionary processes and 2) influence the internal evolutionary process. However, the main concern in this approach is to discuss how management can balance the relative weight between variation and rentention. According to Miner, the continuum of means available for management to influence the creation of variation ranges from the classic rational planning paradigm in the one end to a high degree of employee autonomy in the other end. In the latter one management is not involved in the creation of variation per se but only in the selection among the created variants.

In the light of the present paper, Miner's framework lacks an explicit understanding of how management influences the individual knowledge creation process leading to new variations despite the high degree of autonomy. This paper meets the challenge of addressing the issue of managerial action on lower levels in the hierarchy by taking point of departure in the bottom of the hierarchy - the process of individual adaptation. On this micro level evolutionary theory offers an explanation for how knowledge is created and changed under such conditions of high uncertainty and bounded rationality of the actors (Witt 1995). Individuals develop new knowledge in order imperfectly to cope with an ever-changing environment (Dosi and Malerba 1996). The core of individual decision-making is not a rational choice between alternatives, but the process itself through which the individual tries to understand his environment by identifying relevant parameters, interpret these and try to create alternatives adapted to this

interpretation. In other words, individuals adapt to their environment through learning.

Vergragt (1988) proposes that research lines and results emerge from actors making decisions and choices in the learning process. He especially assigns critical events a major role in forcing actors like researchers to make decisions about the course to be taken. Critical events include changes or surprises emerging from both internal and external environments. Internal critical events appear in the research process when researchers reflect on the accumulated knowledge, experience and feed back from trial and error search processes. These reflections often lead to changes in the perceived risk associated with the project, new opportunities for pursuing other research questions, opportunities to answer other questions than expected or mere serendipity. Externally induced critical events include situations when the researcher has lost the race for priority e.g. because a competitor files a patents application, change in the selection environment because of changes in markets preferences and prices and government regulation. Vergragt also includes organizational and strategic changes at higher hierarchical levels as potential sources of critical events, which researchers occasionally need to adapt their research process to and reconsider earlier decisions.

On the basis of two in depth case-studies of the structure of variation Den Hond (1998) reaches the conclusion that the outcome of innovation processes is highly dependent on how individuals deal with the constraining factors in the selection environment. He writes, "*trajectories develop under the influence of the selection environment and when specific search heuristic are applied. How to proceed is clear, but the results of the innovation process depends on how the innovator(s) deals with the various, often conflicting, constraining factors in the selection environment.*"

Individual adaptation is driven by the self-interest of the individual. Researchers often have incentives to select research activities and to make decisions about their research efforts, which seam most suitable for fulfilling their self-interest in accumulating rewards for their effort (Husted 1998).

First and foremost, the internal selection and distribution of rewards is the engine of the individual adaptation processes. The individual researcher does not have any incentive for adaptation if the internal selection does not function, because individual adaptation is driven by self-interest of the individual in accumulating rewards. The rewards in the internal selection need not to be monetary of nature. On the contrary, several studies indicate that monetary rewards bear a negative influence on the very processes the are intended to enhance (Kohn 1993, Lawless and Price 1992). The negative consequences of using monetary reward in industrial research are discouraging risk-taking and creativity, destroying cooperation and undermining intrinsic motivation (Randle and Currie 1996). An alternative to monetary rewards can be found in the priority-based competition for recognition known from academic science. The priority-based competition works on the principle that the winner takes it all and that the winner is rewarded

with recognition from his colleagues adjusted according to the importance of the contribution. This kind of competition has the positive effects that researchers tend to make decisions which increase the reward potential relative to his own abilities and share information in a timely fashion if they want to establish priority (Dasgupta and David 1994, Stephan 1996). More research-based companies do deliberately take steps to ensure the maintenance of scientific values in their research departments in order to protect scientific excellence. In Olin's Chemical Research management responded to a declining innovativeness in knowledge creation, by, among other initiatives, establishing a management-supported reward program for recognition of scientific accomplishments (Marien 1998).

The benefits for industrial research management by setting up and participating in the internal selection and distribution of reward for achieved results are obvious. The source of reward is in many respects the source of control over the direction of research (Hagstrom 1965). In industrial research productivity is not only a matter of striving for more and better discoveries but of learning how to create these in a manner and area useful to those who must develop and sell the eventual products and services (Bosomworth and Sage 1995). An internal selection environment potentially not only defines the boundaries for individual research processes but also provide guidance for how the results should be presented and put into a business perspective.

