The Dynamics and Functions of Self-Organization in the Fuzzy Front End: Empirical Evidence from the Austrian Semiconductor Industry

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This paper studies the functions, impacts and dynamics of self-organization in the fuzzy front end of innovation. Based on a case study approach, the new product development processes of five Austrian semiconductor companies are analysed. We adopt a complexity science perspective which stresses that self-organization and emergence are key elements of the new product development process. We found that self-organization mechanisms occur in two ways. First, self-organizational activities support formal and top-down managed new product development processes. In this way, they contribute to the acceleration and adaptation of the new product development process and are also a way to overcome bureaucratic structures. Second, we found evidence for the existence of purely emergent bottom-up processes in many cases. In this context, employees intrinsically and without any explicit order or strategy took initiatives to innovate. Such activities run in parallel to or precede formal new product development processes and employees deliberately bypass and even ignore formal processes such as financial incentive systems, suggestion schemes and patenting rules in order to promote their ideas. These activities are often secret until they are mature enough to be presented to the management, when they are then, if evaluated positively, incorporated as official projects in the new product development process.

Introduction

For the management of innovation, various models and approaches have been suggested in the literature. Several approaches, such as the innovation funnel (Wheelwright & Clark, 1992) or stage-gate model (Cooper, 1990), which became widely diffused in many industries (Griffin, 1997; Cooper, Edgett & Kleinschmidt, 2001), manage innovation by structuring, planning and ordering the innovation process. These models rely heavily on planning, anticipation and control. Brown and Eisenhardt (1995), for instance, have categorized such models as 'rational plan', where deliberate planning and action are the main focus of innovation management. Empirical studies, though, show that, first, innovations do not follow these rather simplistic models since, for instance, decisions are not always taken at stage-meetings in the case of an implemented stage-gate process (Christiansen & Varnes, 2007), and second, that innovations often emerge outside the strategically defined core areas, teams or formal processes (Kanter, 1988; Christensen, 1997; Robinson & Stern, 1997). Moreover, some authors (e.g., Brown & Eisenhardt, 1997) have stressed, too, that such models lose effectiveness in an increasingly complex organizational and competitive environment.

Some researchers have taken a critical view on existing innovation processes or new product development (NPD) and argue against a too strongly structured, planned and ordered innovation process, particularly for managing radical innovations. Such studies, for instance, have been carried out in line with organizational theories (Perrow, 1986; Amabile, 1997) or sociological theories (Akrich, Callon & Latour, 2002), criticizing traditional linear models for not supporting learning and creative problem-solving and for being instead means of control through standardization. Thus, authors claim

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that innovation requires not only a sequence of planned actions but also some level of disorder, emergence, improvisation and self-directed teams (Nonaka, 1991; Miner, Bassoff & Moorman, 2001).

Within this stream of literature, more recently, some scholars have incorporated findings from complexity science to explain the dynamics of organizational change and new product development. A complexity science perspective on NPD regards organizations as complex systems and stresses that self-organization and emergence are important elements for developing new products, refuting the assumptions of classical management approaches. Brown and Eisenhardt (1997), Dooley (2002), Gomes and Cunha (2003) and McCarthy et al. (2006) have studied the NPD process by incorporating findings from complexity science. Such a perspective is also taken within our research, but we, however, focus on the fuzzy front end of innovation, investigating NPD projects of five Austrian companies in the semiconductor industry. We contribute to this stream of literature by empirically exploring the role of self-organization outside formal NPD processes. We are particularly interested in the interaction and dynamics between self-organized and explicit management processes as well as in investigating the rationales and motivations of employees to self-organize, questions for which there remains limited empirical evidence (Augsdorfer, 2005).

The paper is organized as follows. First, we present the theoretical framework for our study which rests on findings from complexity science. Then the study design is described, and finally our empirical findings and their implications are presented.

