Organizing uncertainty.
Technological innovation in the semiconductor industry

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Introduction

Based on permanent renewal, the semiconductor industry is well known for its ability to deal with the economic as well as technological uncertainty inherent to innovation. Today, the semiconductor industry coordinates innovation activities for future microprocessors and memories between competing firms and on a global scale. Despite the industry's high innovation rate as expressed in "Moore's law", the development of future technologies appears relatively predictable. We study the practices and structures the industry has developed in order to manage and organize the uncertainty inherent in the development of new products.

Concerning the research and development (R&D) in the semiconductor industry, a global organizational filed has emerged which is coordinated in a very explicit fashion. The reason for this is, that in this industry, high investment costs and short innovation cycles present challenges to common forms of technology development coordination. Especially complex technologies like semiconductors are regularly developed within organizational networks or fields, as single organizations do not possess the complete knowledge required to develop state-of-the-art technologies. Collective coordination on a field level is required, because it is not possible to explore every feasible technological option and decisions as to which options merit further exploration cannot be made based on technical criteria alone. In this way, creating new technologies also depends on creating or changing institutions.

The concept of organizational fields (DiMaggio and Powell 1983) emphasizes the fact that such fields are constituted not only be the relations between organizations, but by the institutionalization which takes place within the fields. DiMaggio and Powell (1983) call this "institutional life". But it is important to note, that a field's institutional life does not simply emerge and exists. On the contrary: In most fields, actors have put a lot of effort into shaping the institutionalization of a field in their interest. In addition, once it exits, the institutional life of a field needs to be maintained.

As an institution, the logic of 'Moore's law' has been a primary benchmark of the semiconductor industry's development. First stated in 1965, the 'law' predicts a steady doubling in the density of electronic circuits every 18 to 24 months (Moore 1965). For decades, this standard

has set the pace for innovation cycles in the industry. Today however, the currently used manufacturing technology – lithography – is no longer capable of further extending Moore's law. It is predicted to reach its technological and economical limits in a foreseeable period. Industry actors are therefore in the midst of a selection process, jointly involved in the pursuit of a successor for the technology that has dominated their sector to date. The need to identify one single "next generation lithography" (NGL) is mostly attributed to cost factors within the industry, i.e., the actors' economic inability to pursue different technological options simultaneously. As semiconductor manufacturing is already a multi-billion-dollar collective effort, even the development and commercialization of one single NGL option cannot be accomplished by an individual company alone (Browning and Shetler 2000). Thus, the search for a new production technology is particularly suited for an examination and analysis of the institutional work involved in the coordinated search for a new technology on the level of organizational fields. As we will see, the industry is still carefully maintaining the fields institutional life in order to facilitate the cooperation needed among multiple fierce competitors across and along different value chains.

Against this background this article explores the following *guiding question*: How are the uncertainties of complex technology development collectively engaged through institutional work? We focus on two concrete practices: *roadmapping* and *organizing conferences*. Both have emerged as central means of coordination (Schubert et al. in press) within the field over the last twenty years, so both can also be seen as central institutionalized practices for innovating semiconductor manufacturing technology. These forms of regulation and coordination are used, because more direct forms are not available to members of the field. No organization or other actor is able to directly coordinate the field. Nobody is able to simply define, which way the industry is supposed to go. Instead field actors use roadmapping and organizing conferences to influence the shared perspectives and believes within the field. Therefore, and more precisely, we ask how these practices create the necessary 'certainties' so that initially fictitious beliefs or "anticipative structures" (Van Lente and Rip 1998) are first transferred into expectations and then transformed into requirements and finally into material arrangements used for high volume manufacturing of computer chips.

Roadmapping refers to the creation and updating of technological roadmaps as a means to coordinate R&D activities. Through roadmapping, shared understandings and norms concerning

future technology development are created, which orient the locally dispersed research and development (R&D) activities of the actors involved. Today, technological roadmaps are commonly used in many industries (Radnor and Probert 2004). They are mostly explicit in form, that is, the respective technological objectives are formulated in a written document, often accompanied by graphical elements that illustrate the respective lines of development. In the late 1970s, Motorola was one of the first companies to use this strategic planning practice. Meanwhile, roadmaps are applied beyond the organizational setting and adopted by interorganizational networks or even entire industries (Phaal et al. 2004).

C*onference organizing* describes activities which set up conferences in order to create a common perspective – anticipative structures similar to roadmaps – concerning the future R&D within an organizational field. Conferences and their organization coordinate interactions and relations among conference participants and are a second crucial means to control information. The practice of conference organization is used by actors to create and stabilize shared perspectives and practices across the organizational field of semiconductor manufacturing. At conferences, different actors who are reciprocally perceived as relevant within the organizational field engage in social interactions in order to exchange information and make collective sense of ongoing activities or events (Lampel and Meyer 2008; cf. also Garud 2008; Oliver and Montgomery 2008). On the one hand, conferences are used to consolidate shared understandings and norms. On the other hand, these events are used to establish and solidify relations among the actors within the field and to produce support in situations of high uncertainty.