Summing up, evolutionary theory provides knowledge about the role of learning in organizations' adaptation processes and how these learning processes can be influenced. The adaptation process of an organization to its environment is seen as a consequence of adaptation in a hierarchy of internal learning processes (Mckelvey 1996, Miner 1994, Metcalfe and Boden 1993). In this framework individual adaptation is conscious goal-seeking guided by mental models of the anticipated future development of the individual's environment (Silverberg 1988).

An analytical framework for understanding how research management can manage autonomous individual adaptation processes to increase the overall fit of the company with its present and especially its future business environment, includes following three issues:

I. Influencing individual decision-making

II. Selecting and rewarding among contributions and feedback from selection

III. Designing internal research environment

Figure 1 below illustrates the interplay between the flow of information and the three means for management to influence individual adaptation processes.

Research management monitors both the internal and the external environment for changes, information and knowledge they find relevant for making decisions.

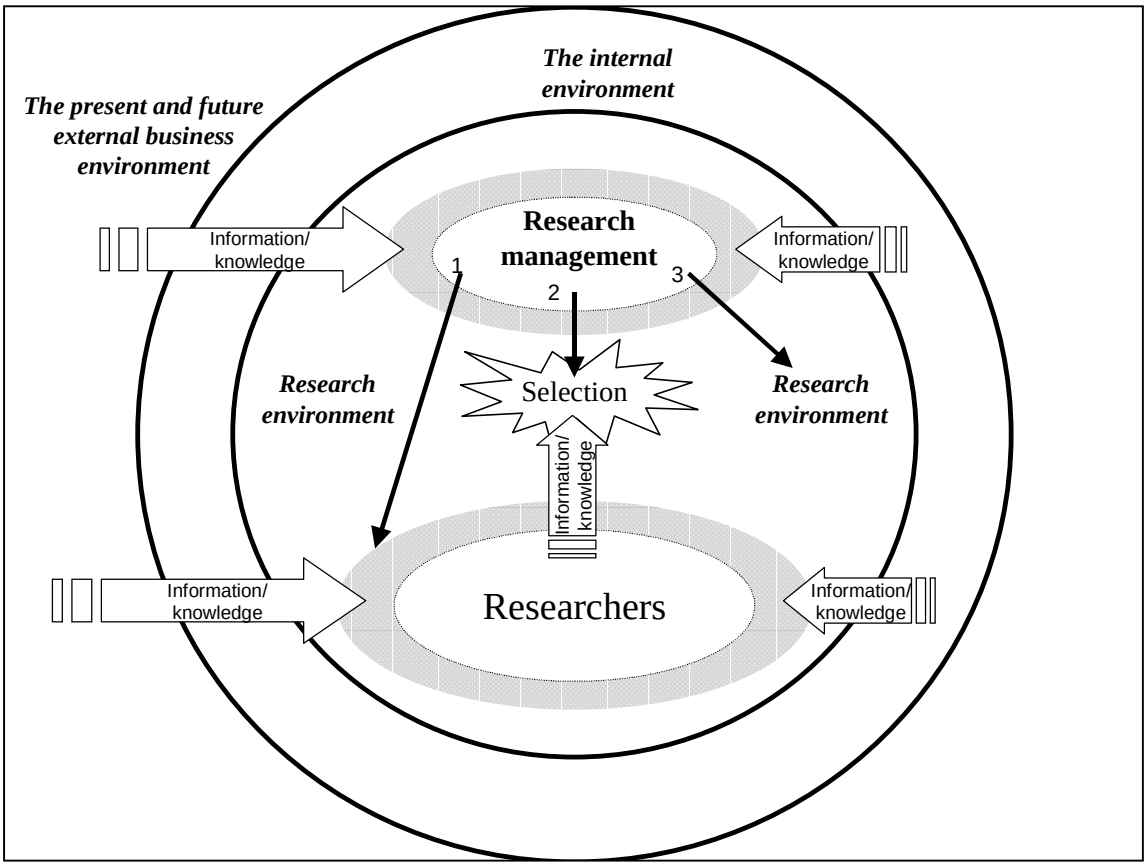

Figure 1: The role of research management as designers of adaptive systems

Individuals use their previous experience knowledge to interpret the input, to identify alternatives of actions and to select between the alternatives. The gray zones around research management and researchers illustrate that shared cognitive frames influence this process. A shared cognitive frame is defined here as a business conception that helps individuals to interpret what is going on in the light of the firms overall interest and to associate appropriate actions with the conceived situation (Witt 1995).