Theoretical Background

The phenomenon of self-organization has been studied within the management literature but mainly in the field of organization studies, for instance, for the formation and management of teams (e.g., Barker, 1993), the establishment of self-managed work teams associated with the human relations school (e.g., Cummings, 1978) or the role of informal organizations and networks (e.g., Crozier, 1964; Krackhardt and Hanson, 1993). More recently, though, within the management literature in general and the innovation literature in particular, some authors have referred to complexity science in order to study informal mechanisms of NPD processes, often focusing on phenomena such as self-organization, emergence and non-linearity (e.g., Stacey, 1996; Anderson, 1999). This literature stream is thus in contrast to the mainstream literature which aims to formalize and control the NPD process.

What is complexity science? Complexity science deals with the dynamics and evolution of complex systems as found in physics, biology, society or the economy. Funnels in tornadoes, flocks of birds and schools of fish are all examples of orderly behaviour in systems that are neither hierarchically planned nor centrally controlled. No single or commonly agreed complexity theory yet exists. However, the complex adaptive systems (CAS) model (Holland, 1995; Kauffman, 1995) has attracted attention, particularly when applied to explaining the behaviour of human and economic systems.

CAS consist of a large number of agents – these can be cells, organisms, populations, organizations, departments, teams or individual researchers – acting and interacting in a non-linear manner according to their local principles or behavioural rules (Holland, 1995). Agents are linked to other agents, communicating and exchanging information and resources. Although these agents behave according to simple behavioural routines at the individual level, they exhibit complex patterns of behaviour at the aggregate level. The properties of self-organization and emergence, non-linear relations between agents, and the existence of feedback loops amplifying the effects of individual behaviours are all important features of complex systems. Self-organization means that new structures, patterns or properties emerge spontaneously without being externally imposed on the system. Dooley (2002, p. 5020) defines self-organization as follows: 'we refer to a system as self-organizing if it undergoes a process . . . whereby new emergent structures, patterns, and properties arise without being externally imposed on the system. Not controlled by a central, hierarchical command-and-control center, self-organization is usually distributed throughout the system'. Emergence can be defined as a process whereby novel and coherent structures, patterns or properties arise on the global level out of the local interactions of the agents (Goldstein, 1999, p. 49).

While authors in the complexity research stream such as Stacey (1996) or Anderson and McMillan (2003) explicitly distinguish between self-organization and self-management, in the organizational literature these terms, together with related concepts such as self-autonomous, self-regulated or empowered teams, are often used synonymously (Ashmos & Nathan, 2002). Usually, these self-managed teams have some leeway in decision taking and the definition of goals are explicitly regarded as a form of managerial control with established reporting and reward structures. In contrast, complexity researchers stress that self-organization is a fluid process with informal, temporary, spontaneous teams where it is the participants who decide who takes part, and not the managers as in the case of self-managing teams (Stacey, 1996).

A few authors have explicitly adopted a complexity science perspective or referred to it when explaining innovation processes and conceptualizing NPD models. Stacey (1996) claimed that managers who innovate mostly rely on self-organizing political and learning processes to produce an emerging, but unpredictable future. Brown and Eisenhardt (1997) studied the innovation processes in the computer industry with its high demand for continuous change and innovation. Their study is influenced by complexity science and the idea that organizational structures and processes are 'neither so structured that change cannot occur nor so unstructured as chaos ensues'. Based on six case studies, they found that successful firms combined limited structure (e.g., with respect to responsibility) with extensive interaction and freedom to create improvisation with current projects. They call these structures and processes 'semistructure', which, according to them, is a balanced state between order and disorder, proposing that the NPD process of successful firms is neither too structured nor to loosely organized. Similarly, Gomes and Cunha (2003, p. 182) proposed an NPD model termed the 'improvisational model', which refers to the temporal convergence of planning and execution, with action viewed as improvised when it 'constitutes a deliberate, real-time response to a problem or opportunity'. Innovation processes are hence characterized by complexity and emergence requiring partially disordered processes. The challenge for management is to somehow use disorder productively, hence to overcome the constraints of traditional linear and sequential innovation models such as Cooper's (1990) prominent stage-gate model. However, Cunha and Gomes do not provide empirical data and examples for illustrating their model in more detail.