We will show how these two practices – roadmapping and conference organizing – are used to shape the field's institutional life by creating shared expectations for the future development of specific technologies, while their use also reduces, or at least pretends to reduce, uncertainty within the field.[1] As shared practices, roadmapping and conference organizing mutually reinforce each other and contribute to the (re)alignment of not only expectations but also of activities and organizations in the field of technology development for semiconductor manufacturing. We also aim to contribute insights to the emerging literature on institutional work: First, collective institutional work is crucial for the creation and maintenance of a field's institutional life.

[1] Another important institutionalized practice is the increasing use of consortia to push the technology from lab to fab, which we discussed elsewhere (Sydow et al. 2012).

Second, we demonstrate the usefulness of a praxis theory approach for understanding the reflexive and recursive properties of institutional work.

Theoretical and conceptual background

Two core ideas from neoinstitutional theory, the concepts of *organizational fields* and *institutional work*, are particularly relevant for this study. The concept of *organizational fields* emphasizes the interrelations, interactions and mutual influences of organizations engaged with a shared issue and, thereby, constituting an area of institutional life (DiMaggio and Powell 1983; Hoffman 1999; Wooten and Hoffman. 2008). Organizational fields constitute an important arena for technological development in general as well as for defining the pace, coherence of the processes and for the commitment of the actors involved in particular. It is the level of organizational fields, which is the described practices are aimed at.

The concept of *institutional work* (DiMaggio 1988, Lawrence and Suddaby 2006) addresses a specific form of social change[2], focusing on "the purposive action of individuals and organisations amied at creating, maintaining and disruption institutions" (Lawrence and Suddaby 2006, 216). *Creating institutions* includes political work, reconfiguring belief systems, and altering the boundaries of meaning systems (ibid., 220). *Maintaining institutions* is defined as adhering to rule systems, and reproducing systems of norms and beliefs (ibid., 229). *Disrupting institutions* aims at ending institutions and includes processes of disconnecting rewards and sanctions from existing rule systems, procedures, and technologies, of disconnecting the moral foundations of particular norms, and of processes of undermining taken-for-granted assumptions (ibid., 234). These three aspects resonate well with the generation, continuation and termination of technological paths, which we have discussed elsewhere (Meyer and Schubert 2007). Institutional work not only highlights the importance of cognitive, cultural and normative aspects of institutions – a basic assumption of institutional thinking (Meyer/Rowan, 1977; DiMaggio/Powell, 1983; Scott, 2001) –, but by drawing on the sociology of practice and actor-

[2] Other forms of social change highlighted by institutional theory are mainly rooted in meso and macro level dynamics. Examples are isomorphic mechanisms in organizational fields (DiMaggio and Powell 1983) and the world polity approach (Meyer 2008).

network theory also emphasizes two additional aspects that have too often been neglected in institutional thinking: the political and material dimensions (Lawrence and Suddaby 2006, pp.218 and pp.242).

In our view, the concept of institutional work is crucial for an understanding and explanation of an organizational field's dynamic. However, the concept needs some theoretical refinement. In this paper, we outline a praxis theoretical approach informed by structuration theory (Giddens 1984) to clarify, how institutional work can contribute to the development and maintenance of a field's institutional life.

From this perspective, institutional work can and should be understood as a process of structuration, paying attention to the institutionalized character of the practices and events as well as to the process of continuous institutionalization. This allows institutional work to be described as a process which is reflexively and recursively produced and reproduced by knowledgeable agents in time-space, who in their interactions, refer to the more enduring aspects of the social – structures and institutions in particular –, and, thereby, reproduce or transform them at the same time (Giddens 1976, 1979, 1984). We see roadmapping and conference organizing as collective practices of "selective 'information filtering'" (Giddens 1979, 78; 1984, 27), i.e. as strategic practices of reflexively and recursively gathering, storing, and disseminating information. In other words, roadmaps and conferences are specific locales (Giddens 1984, 118) which provide a socio-material setting for *controlling relevant information*.

Finally, the processes of creating, maintaining, and disrupting institutions are separable only analytically.[3] Rather, they are interrelated and as such moments of a single process of social structuration. For example, creating institutions means disrupting some institutions and maintaining others. Creating an industry-wide view on technology development always involves the disruption of established understandings of technological options while simultaneously maintaining Moore's Law as an industry-wide guideline and actually developing the technologies themselves.

Lawrence and Suddaby present a fruitful emphasis on cognitive, cultural, normative, as well as political aspects of institutional work. However, from a structuration theory's point of view

[3] Lawrence and Suddaby (2006) treat these three elements separately, but already in the variety of examples they have collected, it becomes apparent, that this is an analytical distinction.

these aspects can be elaborated by aligning them with the rules of signification and legitimation as well as the resources of domination (Giddens, 1984, 25). From this perspective, institutional work addresses the *reproduction and transformation* of:

- *practices of communication* and rules of *signification*, i.e. meaning systems and general procedures and technologies of communication recursively used in communication, such as those implemented in the process of roadmapping which connect subgroups with the steering committee and with the companies, consortia and research facilities in the field;
- *practices of power usage*, such as practices of collaboration and the application of material artifacts, and resources of *domination*, such as money, knowledge, sets of relations, and so on, recursively used in influencing processes of roadmapping and conference organizing;
- *practices of legitimation* and rules of *legitimation*, recursively used to implement new or to strengthen approved ways of sanctioning, as in the recurrent reference to Moores's Law and in the emphasis of pressing uncertainties that need to be overcome to secure the success of the industry.