"Learning is local, being highly affected by the cognitive frames and actual competencies of firms, and is cumulative in that its builds on what has been already learned" (Dosi and Malerba 1996)

The black arrows illustrate the managerial influence on individual adaptation processes by: 1) setting goals and creating and maintaining shared cognitive frames, 2) selection on the actual output from individual research processes instead of selection on a intentional basis only, and 3) influencing the internal research environment e.g.by restricting the input for variation by making some

information easier available than other, investments in instruments and facilities and setting the stage for interaction internal of research, with other functions in the company and external with the research community, customers etc.

The rest of this paper focuses at how research management can influence individual decision making.

Influencing individual decision making

Autonomy does far from imply that all decisions in industrial research should be decentralized to the individual or team of researchers. The range of decisions, which bear influence on which results and how the knowledge is exploited and research management with benefit can decentralize to individual or team of researchers includes decisions regarding:

The research process. When researchers e.g. decide what activities to take up, which methods to apply and reflect on the accumulated knowledge, experience and feed back from trial and error search processes

Change of focus in the research process. Coincidence – often coined as serendipity - plays a major role in industrial research (Rosenberg 1990). New unintended opportunities often emerge in the research process, however as observed by Stephan (1996) the following up is not accidental. It is in the interest of the company that its researchers first recognize the potential when it emerge in the research process and then decide to pursue those of the opportunities, which seem most rewarding in the light of the company's interests.

Disclosure of knowledge. Knowledge is only disclosed if somebody decides to do so (Hicks 1995). When first new knowledge is articulated research management can to certain extent decide to whom and on which conditions knowledge should be disclosed. But it is the individual researcher who decides when and how complete he wants to disclose his knowledge.

Access to external knowledge. The access to external knowledge is partly shaped by individual decisions e.g. about what literature is important to monitor and which personal contacts are established and maintained.

The challenge for research management is to influence the mentioned individual decisions in order to increase the probability that they come up with and present results in way useful for the company's adaptations to its environment.

A well-known approach for management to communicate its interpretation of the environment is setting goals without specifying which methods and approaches should be applied in order to reach the goals. In an evolutionary perspective, goals serve the purpose of supplying lower levels in the hierarchy with selection criteria for guiding their own decisions about what to do. Goals enable employees to ask themselves whether a given action or routine is in harmony

with a given goal. As Simon (1959) puts it, goals create the grounds for the decisions taken by others in the future.

Researchers make decisions on a continuos basis about what activities to take up, what methods to apply, how to interpret the result in the research process etc. Research goals could support all these individual decisions by providing the researcher with guidelines for making their decisions. When the goals are very clear, then research activities are clearly defined (Miner 1994 and Bossomworth and Sage 1995) and individual goal tends to be compatible with the organizational ones (Bland and Ruffin 1992).

The seeming inconsistency of setting goals for a research organization with the need for individual autonomy is discussed in several studies from the early 1960s. The thorough investigation of freedom versus coordination found that coordination of research groups towards shared goals was clearly compatible with individual autonomy (Pelz and Andrew 1966). Their research showed that both university and industrial researchers found themselves more productive when their research was in general influenced by several external sources like management and colleagues. Moreover, the researchers in the investigation pointed out that they saw a positive correlation between external induced boundaries for search and their own job satisfaction as long as the researchers believed that they still had a high degree in autonomy. As illustration of their conclusion the authors quote a scientist saying "The organization points out what mountain they want us to climb, but how we climb it is up to us". Also, Hagstrom (1965) supports the view of compatibility between goal-setting and autonomy by arguing that autonomous researchers align individual goals with organizational goals in order to reduce their uncertainty of not being recognized for their effort. By following the organizational goal they secure a receptive environment that will understand value their results and reward them accordingly. Surprisingly, then the same pattern of individual caution towards the needs of the hosting environment is expressed in situations with a very high level of autonomy. Augsdorfer (1996) concludes based on a survey of bootlegging activities in 65 industrial research laboratories that even when research activities were hidden for management as bootlegging activities the output was not in contrast to the overall strategy of the firm.