McCarthy et al. (2006) perceive NPD as a complex adaptive system of decisions. They present some propositions on how decision-making is influenced by non-linearity, self-organization and emergence. They argue that the decisions taken by the NPD team are affected by the decision rules. Based on case study research, McCarthy et al. (2006) reported, for instance, that in one case a significant product idea emerged during intensive interaction at a social event, where a spontaneously formed group was able to co-operate and solve problems beyond usual bureaucratic constraints. They referred also to a case where a radical new innovation emerged just because the project team disregarded the process rules and procedures, a finding which is in line with Olin and Wickenberg's (2001) observations on rule-breaking.

Although only a few scholars have adopted a complexity science perspective, some common features and elements of a complexity-based NPD model can be identified which also serves as a framework for our study. First, in highly dynamic environments, self-organization amongst different agents is crucial for producing innovative outputs. The configuration of project teams, consisting of researchers from different disciplines, departments and fields is, in part, a self-organizing process. Self-organization is an important factor in the search phase and leads to strong teams with the ability to overcome internal organizational barriers. Even though the classical organizational and innovation literature has investigated the role of informal organization, self-managed teams and product champions in association with bottom-up innovations (e.g., Schön, 1963; Howell & Boies, 2004), the complexity science perspective highlights in particular the formation of self-organized NPD teams. These teams emerge without any explicit management order as a key and regular feature of complex systems and not as a rare, extraordinary event. Moreover, characterizing an NPD activity as bottom-up does not necessarily mean that it is self-organized, too, because it may also be managed as in the case of, for example, organizing creativity workshops or the implementation of ideas from suggestion schemes.

Second, self-organization and emergence depend on rich interaction between agents. The quality of dialogue, communication, collaboration and argumentation in R&D and NPD settings is a key enabler of self-initiated learning processes. Thus, for self-organization and emergence to occur, the necessary framework conditions must exist; the primary function of management is to provide them, and hence excessive attempts at standardization and control can be counterproductive.

Based on this framework of the NPD process we aim to study the types, functions and processes of self-organization in the fuzzy front end of innovation. We are interested in the motivations and mechanisms for self-organizational activities, the interaction between different organizational members and its interaction with formal NPD processes. We focus on the phenomenon of self-organization and do not deal in more detail

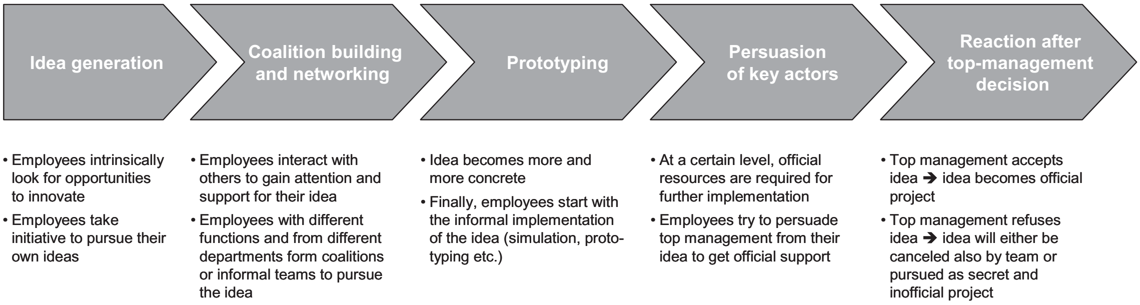

Figure 1. The Evolution of a Self-Organized Innovation

with other features of complex systems such as non-linearity.

Methods

The NPD practices of five Austrian companies in the semiconductor industry were examined in order to study the types, impacts and functions of self-organization. We have chosen this industry with its high dynamics, velocity and demand for continuous innovation, as we expected that self-organization was crucial to compete successfully.