Of course, also this distinction is merely analytical. Actors can and do coordinate a field via institutional work in institutionalized settings simultaneously along the three social dimensions, signification, domination, and legitimation, e.g. by influencing meaning systems, resource usage and evaluation forms in an organizational field.

Since institutional work is understood as work which *intends* to shape institutions, further remarks are necessary: Agents, be they the state, state-like agents or networks of collaborating agents, do not always achieve their intended objectives. There will always be unintended consequences of purposeful action as well as conditions actors do not understand. In contrast to undersocialized concepts, agents in the structuration theoretical approach are seen as having less freedom to act since they always do so in an environment regulated by sets of social systems and institutions, which constrain this action – but which of course also allow the actor to act competently. Actors in this perspective are, however, also not oversocialized. Due to the contingent (re-)production of the social and the dialectic of control, agents always have at least some control over the conditions of their activities and are always able to act otherwise – at least to a certain degree. Nevertheless, institutional focuses on activities which are intended to

shape institutions. Which is helpful in understanding the case we describe here can be a problem when it comes to more general questions of institutional change: Other forms of institutional change are neither recognized in the concept nor is the concept embedded in a larger frame which would allow for an analysis of institutional change on a broader scale.
The concept of institutional work – especially used in a form informed by structuration theory – does not imply that actors can freely and easily change whatever they want. They are bound by social as well as material constraints. Even if they have the necessary resources to engage in institutional work, the setting they act in is highly institutionalized and the outcome may be mainly unintended or even undesired. This results partly from the fact that institutional work always relies and is based on existing institutions. In our example, actors use existing institutions like conferences to influence the perception of technological options and their evaluation. While trying to change or influence some institutions, actors – maybe consciously, maybe not – reproduce and stabilize others.

The described usages of institutionalized practices are forms of powerful enactment (Weick 1995). By influencing expectations and actions, or by contributing to a technological bandwagon, groups of actors influence their environment by constructing a specific perspective and acting accordingly. Similar to a 'scientific bandwagon' (Fujimura 1988), after a period of time actors tend to rally around a specific development option because others have done the same (Abrahamson and Rosenkopf 1993). When support for one development option reaches a certain level, the overall tendency is for it to stabilize and gain even greater momentum. Hence, visions and fictitious descriptions of future technological milestones are first transformed into requirements, then realities, and finally attain the status of inevitabilities (Van Lente and Rip 1998). By putting descriptions of possible futures in writing, they become objectified. These documents and the "facts" they describe confront actors in the field as facilities outside of themselves. Part of this is the transmission of meaning and shared beliefs to parties who played no role in their construction, both inside the field and out. Following Berger and Luckmann, this is a crucial step in the creation of cultural and cognitive institutionalization (Berger and Luckmann 1967). Documents and proofs are created which seem to neutrally demonstrate which technological option is superior. The process of cultural and cognitive institutionalization is not only intertwined with processes of normative institutionalization and institutionalization of domination, but also recursively (re-)produced by knowledgeable agents in time-space.

Summing up, we conceive and observe political forms of institutional work in the semiconductor industry as a means to coordinate the organizational field in order to reduce uncertainty with regard to techno-material arrangements. In contrast to risks, we perceive uncertainty – in line with Knight (1921) and other critiques of probabilistic risk conceptions (e.g. Smithson 1989) – as a state in which not even subjective probabilities are available to evaluate future (in our case: technological) outcomes. In the quest for a novel dominant design in the semiconductor industry, uncertainty is highly prevalent, not only with regard to the technological outcomes and choices at stake, but also the economic implications and future changes in the semiconductor industry landscape. *Roadmapping* and *conference organizing* are two of the main practices of institutional work in this field to deal with this uncertainty and to generate a future which, at least partly, allows for the extension of Moore's Law. They do so by influencing the field's participants' perspective on and evaluation of potential technological options. After a discussion of our research methods, we describe these two practices in greater detail and analyze their contribution to the maintenance of the field's institutional life.

Research setting and methods

The case of the search for an NGL option in the semiconductor industry was selected for three reasons. First, this organizational field is currently characterized by a variety of actors collectively involved in the joint production of future technological options in semiconductor manufacturing. Different actors in North America, Asia, and Europe work to coordinate their efforts with the objective of continuing, extending or redirecting this highly dynamic development. Second, the selection, development, and introduction of a new manufacturing technology for computer chips, which we have been studying since 2003, and which is currently a key issue in this industry, serves as an excellent opportunity for the analysis of institutional work. Various companies try to influence, even to dominate, the industry by shaping institutions and ultimately implementing their preferred options. Third, this industry constitutes an intriguing object of study due to its economic importance for highly industrialized societies (Peters 2006).

Based on the assumption that strategic practices and institutional work can only be adequately interpreted through the perspective of the actors involved – be they individual or organiza-

tional actors –, we adopt an interpretative research methodology (Lincoln and Guba 1985). This methodology allows us to comprehend how expectations of future technologies are transformed into workable manufacturing solutions through the work of institution builders, not few of them scientists and engineers. We chose to conduct a longitudinal case study (Yin 2009), as this approach allowed us to generate novel insights as to the development of technologies over time and how actors in this respect engage in institutional work.