Besides focusing the attention of researchers research goals also increase productivity in terms of produced papers and results. An extensive literature review by Bland and Ruffin (1992) shows that several studies of research productivity refer to clear goals that serve a coordinating function as having a significant impact on research productivity. Pelz and Andrew (1966) deliver the most significant support for this observation based on a survey including more than 1300 researchers from both universities and industrial research. Their work points out that high performance results from situations where the scientist had both high influence on the research direction and high involvement from several others e.g. through research goals, whereas complete autonomy and too tight control both result in low performance.

Setting goals in research differs from setting goals for other kind of corporate activities on a number of dimensions. First, the time span in research limits the value of the corporate interpretation of its environment expressed in its goals for guiding research. Research often produces results with implications for the company at least 5-10 years ahead while for example corporate strategy holds a more limited time perspective of around 2-3 years. This difference in time perspective together with the inherent uncertainty in research in terms of when results appear and which kind of value they might create, reduce the usability of corporate goals as selection criteria for research.

Second, the ability of research to deliver unexpected outcome means that possible future alternatives for adapting to the business environment are difficult to anticipate on corporate level. In other words, top management does often not possess the needed knowledge about what changes in the business environment have significance for the firm's future adaptability.

Third, the asymmetric distribution of knowledge between top-management and company researchers implies furthermore that top-management does not possess the needed knowledge for identifying the range of possible actions, which the company is able to mount as a response to perceived changes in the environment.

As a consequence of these specific features of research as a corporate activity, it is a core activity in research management to monitor and interpret the business environment directly[1] and to use this interpretation for creating and selecting among alternatives (Mckelvey 1996). Corporate goals and strategy only serve as a guideline for research management in the process of monitoring the business environment.

However, due to the high level of uncertainty in research and the asymmetric distribution of information (the individual researcher is supposed to know more about his area than their managers), research managers often are in a situation where they are not able to interpret and communicate their understanding of the business environment in a way that alone can be used for guiding other people's decision making. Management can in such situations supplement goal setting by creating and influencing shared company related cognitive frames.

Applying the concept of cognitive frames to research implies that research management can influence and hence coordinate the decisions of individual researchers by activity fostering and maintaining a shared cognitive frame among the firm's researchers. The benefit of this approach would be that research management increases the likelihood for that autonomous researchers interpret their environment in the light of the firms interest (as they are perceived by management), and that they make decisions which are in line with the firm's interest and coordinated with the action of other researchers in the company.

[1] Van Lente 1994 deals with how anticipations are created and shared in and between organizations. His research shows that anticipations are socially constructed and serve the dual purpose of guiding the actions of researchers and legitimize action.

Cognitive frames emerge and change through the communication processes in the social environment, which supplies individuals with tacit knowledge, interpretation pattern and norms of behavior. Developing potentially self-fulfilling prophecies appears to be an essential promotional strategy[2] in science and technology (Guice 1999). With empirical evidence from the field of microelectronic Guice (1999) supports that trend-promotion plays an important role in creating a shared vision of the future. According to Guice, trends are especially important as guidelines for participants in high technology fields because of the high level of competitive risk, interdependency and entrenchment of particular technical approaches. Trends enable individual researchers who subscribe to the trend, to feel confident that others will recognize the value of their specialized research effort in the field.

Moreover, research management can use the internal selection process to stimulate individual reinforcement processes by providing a clear feedback from the selection process allowing individuals easier to identify what features of the contributions have trigged a reward. Since the underlying process of creating and diffusing cognitive frames can be considered as an evolutionary process, it will also exploit the features of self-reinforcement. That cognitive frame, which appears more suitable for leading to the right decision, will attract most attention and be imitated more often than less successful cognitive frames.

The value of developing shared cognitive frames finds also evidence on interorganizational level. Guice (1999) delivers empirical evidence that DARPA[3] had a much more important function than only transferring funds by developing networks of communication among research groups and organizations. The agency staff continuously scanned various sources of information with the aim to spot new promising but so far unexploited scientific areas for military use. The information was used by managers to attract the attention of researchers by creating communities, employing meetings, personal conversations, e-mail and telephone calls. Guice's (1999) observation leads to the conclusion that the core of DARPA's activities is communication among research organizations, group-building and hereby promoting and pushing the creation of a shared conception of future opportunities among researchers.