The enterprises analysed were Austrian companies as well as Austrian subsidiaries of international firms. The companies were Supertec with nearly 1,000 employees, Chipcom employing about 1,500 employees, Microwaver with approximately 2,500 employees, Silicius engaging around 700 people, and finally NewCo, a start-up company with 120 employees. The number of employees refers only to the Austrian subsidiaries.[1]

We have chosen a case-study approach as an appropriate methodology in order to study in-depth the dynamics of self-organizational innovation activities. The case study combined multiple data collection methods and included semi-structured interviews, which lasted between 40 and 90 minutes and were conducted in a narrative way, i.e., personal and subjective impressions were gathered and relevant artefacts (e.g., mission statements, arrangement of offices) observed. The interviewees were the five heads of the R&D departments of each firm as well as employees of the R&D department. Based on the interviews with the R&D directors, two to three NPD teams were selected in each company for further investigation of initiatives, in which self-organizing activities played a significant role in the NPD process. Two developers from each team were interviewed subsequently to investigate the role, effects and motivation for self-organizational activities from the employees'; point of view. In total, 12 NPD teams with 24 people were interviewed. These interviews were conducted with a semi-structured questionnaire covering a set of common questions and some specific questions for the R&D directors as well as the team members. Asking management and employees nearly the same questions contrasted their different perceptions of the activities and organizational processes.

Each examined self-organizing activity was seen as separate case and considered as relevant for further observation. Based on these settings, the collected cases were analysed in an iterative process. This was done mainly by combining within-case analysis and cross-case analysis. Hence, first of all the typical patterns and characteristics of each case were analysed, then, in the cross-case analysis, these findings were compared with findings from the other cases. Therefore, we were looking for similarities as well as significant differences between the cases. Identified similarities confirmed our assumptions and fostered validity; differences, however, offered the possibility to verify our research questions, further explore the case to reveal inconsistencies, and finally generate new insights. Based on these analysis methods we also inducted our process model for a purely self-organized NPD process (see Figure 1).

Findings

Our investigation revealed evidence that self-organizing dynamics strongly influence the fuzzy front end of innovation in the semiconductor industry. We identified two different patterns of self-organizational activities: first, self-organization performs a significant role in

[1] For reasons of confidentiality, the real names of the companies have been made anonymous.

interaction with the formally managed NPD process; and second, many innovations in the semiconductor industry have their origin in a purely self-organized process.

We will start by illustrating the latter, the evolution of a bottom-up NPD process, which is the focus of this paper.

The Evolution of a Self-Organized NPD Process

Based on the case studies, we inducted a general process model of the dynamics of self-organization in the innovation process. This general process model integrates patterns and similarities found in nearly all examined cases to one coherent construct. Thus, the empirical evidence of our case studies revealed that a purely self-organized NPD process can be divided into five phases (see Figure 1). Yet, it should be made clear that this is a linear illustration of the general process and in some cases phases may overlap, run in parallel or can be repeated.

Idea Generation

A self-organized bottom-up innovation starts when some individuals, without any explicit order from an outside source (e.g., top management), search for opportunities to innovate. The self-organizing activity is mainly driven by intrinsically motivated employees. Although the sources for these opportunities vary (e.g., inputs from customers, external partners, internal colleagues), our research has shown that the informal interactions in the shadow organization and personal networks play a very important role. Thereby, employees interact with each other in a casual way, often outside official working hours (e.g., during breaks, lunch, spare time) and at locations other than their official offices. During these informal interactions within their networks, they also exchange their problems, insights, approaches and single ideas which often sparks an intensive and dialectic discussion about these issues and thus leads to the emergence of novel ideas or solutions, for example for technical problems or new customer needs. Nearly all interviewees stated that these interactions were the main source and departure point. One R&D employee of Chipcom described the situation very well: 'The informal communication is so important, because you just feel the mood and you know exactly what it is about. You just grab things, consciously and also unconsciously, even though you are often not the direct addressee of the information. But you just pick it up and process it. Thus you know the problems and issues and can therefore help immediately'. This is exactly the phase when the subjective intuitions, ideas and hunches of individuals are tapped and their tacit knowledge is converted into explicit knowledge (e.g., Nonaka & Takeuchi, 1986; Stacey, 1996).