Data sources and data collection

Aside from an initial survey of secondary sources (e.g. scholarly and non-scholarly publications), four main data sources were used to analyze forms of coordinating fields and the role of institutional work in them. This allowed us to triangulate our sources as well as to prevent post hoc rationalizations (Lincoln and Guba, 1985). In addition, the approach chosen – especially triangulation through multiple sources and our prolonged engagement in the field – assisted us in avoiding misinterpretations of such complex social and technical dynamics.

Secondly, as of this publication, over one hundred semi-structured interviews related to the pursuit of NGL technologies were conducted with semiconductor industry experts and senior executives. We identified interviewees by theoretical sampling (Glaser and Strauss 1967, 45) and 'snowball sampling'. Initial contact partners were asked to identify other potential respondents involved in coordinating industry activities as well as the practices of roadmapping and conference organizing as these two focuses evolved in our research. This way, we were able to identify the relevant actors from within the field and to map their strategic positions in companies as well as the organizational field. This process converged into a set of key respondents whom we contacted and interviewed. The interviews were conducted during on-site visits or by telephone, and recorded and transcribed verbatim for subsequent analyses. Also, we conducted *follow-up interviews and e-mail correspondence* with key respondents as a form of member validation (Seale 1999). This inside perspective allows us to follow the delicate maneuverings and activities within the field as sets of developing practices, which are being recursively and reflexively re-produced by the actors.

Thirdly, an annual *panel* was implemented between 2007 and 2010. Experts with varying organizational and professional backgrounds and solid insights into the technological development process were interviewed on a more general scope of topics.

Fourthly, we used material from participant observation during on-site visits and in particular from conferences through both direct attendance (i.e. members of our research project attended relevant events from 2001 to 2011 (e.g. Fifth SEMATECH Workshop on Next Generation Lithography, International EUVL Symposium, SEMATECH LithoForum, SEMATECH Maskless Workshop, SEMICONWest, ITRS Public Spring and Summer Conferences) and the analysis of archival data such as conference presentations, slides, and public announcements related to the ITRS meetings. This approach proved particularly valuable insofar, as we were able to grasp the 'social microcosms' (Lampel and Meyer, 2008) more comprehensively as we were, for instance, able to observe firsthand the consensus making processes that serve to reduce uncertainty (e.g. voting at conferences). Moreover, attending a number of different venues sensitized us for how institutional work unfolded over time and space. What is more, impromptu interviews and informal conversations at these venues (e.g. during lunch) or offsite (e.g. at dinner receptions) enabled us to obtain information that might have been difficult to obtain in the course of formal interviews.

Finally, industry respondents were asked to comment on prior drafts of this study in order to enhance internal validity. We report only those results that were consistently validated by a large cross-section of interviewees and research experts.

Roadmapping and conference organizing as forms of institutional work

Roadmapping as well as conference organizing are concrete examples of institutional work which have three distinct properties: they are performed by a collectivity of actors, they are aimed at the level of the organizational field, and they are continuous efforts which try to maintain and adjust an existing socio-material order.. Though presented separately in the following considerations, the practices of institutional work as well as their different properties permanently comingle in praxis. Both examples represent collective activities aimed at coordination to organizational field of R&D in the semiconductor industry. We mainly focus on the ongoing activities of reflexively and recursively maintaining an existing order. Another option would be

to look at creating and establishing these practices in the first place, but we have chosen to look at the ongoing activities because they provide a good example of how an organizational field needs permanent maintenance. In addition we can show, how such activities of institutional maintenance always include aspects of institutional creation and disruption.

Roadmapping as institutional work

So far, roadmaps have frequently been researched in terms of their content as displaying future technological challenges (e.g. Galvin 1998; Lee et al. 2011). Less often explored is the way in which roadmaps are actually used in practice and how they are (re)produced as a strategic practice to coordinate R&D activities. In terms of institutional work, it is of course an interesting question of how such means of engaging the future and enabling cooperation are established within the field. For our proposed research question however, we will concentrate on their practical use of an established roadmapt in order to select a technologically feasible and economically viable technological solution by influencing the perception and evaluation of technological options by field participants.

The International Roadmap for Semiconductors (ITRS) is considered by far the most important roadmap of the semiconductor industry. Moreover, it is frequently cited as a role model for other industries and even the "mother" of all roadmaps (Probert and Radnor 2003). Yan Borodovsky, head of advanced lithography at Intel, highlights the relevance of roadmaps for the field:

> "Roadmaps are there to debate the Path. [The] Path to achieving those goals (roadmap) was, is and will be subject to unending debates as it reflects fundamental uncertainty of assessing risks to schedule and yields of ever more complex novel technologies over extending existing "tried and true" approaches beyond its originally defined limits in the absence of data" (Borodovsky 2006: 31).

The origins of this industry-wide roadmap can be traced to the National Technology Roadmap for Semiconductors (NTRS), which the U.S. semiconductor companies introduced in 1992 due to accelerating costs for research and development. After three editions (1992, 1994 and 1997),

the participant base of roadmap authors was broadened and the NTRS subsequently reformulated in 1999 by additional members from Europe and South East Asia, the product being the ITRS. Since its inauguration, the ITRS as a written artifact has been (re)produced on a yearly basis, published in even-numbered years as an update and in odd-numbered years as a full revision. The ITRS displays future technological milestones.[4] Its financial backing and development is globally ensured by industry associations, predominantly from North America (e.g. the Semiconductor Industry Association), Europe (e.g. the European Semiconductor Industry Association) and Asia (e.g. the Taiwan Industry Association), as well as by member organizations (e.g. IBM, Intel or Samsung), which contribute by providing information and sending members to meetings.