The risk by focusing on creating and maintaining a shared cognitive frame is that one cognitive frame becomes highly dominant. As several authors have observed one of the most common course of corporate failure is the lack of ability to recognize the importance and value of other alternatives than the already known ones. A uniform reaction pattern due to a well established shared cognitive frame increases the risk of creating and maintaining core rigidities, despite diversity in background and knowledge. An important managerial task is to continuously

[2] According to Guice (1999), promotional arguments are the mirror image of scientific argument. They put the relevance of the information to social context by exploiting an emotional rhetorical strategy to promote general and inclusive claims. Because of its broader contextualization of the promotional argument guides better the audience's actions than the scientific argument.

[3] The US Defense Advanced Research Projects Agency.

question whether the present way of interpreting changes and information from the environment is the best way. Another risk is that researchers spend too much time on gathering and evaluating information instead of doing research.

Conclusions

Creativity is not the only rationale for allowing a high degree of autonomy in research. This paper argues that also other factors, such as complexity, rate of change, uncertainty combined with an asymmetric distribution of knowledge between research management and researchers justify a high degree of autonomy in research. The range decisions, which should be made autonomous, are decisions related to the research process, change of direction in the process, disclosure of knowledge and access to external knowledge. The other consideration is that decisions in research often have a decisive influence on the future of the company and depend on internal systemic mechanisms of the company e.g. the actions of suppliers of complementary competencies. In other words, companies need to maintain kind of influence on individual researchers in order to develop their research activities in a long-term company perspective.

However, autonomy does not inevitably imply that individual research processes and decisions should be beyond managerial influence. The paper proposes that research management under these conditions should be considered as a process of designing organizations as adaptive systems.

Evolutionary theory provides knowledge about the role of learning in organizations' adaptation processes and how these learning processes can be influenced. The adaptation process of an organization to its environment is seen as a consequence of adaptation in a hierarchy of internal learning processes. In this framework individual adaptation is conscious goal-seeking guided by mental models of the anticipated future development of the individual's environment. Management influences the individual learning processes by having impact on the cognitive environment, communication and other parameters relevant for individual adaptation.

An analytical framework for understanding how research management can manage autonomous individual adaptation processes to increase the overall fit of the company with it present and especially its future business environment, includes following three issues:

1. Influencing individual decision-making
2. Selecting and rewarding among contributions and feedback from selection
3. Designing internal research environment

Setting goals for research serves the double purpose of 1) focusing the research and 2) increase the productivity of research. Goals both limit the variation and increase the productivity as long as the goals are not too narrow defined but define boundaries for what is interesting for the firm. Criteria to be used in setting basic research goals and objectives are related to the following:

- Research management's anticipation of the future business environment directly. The anticipation reflects the corporate goal
- Should set the overall direction only
- Be in a form useful for individual decisions

Supplementary to goal-setting research management can influence the individual adaptation process through influencing the cognitive frame that enables individual researchers to monitor their environment. By creating and maintaining the shared cognitive frame research management enables the company's researchers to coordinate and evaluate their actions in the light of the firm's interest. In this perspective, the primary role of management is to devise processes for individual sense-making for the development and exercise of a corporate imagination, and articulate new strategic logics for improving the adaptive capabilities of individuals.

References

Aldrich, Howard K [1979], *"Organizations and environments"*, Englewodd Cliffs.

Augsdorfer, Peter [1996], *"Forbidden Fruit"*, Avebury, Great Britain and USA.

Bland, Carole J. and Mack T. Ruffin IV (1992): "Charateristics of a Productive Research Environment: Literature Review", *Academic Medicine*, Vol. 67 Number 6.

Bosomworth, Charles E. and Sage, Burton H. Jr. [1995], "How 26 Companies Manage Their Central Research", *Research - Technology Management*, Vol: May-June, Pp. 32-40, Industrial Research Institute,

Campbell, Donald T. [1960], "Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes", *The Psychological Review*, Vol: 67, Pp. 380-400.