Coalition Building and Networking

After the idea has become more concrete, the inventors try to draw the attention of other individuals to their idea to get support for further pursuit. Thus, the inventors specifically try to attract those people who are considered important for the implementation. However, not only people with the appropriate know-how are considered important, also those with power or the right networks and contacts are seen as relevant enablers for the innovation. This phase is again dominated mainly by bottom-up mechanisms within the personal networks often spreading their vibes throughout several levels of the hierarchy and thus attracting people with different functions and often from different departments. In this manner, more and more people who are convinced of the idea and realize the need for action are attracted, although the idea or invention is still not an official project. This process finally leads to the building of coalitions, clusters or even teams around that idea and to the persuading of and negotiating with others to support that idea and to potentially crystallize it into an innovation. This stage is also self-organizing in the sense that it is informal and not centrally organized or planned (Stacey, 1996).

In this context, it must be mentioned that already in this early stage the R&D director often gets informed about the intentions of the engineers. Since he knows both the market and customer requirements as well as the technical aspects, he usually enjoys a very high reputation and confidence in the view of the engineers. Therefore the R&D director acts as a first filter and assessor and also helps to develop the idea in the right direction. As one engineer of Silicius stated: 'The R&D director is the heart of the whole development, since he knows the market and the customers. He is the one who dictates the direction for the new product'.

Prototyping

Once coalitions or informal self-organized teams have been formed, they start with the first steps of the implementation of the potential innovation: this realization mainly takes places unofficially and beside the normal work. Because the inventors operate outside the formal structures – more or less secretly – and thus without any official support from the management, they depend mainly on the support of their colleagues to be able to work on their innovations. This support primarily contains the access to valuable resources such as infrastructure (e.g., production machines, simulation tools) or the supply of materials (e.g., wafers), which is normally restricted. However, as one employee of Supertec noted: 'with the right connections and networks, the access to these important resources can easily be granted in an unofficial way.' The same employee mentioned, furthermore, that good relationships enabled him in the past to get free access to the production machine and wafer materials, which is normally highly restricted, and hence allowed him to produce some prototypes. Usually, when following the official protocol, it takes a couple of weeks and a lot of formalism to get a slot with a production machine to produce and test a new prototype. Yet, together with the responsible persons from the production department, the developers used the machine late at night when the factory was closed, to produce some new prototypes. Furthermore, the employees of Supertec also confirmed that many colleagues concealed the unofficial operations of the inventors. In addition, these colleagues have even taken over the officially assigned tasks for the inventors, so that they were able to work on their own secret project.

Although all examined companies show strong efforts to identify informal activities and make them official as early as possible, we got the impression that the inventors – most of the time with the knowledge of their R&D director – nevertheless often worked as long as possible secretly and unofficially on their own innovations. The major reasons why they work 'underground' are summarized in Table 1. In this context, we were also able to illustrate the role of financial incentives systems and patents which too deliver reasons for keeping NPD activities secret. All companies examined offered a bonus for inventions or patents, which means that the employees get a considerable amount of money if they make an invention or file a patent. In many cases, though, inventors abandon these bonuses as they prefer to pursue their intentions secretly. With respect to patents, the case studies also revealed that they were not welcomed by certain inventors either, as companies often file them only to thwart competitors but without any real intention to further pursue the invention. Thus, filing a patent may be associated with the risk that the innovation may not be developed for strategic reasons. So far, the case studies have revealed that intrinsic motivations were the prime force for self-organized innovation activities.