The (re)production of the roadmap artifact is ensured in the first place by a detailed and multi-level process of information collation that exhibits a clear division of labor. *Technology Working Groups* (TWG), in which specific aspects of current and future states are identified by delegates from the field are crucial in this process. Every TWG is formally responsible for the production of a specific chapter of the ITRS. Chapters address topics such as *Lithography*, *Process Integration*, *Metrology* or *Emerging Research Devices*. Participation in these TWGs is voluntary and formally open to all interested parties.[5] During the research and drafting process, key challenges, which are subsequently transformed into measureable output, are discussed by the relevant actors.

The cooperative efforts from the TWGs are continuously reviewed by the ITRS's executive committee, the so-called International Roadmap Committee (IRC), that "meets […] three times a year, so there's actually a lot of […] interchange there" (I-32). This body's objective is to

[4] Apart from the uncertainty deeply embedded in the practices of reformulating the ITRS, the ITRS is proactively constructed at a slower pace than that pursued by the organizations involved. Actors within the field have developed a pithy term for this 'misalignment': "Wall Street" (I-98) refers to the common practice of organizations involved deliberately slowing down the rate of ITRS-related technological milestones compared to their internal targets in order to appear more innovative and competitive, since they can then get ahead of the industry-wide formulated ITRS objectives.

[5] However, the TWG heads actually have the right to refuse interested parties if they are presumed unable to make an adequate contribution to the TWG. What is more, it is noteworthy that with the exception of one TWG, all TWGs – even since turning the NTRS into the ITRS – are led by representatives of US-American organizations.

maneuver among the different interests of the actors involved, thereby ensuring the outcome: "IRC members decide policy and set guidelines for the ITRS" (ITRS 2009).

The ITRS is crucial for the creation of an industry-wide consensus and for the shaping of the views and also activities of multiple and heterogeneous actors in the field. It entails a formally organized procedure for gathering, storing and disseminating information on technological progress as well as challenges and is used for strategically controlling this information. As a social practice, roadmapping reflexively and recursively ties the actors in the field into a collective effort, which in turn shapes the institutional set up of the field. This is not only true for the various participants in the process of the ITRS production but also for the manifold firms involved in the process of technology development along the value chain. Manufacturers and suppliers use the ITRS to orient their activities and act in accordance to its predictions and requirements. Besides the firms directly involved in the process of technology development also other actors utilize the ITRS to coordinate their activities, e.g. venture capitalists:

"The background here at [our venture capital organization] is that we make investments that also have a strategic purpose […] The Sematech Roadmap is, of course, important and it is important that we stand behind it, otherwise we would invest in the wrong companies" (I-63)

The positive evaluation of a technological option on the ITRS is an important aspect in the decision to fund a specific company. The institutional work found here first of all concerns changes in the rules of signification and legitimation, turning the ITRS into a central artifact within the field. In a second move, after the ITRS was acknowledged as a significant and legitimate local for technology development, it could be turned into a resource of domination by placing or removing technological options.[6]

Further, the ITRS itself is recursively and reflexively created and maintained as an institution in the process of technology development. This way, it is a central part of the field's (re)production, which is acknowledged in the ITRS itself:

> "The overall objective of the ITRS is to present industry-wide consensus on the "best current estimate" of the industry's research and development needs out to a 15-year horizon.

[6] Of course, also the specific roles and competencies of actors like the working groups and the Committee are constructed in the process. Like all actors, they are highly scripted (Meyer 2008). To analyze this in greater detail would lead to a different focus of the paper.

> As such, it provides a guide to the efforts of companies, universities, governments, and other research providers or funders. The ITRS has improved the quality of R&D investment decisions made at all levels and has helped channel research efforts to areas that most need research breakthroughs" (ITRS 2009: 1).

Two very different aspects are mentioned in this self-description. On one hand, the ITRS supposed to present an industry-wide consensus. On the other hand, it 'guides' and 'channels' research efforts. The ITRS not only focuses on sense-making and meaning constitution (Weick 1995); it is also an instrument of an inherently political character. 'Guiding' and 'channeling' contribute to the maintenance of the field's conditions of reproduction.

A member of one TWG at an ITRS meeting in spring 2011 told us that he and his TWG members usually face the option of communicating results in line with what they presume to be most likely in the future and with what they would like to be most likely in the future:

> "We always have this discussion about the roadmap: Is this only a projection how we expect the future to be or do we use the roadmap to shape the future? […] And of course different interests collide here – personal ones, company interests, the environment, group dynamics, everything at the same time. […] This time we have decided to define a direction". (I-)

Though the ITRS might prima facie seem to present a neutral display of options and beside the fact the process of roadmapping is highly institutionalized, the roadmapping process is actively influenced, especially by large organizations like Intel. The influence takes place in different ways: major players take part in all working groups relevant to their interests. In addition, they are key actors in the International Roadmap Committee. Such key actors also regularly make business announcements which influence the roadmapping of specific technological options.