Christensen, Jens Frøslev [1998], "The dynamics of the diversified corporation and the role of central management of technology", *Druid working paper* 1998-4, Copenhagen Business School.

Cohen, Wesley M. and Levinthal, Daniel A. [1990], "Absorptive Capacity: A new perspective on learning and innovation", *Administrative Science Quarterly*, Vol: 35, pp. 128-152, Cornell University, USA.

Coombs, Rod [1996], "Core competencies and the strategic management of R&D", in Belcher, Alice; Hassard, John and Procter, Stephen J. [1996], *R&D decisions: strategy, policy and disclosure*, pp. 25-41, Routledge, London.

Dasgupta, Partha and David, Paul A. [1994], "Toward a new economics of science", *Research Policy*, Nr: 23, pp. 487-521, Elsevier Science B.V., North-Holland.

Den Hond, Frank [1998], "On the structuring of variation in innovation processes: a casse of new product development in the crop protection industry", *Research management*, vol 27, pp 349-367.

Dosi, Giovanni and Marengo Luigi [1994], "Some Elements of an Evolutionary Theory of Organizational Competencies", *Evolutionary Concepts in Contemporary Economics*, The University of Michigan Press.

Dosi, Giovanni and Malerba, Franco [1996], "*Organization and Strategy in the* Evolution of the Enterprise", MacMillan Press.

Etzkowitz, Henry and Leydesdorff, Loet. [1998], "The Endless Transition: A Triple Helix of University-Industry-Government Relations". In *Minerva*, 36, pp. 203-208.

Frenken, Koen, Paolo P. Saviotti and Michel Trommetter [1999], "Variety and niche creation in aircraft, helicopters, motorcycles and microcomputers", *Research Policy*, Vol 28, pp. 469-488.

Gambardella, A. and S. Torrisi [1998], "Does technological convergence imply convergence in the markets? Evidence from the electronic industry", *Research Policy*.

Gibbons, M et al [1994], "The new production *of knowledge - the dynamics of science and research in contemporary societies"*, Sage Publications, London.

Guice, Jon 1999: "Designing the future: the culture of new trends in science and technology", *Research Policy* vol. 28, pp 81-98.

Hagstrom, Warren O [1965], *"The Scientific Community"*, Basic Books Inc, New York.

Helfat, Constance E. [1994], "Firm-specificity in Corporate Applied R&D", *Organization Science*, Vol: 5, Nr: 2, pp. 173-184, The Institute of Management Sciences.

Henderson, R and Cockburn, I [1993], *"Scale, Scope and Spillovers: The Determinants of Research Productivity in the Pharmaceutical Industry"*, Workingpaper no. 4466, National Bureau of Economic Research, Cambridge.

Hicks, Diana [1995], "Published Papers, Tacit Competencies and Corporate Management of the Public/Private Character of Knowledge", *Industrial and Corporate Change*, Vol: 4, Nr: 2, pp. 401-424, Oxford University Press.

Hounshell, David A [1996], "The Evolution of Industrial Research in the United States", in Engines of Innovation, Harvard Business School Press, Boston.

Husted, Kenneth [1998], "Industriel forskning: styring og autonomi", Ph.d-serie 10.98, Copenhagen Business School

Kline, Stephen J. and Rosenberg, Nathan [1986], "An overview of Innovation", i *The positive Sum Strategy*, National Academy Press, Washington

Kohn, A [1993], "Why incentive plans cannot work", *Harvard Business Review*, September-October

Lawless, Michael W. and Price, Linda L. [1992], "An agency perspective on new technology champions", Organisational Science, Vol: 3, Nr: 2, pp. 342-355, USA.

Marien, Bruce A. [1998], "Protecting Scientific Excellence", Research Technology Management, March –April 1998, pp 39-43.

Marengo, Luigi [1992], "Coordination and organizational learning in the firm", *Journal of Evolutionary Economics*, Nr: 2, pp. 313-326, Springer-Verlag.

Mckelvey, Maureen [1996a], "R&D as Pre-market Selection: Of Uncertainty and its Management", *Paper til den 6. Internationale Schumpeter Society Conference*, Stockholm.

Metcalfe, Stan and Boden, Mark [1991], "Innovation strategy and the epistemic connection", *Journal of Scientific & Industrial Research*, Vol: 50, Nr: October, pp. 707-717.