As already mentioned above, the R&D directors most of the time knew about the intentions of their engineers, supported these and gave them the leeway to work on their plans until they could present a reasonable outcome.

Persuasion of Key Actors

While at the early stages informal implementations are mostly possible with very few problems, they become more and more difficult with the further advancement of the project, until a certain point is reached, where organizational support and formal structures are required for further effective implementation. At this point, the inventors, mostly with the support of the R&D managers, present their innovation to the top management and try to persuade them that their innovation should become an official project and thus get organizational resources. To present a more effective case, the innovators often not only try to mobilize key actors (e.g., product or marketing management) for their lobbying activities, but also try to influence the top management by providing biased or filtered information. As one developer of Chipcom stated: 'By giving the top management the "right" information, you can control and influence them very well'. This means that the innovators try to push through their interests with manipulation. In this context, it has also been observed that sometimes the formal innovation strategies or processes are being manipulated and therefore threatened if the employees behave opportunistically and thus want to enforce their own interests. As one developer said: 'Sometimes we sabotage the formal innovation strategies and plans to push through our interests'. These circumstances reveal that also conventional formal innovation processes and strategies are threatened by a principal-agent dilemma if the interests of the employees are not aligned with those of the company or management.

Reaction after Top-Management Decision

After the top management has been informed about the self-organized innovation, the new innovation is discussed within the management. Generally, the less this innovation fits into the strategy, the harder it is for it to be accepted. Usually, various evaluation methods (e.g., market studies or feasibility tests) are

Table 1. Reasons for Self-Organizationally Driven NPD Activities

Reason of employees for self-organized NPD activities	Description
To avoid ideas being killed by presenting unfinished work	Innovators are afraid that the top management or other employees will interfere too much and thus the risk arises that their initiatives will be killed. The R&D director of Chipcom described this with the slogan 'Never show fools unfinished work'.
To bypass time-consuming and cumbersome formalism	Formal procedures and requirements (meetings, presentations, reporting, etc.) are seen as constraining and time consuming, which prevent people from pursuing their new ideas within the official procedure.
Innovation is outside the roadmap	Innovators are afraid that ideas outside the strategy or core business will be refused by the management, since these ideas probably will not fit into the company's existing roadmap.
To realize ideas in a situation where top management is satisfied with the current technology and/or products	In many cases the top management acts according to the slogan 'never change a running system' expressing that it is satisfied with the current products or processes and therefore does not want to take additional risks. For these reasons the inventors try to bring their innovations to a mature stage and show concrete results before approaching the top management.
No fear of failure within the personal network	Employees working in secrecy within their informal network often feel more comfortable and are not as afraid of potential failures or flops.
Not allowed to engage in other fields	In some cases employees are not allowed to engage in fields outside their official task and therefore work secretly on their own ideas.
Fear of relinquishing ideas to others	Innovators are afraid that they would have to relinquish their ideas to other developers or departments. Innovators hence try to protect their 'babies' by a secret implementation.

applied to decide about the further process. If the project is accepted, the informal team then becomes an official project team and will be incorporated into the organizational structure. The former informal process is now being managed as an official and formal innovation project with all appropriate procedures (such as milestones, reports, etc.).

A refusal of the project can lead to the frustration of the inventors and very often these aspects are a further reason why employees try to work a long time secretly on their ideas. However, even if projects were declined, some inventors stated that they continued working on the innovation behind the management's back, but very often with the awareness of the R&D director.

The previous characterization of the mechanisms reveals evidence that the entire early phase of an NPD may emerge without any control instance, just by the internal self-organizing dynamics and interactions of employees who form an innovation team. However, we also found some differences between the companies. Supertec, Chipcom, Microwaver and NewCo have a formally well-structured and standardized stage-gate NPD process. Silicius, in contrast, has a very tightly structured formal development process since it wants to closely organize and control all stages of the NPD process. Self-organizing activities of employees – also outside their assigned focus fields – are very appreciated at Supertec, Chipcom and Microwaver. At NewCo, the start-up company, they are seen as a very important component of the development process and are therefore a major part of the company's values and culture. At Silicius, in contrast, self-organizing activities are also much appreciated, but only within the assigned focus fields, since Silicius is, first, afraid of potentially losing control over the process and, second, wants its employees to invest all their energy in their assigned tasks.