An example of how the ITRS is used to "guide" and "channel" is the newly added section of the 2009 ITRS which deals exclusively with carbon-based technologies. For the 2009 roadmap, the International Roadmap Committee explicitly asked the two working groups Emerging Research Devices (ERD) and Emerging Research Materials (ERM) to make a suggestion as to which kind of technological options the industry should focus on in the future:

> "Finally, the ITRS' International Roadmap Committee (IRC), recognizing that it may be timely to accelerate development of one or two of the most promising proposals for well-defined new information processing devices, requested the Emerging Research Devices

> and Emerging Research Materials working groups to recommend one or two of the most promising emerging research device technologies for detailed roadmapping and accelerated development" (ITRS 2009: 9).

It becomes obvious, that the roadmap is not merely descriptive, it is actively used to coordinate, to channel, and to speed up specific technological developments. As a reaction to this request, both working groups, ERD and ERM, recommended one option: carbon-based nanoelectronics. As a result, these technologies and their potential are discussed in greater length in the 2009 ITRS. Elaborate plans for their development and implementation are presented in the roadmap; other options are not discussed in this form. It is important to note that even the new materials finally discussed in the ITRS – carbon based materials – do not fulfill the requirements normally applied to new technologies added to the ITRS. One of the TWGs members described this process:

> "So we looked at all [options] and actually the overall consensus was that none of them looked that promising. So no one said, look, we really want to put it in the ITRS. […] But we also felt like, but it is not like we don't have preferences here. […] Well the best thing is to put up the carbon electronics, seems to have a lot of good possibilities here. […] We realized, that all of this devices which we are looking at – for five or six years now – and none of them is fully ready to be part of the normal TWGs, but we get pressure from the main ITRS as well, to say, well, we understand that you are not ready, but we would like some guidance." (I-)

This explicit sponsoring of carbon-based devices is intended to create a momentum, which in the best case would turn out similar to a self-fulfilling prophecy. Actors enact the environment according to their descriptions of it. They are presented in a way which suggests, that they fulfill requirements for new technologies in the ITRS. This is more than likely to trigger an increase in research activities and might start a dynamic similar to a self-fulfilling prophecy – even though the technical challenges cannot be simply wished away. This way, new orientations are created and the field's overall direction (Moore's Law) is maintained, even if this increases uncertainty and marginalizes other options. In combination with the previously described use of the ITRS by venture capitalists to reduce uncertainty, it becomes apparent that

such a decision to favor one technological option can heavily influence the development of the industry.[7]

This example also shows how the practice of roadmapping is reflexively and recursively tied into the re-production of the organizational field. The actors judge their actions by the standards of the roadmap process and by the expected consequences. R&D efforts are not merely mapped by the ITRS, but are oriented towards its support in creating a certain future.

The creation of the ITRS is an elaborate form of institutional work in a highly institutionalized setting in which actors try to align the weight assigned to different technological options in the roadmap with their own strategic interests in order to contribute to the reflexive coordination of the field. Most actors in the field are aware of these different ITRS properties. Nevertheless, once the roadmap is published, it is widely perceived as at least partially binding and, moreover, communicated as being an allegedly 'objective' definition of the situation.

Conference organizing as institutional work

The organization of conferences is an equally institutionalized and strategic coordinative practice which contributes to the creation and maintenance the field's institutional life. Conferences as institutionalized events enable by far the largest gatherings of the industry's key actors and have an important signaling effect for the whole field.

Research on conferences (e.g. Zilber 2007), in particular studies that examine them as field-configuring events, mostly concentrates on the event itself (e.g. Montgomery and Oliver 2008). Much less attention has been paid to how events are planned and related to other ongoing activities, or to how conferences are socially embedded. This is necessary to adequately incorporate the interaction between organizations and the field in our analysis.[8] In those cases where multiple events are analyzed, the authors usually revert to quantitative database analyses involving

[7] However, simply putting a technological option onto the ITRS will not make it come true by itself. In current semiconductor technology development, extreme technical and financial challenges still have to be solved before the promise becomes production.

[8] Garud's (2008) account of the interconnected activities unfolding in the course of three conferences remains an exception in this regard.

unconnected events (e.g. Zollo 2009). In contrast, we address actors' repeated engagement in the organization of conferences as an ongoing practice.

There are different crucial conference series in the field of the semiconductor industry. Some series of conferences target a broad audience, for example the NGL community as a whole. Others cover a specific technological value chain like that of EUVL. As for NGL efforts, one of the important venues is the annual conference of the *Society of Photo-optical Instrumentation Engineers'* (SPIE), which is attended by all major players in the semiconductor industry. Though technological details may be dealt with more effectively at specialized conferences, SPIE is considered within the field to be crucial for creating momentum when it comes to a NGL. Another key conference series has been the *workshops on Next Generation Lithography*, which was specifically organized by SEMATECH to accelerate the decision-making process for NGL.