Metcalfe, Stan and Boden, Mark [1993], "Paradigms, strategies and the evolutionary basis of technological competition", *Technological competition*, pp. 83-103, Routledge.

Metcalfe, Stan and Mario Calderini [1997], "Compound learning, neural nets and the competitive process", *CRIC Working Paper* No 1, University of Manchester.

Meyer, Marshall W. [1994], "Turning Evolution Inside the Organization.", *Evolutionary Dynamics of Organizations*, pp. 109-116, Oxford university press, Great Britain and USA.

Miner, Anne S. [1994], "Seeking Adaptive Advantage: Evolutionary Theory and Managerial Action", in *Evolutionary Dynamics of Organizations*, pp. 76-89, Oxford university press, Great Britain and USA.

Mort, Joe [1994], "Science, technology and innovation: an evolutionary perspective", *Int. J.Technology Management*, Vol: 9, Nr: 1, pp. 30-42, Inderscience Enterprises Ltd., USA.

Nelson, Richard [1991], "Why do Firms Differ and how does it Matter?", *Strategic Management Journal*, Vol: 12, pp. 61-74.

Pavitt, Keith [1998], "Technologies, Products and Organization in the Innovating Firm: What Adam Smith Tells Us and Joseph Schumpeter Doesn't", *Industrial and Corporate Change*, Vol 7, Number 3, pp 433-452.

Pelz, Donald C. and Frank M Andrews [1966], *"Scientists in organizations"*, John Wiley and Sons, New York.

Randle, Keith and Currie, Frank [1996], "R&D strategy and the implications for management control", i Belcher, Alice; Hassard, John and Procter, Stephen J. [1996], *R&D decisions: strategy,policy and disclosure*, pp. 78-100, Routledge, London.

Rosenberg, Nathan [1990], "Why do firms do basic research with their own money?", *Research Policy*, Vol: 19, pp. 165-174, Elsevier Science Publishers B.V., North-Holland.

Rosenbloom, Richard S and Spencer, William [1996], *"Engines of Innovation"*, Harvard Business School Press, Boston.

Rostrup-Nielsen, Jens et al [1997], *"Den vanskelige balance - en bog om forskningsledelse"*, Akademiet for de tekniske Videnskaber, Danmark.

Roussel, Phillip A; Saad, Kamal and Erickson, Tamara J. [1991], *"Third generation R&D"*, Harvard Business School Press, Boston.

Saviotti, Pier Paolo [1996], *"Technological Evolution, Variety and the Economy"*, Edward Elgar Publishing Company, Great Britain.

Sanches, Ron [1997], "Strategic Management at the Point of Inflection: Systems, Complexity and Competence Theory", *"Long Range Planning"*, Vol: 30, pp. 939-946.

Silverberg, Gerald [1988], "Modelling Economic Dynamics and Technical Change: Mathematecal Approaches to Self-Organisation and Evolution", i *Technical Change and Economic Theory*, pp 531-59, Frances Pinter, London.

Simon, Herbert [1959], "Theories of decision-making in economics and behavioral science", *American Economic Review*, Vol. 49, pp. 253-83.

Simon, Herbert [1962], "The architecture of complexity", *Proceedings of the American Philosophical Society*, Vol 106, pp. 467-482.

Stephan, Paula E. [1996], "The Economic of Science", *Journal of Economic Litterature*, Vol: XXXIV, Nr: September, pp. 1199-1235.

Teece, David J. [1988], "Profiting from Technological Innovation", in Tushman, Michael and Moore, William: *Readings in the Management of Innovation*, Ballinger Publ. Co., Cambridge.

Van Lente, Harro [1994], *"Promising Technology – The dynamics of expectations in Technological Developments"*, Univeristeit Twente, Amsterdam.

Vergragt, P. J. [1988], "The social shaping of industrial innovations", *Social Studies Science* 18, pp. 483-513.

Vincenti, Walter G [1990], "What Engineers Know and How They Know It", John Hopkins University Press

Witt, Ulrick [1995], "Imagination and Leadership - The Neglected Dimension of an (Evolutionary) Theory of the Firm", *Paper til "Technology and the Theory of the Firm - Social and Economic Perpsectives*, Reading, UK.