Apart from these purely bottom-up processes, self-organization also plays an important role within the formal NPD process, which is described next.

Self-Organizational Activities Facilitating the Formal NPD Process

Self-organizing mechanisms affect official top-down imposed innovation processes in various ways. Nearly all of the characteristics and activities described above in the process of a pure bottom-up innovation also appear in different ways in official top-down imposed and organized innovation processes. Since these behaviours often improve the formal innovation process, they are at least tolerated and often even desired by the management. As most of these self-organizing activities were already described in the above illustrated process of a bottom-up innovation, only some key characteristics in the formal innovation process are described in the following.

The respondents argued that self-organizing had become evident when rules, structures, procedures, etc., of the formal NPD process were changed according to their interests, or, in some cases, simply ignored. In that sense, self-organization allows NPD teams to define and adopt their own rules as already proposed by McCarthy et al. (2006). This happens mostly when rules are perceived as complicated, impractical or bureaucratic. Hence, self-organization acts to overcome formal organizational barriers. Despite the fact that all companies examined had a standardized, well-structured stage-gate NPD process, we observed that, particularly in the early phase, loose structures and little formalization dominated the innovation process, even at Silicius with its very tightly structured stage-gate process. In this context, it also became evident that certain entities in the hierarchy were deliberately bypassed or that certain actions which are formally not allowed were bridged via the personal network. The possible impacts of these rule breakings have already been studied and pointed out by Olin and Wickenberg (2001). We observed, too, that formal procedures were considered as second choice when the informal failed to work. As one developer at Supertec stated: 'If I don't get it by the informal way then I use the formal procedures or sometimes contact my manager to get it through the official way'.

The R&D employees interviewed claimed that self-organizational activities were necessary in those situations where the organized process left leeway for action and creative problem solving. Thereby, employees often adapt the official rules and procedures according to their own practices, methods or tools to better execute the top-down imposed NPD process.

In addition, employees said that they often left their formal position to fulfil tasks for which they were not officially designated. These examples illustrate again how informal self-organization and formal procedures coexist to produce innovative outcomes. They also reveal that the top-management sees these informal and self-organized activities as a very important component and also complement in the innovation process, although they are still not acknowledged in the company's formal NPD process.

Discussion and Conclusion

The models and notions of complexity science have gained attention within the innovation literature in the last few years to explain the development and diffusion of innovations. In this context, Tsoukas (1998) points out that the main contribution of such an approach is that a socially constructed analogy can spur the understanding and thinking about organizations, and could shift the attention to previously unsuspected, or only peripherally relevant phenomena of an object. The current study is an exploratory investigation about the types of self-organizing activities in NPD processes and its motivations and therefore enlarges the currently limited empirical findings in this field.

The process of a self-organized NPD activity as described here covers the phase which some authors have defined as the fuzzy front end. Smith and Reinertsen (1991), for instance, have considered the earliest stage of the NPD process prior to the first official group meeting as fuzzy front end. Reid and de Brentani (2004) have argued that, in the case of radical innovations, it is, in particular, individuals who develop new ideas by understanding emerging patterns in the environment, 'with little or no direction from the organization'.