We claim that this construction of events is by no means driven by consensus, but – similar to roadmapping – a highly political process, where the outcome is claimed to be the 'objective' assessment of technological alternatives' potential. In their meaning and relevance, these events are actively constituted as such; they do not simply exist (Munir 2005; Hoffman and Ocasio 2001). Similar to intraorganizational meetings (Jarzabkowski and Seidl 2008), we perceive conference organizing as a strategic practice for the *creation* of field configuring events. Conferences are fine-grained and highly institutionalized organizational locales and practices. Conference organizing means to coordinate the interplay between key sessions and poster presentations, to select key note speakers and so on and to orchestrate all parts to create a convincing whole. The impact on the NGL community is ultimately influenced by the overall composition of conferences.

Conference organizing in the semiconductor industry follows an overarching choreography which – by using institutionalized practices – includes the creation and preservation of shared views and the abandonment of others. For this choreography, we identified the following seven elements:

First, conference organizing is characterized by meticulous reflexive planning. This concerns pre-planning and organization of the conferences, the organization of the venues as such as well as follow-up activities. As for the conferences described in this paper, the respective agenda was usually set by SEMATECH, whose representatives, also often based on the ITRS,

provided relevant input to the organizing committee or at least chose its members if the participants in question were not affiliated with a member organization of SEMATECH. SEMATECH (Semiconductor Research Technology) is the most important Consortium for technology development within the field. Industry consortia such as SEMATECH play a highly important role in the configuring of the semiconductor industry as an organizational field, maintaining its institutional life and focusing institutional work.[9] Prior to the meeting, a detailed agenda was developed concerning how the event should unfold and how presentations and accompanying discussions should be held. Institutionalized conference organizers exert significant influence this way. This can be seen from the decisions about the allocation of time slots. SEMATECH, the organizer of the conference had explicitly favored EUVL. This preferred technological option has regularly been allotted more time in the beginning of venues when the number of attendees usually is the highest. Also, physical spaces have often been chosen accordingly, i.e. scheduled for the main hall. For instance, at an important venue for the field, the Fifth SEMATECH Workshop on NGL in Pasadena in 2001, representatives of EUVL were scheduled to present and discuss their results for four hours in toto, whereas representatives advocating alternative technologies like *Electron Projection Lithography* were allotted 75 minutes (Möllering 2009). In a similar vein, e.g. at the EUVL Symposium in Prague in 2009 and other conferences, the allocation of presentation formats and physical space differed significantly. There, participants presented their research results in keynotes, regular presentations or in poster presentations. While the latter group displayed 118 posters in a small room, keynote speeches, in contrast, were held in a large conference hall accommodating up to 500 symposium attendees.

Second, and closely related to this more implicit ways of ascribing significance to selected technological options and the respective representatives involved, actors also explicitly and literally receive different labels. For example, at the Pasadena workshop, actors representing favored technological options were referred to as "technological champions", or they wore different name tags (e.g. "Keynote" vs. "Speaker"), as was the case at the SEMATECH Litho Form staged in New York in 2010.

[9] The same is also true for organizing conferences. We have discussed the importance of consortia in the semiconductor industry elsewhere (Sydow et al. 2012).

Third, organizing actors attempt to create an explicit consensus from the conference attendees in the form of an 'opinion poll' regarding the specific technological options involved in future trajectories. This was supposed to help to legitimize the path chosen, as all actors from the organizational field were able to voice their opinion in a purported unhindered and objectively informed manner based on the presentations and discussions at these venues. At this stage, however actors were more than likely already influenced by the specific staging of the venues. In order to account for impact of the conference, some conferences have a survey before and after the conference itself in order to make shifts in opinions visible.

Fourth, the survey's results are distributed in the course of the event and evaluated at its conclusion. It is noteworthy that the survey results are presented and interpreted by organizing committee members. For instance, at the Litho Forum 2010, the director of lithography of SEMATECH, Bryan Rice, who is an Intel assignee to SEMATECH, gave a speech discussing the results of the Litho Forum at the end of an exclusive dinner on the final conference evening. In contrast to conference presentations throughout the rest of the Litho Forum, there was no discussion time allotted for this speech. The lack of mobile microphones may also be seen as conditions preventing a spontaneous discussion. In this connection, EUV was allegedly 'obviously' declared the field's preferred technological option. However, this remark was flanked by sarcastic murmurings from a large part of the audience surrounding one member of the research team, as the participants did not appear to favor EUV as a NGL as much as the SEMATECH representative did.

Fifth, as a follow-up to the conferences, media coverage and documentation of the results corresponded with the survey results and the information and interpretations provided by the keynotes or technological champions. For example, for the NGL Workshop in Pasadena, an extensive online archive documents the conference events, materials, surveys and presentations.[10] Other venues have been subject to similar post-event treatment. For instance, in a presentation SEMATECH's director of lithography referred to the results of previous venues as a "clear mandate" by the industry for SEMATECH to pursue EUVL-related technological advancements. SEMATECH documents these proceedings in general and makes them – with a small time lag – publicly available via its online archives (SEMATECH 2010).

[10] www.sematech.org/meetings/archives/litho/ngl/20010829/, accessed 2011-05-05.

Sixth and closely related to the previous element of this form of institutional work, actors reverted to previous conferences and accompanying survey results in subsequent activities and statements. Later allusions were not only made to presentations and/or survey results, but also to the other key practice described here, that is, to the shaping of the ITRS, in effect linking both practices. Reverting to prior conferences is important insofar as it permits (re)interpretations of past results and the establishment of allegedly coherent line of reasoning.