We have found that the self-organized innovation activities were highly important for the innovation output of all semiconductor firms studied, either as purely self-organized early NPD activity or to modify, bypass or complement the formal NPD process. The activities we have observed were not the result of planned creativity workshops, regular scanning activities, an R&D strategy or any other formal innovation management actions usually organized by the management to foster the NPD process. Although the companies were not able to measure precisely the impact and relative share of self-organizational activities in parallel to the formal activities or the number of purely self-organized innovations, they were considered as a major element of innovation activities and crucial for achieving performance. According to respondents, up to one-third of all formal NPD projects which successfully ended up in a new product launched on a market had their roots in self-organizational activities outside the formal process. Our findings are hence in line with those of Augsdorfer (2005), who studied the role of bootlegging in NPD. Augsdorfer stresses that many innovations have their origins in the corporate underground, which is seemingly valuable for the firm, too. However, unlike our study, Augsdorfer (2005) focused on the strategic fit of bottom-up innovation activities without investigating the process, interactions and motivations behind such activities. Moreover, the literature on bootlegging mostly does not investigate the interaction of informal and formal activities and hence corresponds only to the purely self-organized NPD process.

Studying self-organized NPD initiatives based on our process model revealed that, while in the beginning these activities were kept secret, they became increasingly integrated with the formal NPD process later on. We also found that middle managers, i.e., the R&D directors, were nearly always aware of these activities, endured them and often even supported them. Thus, they play a very crucial role in this context, since on the one hand, they often realize the future success of the potential innovation and try to promote it, and on the other, they also have to represent the interests of the company. Therefore they have to balance carefully these two different interests. Moreover, with their strategic and market knowledge, they are, from the viewpoint of the subordinate developers, a good filter for bottom-up initiatives, a fact which has been stressed in the corporate venture literature (e.g., Burgelman, 1983). R&D managers were aware of and tolerant of the self-organizational activities, partly supported them and thereby deliberately managed the NPD process by synchronizing formal and informal processes. Thus, managers performed some kind of loose-tight control, tight in the sense of formally controlling the innovation process, loose in the sense of tolerating self-organized activities. The implication for management in general is to accept the hidden life of organizations in order to facilitate innovation.

The findings of our study are also related to the notion of skunk work (e.g., Kanter, 1988), which is often mentioned as a possibility to facilitate the innovativeness of organizations. However, while skunk work is usually deliberately managed and supported by management, self-organizational activities are often performed in the corporate underground without any managerial intention.

Our research is related to the concept of product champions (e.g., Rothwell, 1994), as the organizational members associated with self-organized innovation activities have features of champions. The literature on champions mainly stresses their role to overcoming organizational barriers, linking R&D and marketing by informal contacts or their power function to support innovations. Accordingly, self-organized early NPD activities as found here correspond to the bottom-up emergent view of championing as identified by Day (1994). However, the question on whether champions'; activities are more formal or informal is not always thoroughly investigated in the product champion literature. Moreover, champions are not always explicitly associated with the very early phases (e.g., Reid & de Brentani, 2004), but are regarded as supportive after the idea generation phase. Yet, some authors (e.g., Cooper, 2006) propose the careful selection of product champions by the management which is in stark contrast to a complexity science perspective on self-organized activities.

We have found evidence that formal systems such as stage-gate systems, financial incentive systems or patenting policies were bypassed or even ignored by the teams in order to push their ideas and projects. Our findings are hence in line with some literature stressing that intrinsic motivation is the prime driving force for creative and innovative work and that formal systems may be counterproductive and have unintended effects, and are thus often ignored or bypassed by organizational members (e.g., Katz & Allen, 1982; Osterloh & Frey, 2000).

When interpreting the results of this study, one must consider some limitations. We have studied innovation in the semiconductor industry and thus generalizations have to be made with caution. We have not examined in more detail the conditions and organizational factors such as leadership style, extent of hierarchy or culture which facilitate or harm self-organizational activities, which is addressed in another work (Koch, 2007). Moreover, we have not studied the co-evolution of the organizations in relation to their environment consisting of other complex systems, e.g., their competitors, which would require a longitudinal study setting. Finally, we have not investigated the outcome of different NPD projects (e.g., are self-organized new products more innovative or more successful?). These are interesting questions for future research.

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