Finally, every conference is part of a series of conferences and is embedded in the set of conferences taking place within the field. The institutional impact of conferences is constituted by the interplay of these sets of interrelated gatherings, which are used by strategically placed actors to filter and store information as previously described.

In effect, the described choreography enacts strategic guidance and orientation that the semiconductor industry creates in the pursuit of an NGL. Even more than the ITRS, the conferences are social and material locales of institutional work, where the allotment of time, space and visibility are elements a lager strategic maneuverings. Thus, conferences are able to influence the cognitive landscape of the field:

> "In addition to technical exchange, conferences are also important when it comes to creating a positive 'push'. There's excitement about breakthroughs demonstrated in different areas […] simply some positive press" (I-03).

To use Giddens' concepts, conferences are locales to exchange information, but they are also used to to qualitatively and quantitatively control information. Internal circulation of information is heavily imbued with the strategic intentions of influential actors (e.g., sponsoring organizations) trying to rally others to support specific technological options. Interviewees described for example the activities of actors promoting EUVL as the best NGL as follows:

> "They [the key actors] use all means at their disposal. They make sure that there are prominent keynote speakers at conferences who are pushing for EUV and they have no qualms about standing up and saying that all major issues have been resolved, that the industry just needs to implement the solutions. This makes people think: 'Great, we just need to do it and it will work'. But that is not true" (I-01).

Especially information is issued and manipulated specifically for external parties. Examples are summaries and final statements issued at conferences. They are presented as a reliable overview of the actual situation as to the future possibilities within the field. They are then used by

participants as well as by external parties as guidelines for further activities within the field and therefore reduce uncertainty concerning the variety of potential technological options. Conferences have long been part of the field's rules of signification and legitimation. As the main locales of gathering, they constitute a major aspect of the field's institutional life and likewise serve as central resources of domination. As we have shown, this requires constant institutional work, maintaining the conferences position within the field as well as meticulous planning of the setting, sometimes down to the absence of portable microphones in order to hamper open discussions.

Venues like the key conference SPIE simultaneously represent a locale in and a practice by which evaluation criteria for technological options are shaped on an industry-wide level, as industry actors use interpretative schemes that refer to the topics discussed at the conference, above all the technological options to be pursued. In other words, conferences serve as venues where interested actors reflexively disseminate information about activities and ascribe relevance to the specific technological options under discussion.

The impacts of roadmapping and onference organizing on the field

Even if described separately, as mentioned before, the practices of roadmapping and conference organizing are deeply intertwined in many different ways. The ITRS influences conferences, their structure, its course and the evaluation of its results. And the ITRS is influenced by conferences and the presentations given at them. Already the production and continuous update of the ITRS is ensured through a series of workshops dedicated to this task. In their combination, the different institutionalized practices constituting the ITRS and the different conference series are responsible for the development of shared perspectives on technology and practices of their creation and evaluation. By creating and circulating texts and documents – information collation, storage, and dissemination – in an institutionalized way, roadmapping especially contributes to the creation and maintenance of shared perspectives on the potential of different technological options and of evaluation criteria for new technologies in general. By doing so, at the same time it contributes to the disruption of other options and criteria.

In line with Giddens, these activities are aimed at selective 'information filtering', i.e. at reflexively regulating the field to reduce uncertainty and allow action in an institutionalized way. This becomes obvious in formal decision processes such as conference votes, which are often

conducted after choices have been made. Expectations about the future in general and the future development of certain technologies in particular induce specific activities concerning the realization of promising technologies, which in return influence expectations about future developments. In this way, expectations and activities become self-reinforcing, which leads actors to view their own participation in certain activities as necessary, and even mandatory. Yet, it is these very same activities which mandate their own execution, i.e. create the requirement to participate in them. As with self-fulfilling prophecies, at some point the expectation that certain developments will materialize in the future becomes rational – regardless of its originally ascribed rationality content. Roadmapping and conference organizing increase the momentum of a specific technological option: They shape the overall conditions of technology development by anchoring particular technology options and their evaluation within the organizational field. Actors attempt to implement future predictions and visions because they expect others to do the same and fear that they might fall behind if they do not concentrate their efforts toward developing what are perceived as strong technological options.

The irony of this process is not lost on its participants. One interviewee and a leading research consortium member succinctly formulated his viewpoint regarding roadmapping as follows:

> "Look, I think by and large when you look at it, I think it's a pretty successful process, apart from the fact that it's completely unable to predict anything" (I-32).

Even though these processes may arguably be completely ineffective when it comes to making accurate predictions – and, indeed, how could they? – they do enable collective coordination and action and, therefore, are crucial in terms of the reflexive self-regulation within the semiconductor field. Activities like roadmapping and conference organizing do not reduce uncertainty on a purely technological level. The technical options and obstacles stay the same. But they change the perspective on these options and increase commitment for some of these options while reducing it for others. Primarily, uncertainty is reduced on a purely cognitive level, but because people act based on this, this also influences the purely technological dimension. As mentioned in the beginning, "anticipative structures" (Van Lente and Rip 1998) are transformed into expectations which can probably lead to the realization of new technological options.

Conclusions and Directions

Roadmapping and conference organizing are essential forms of (re)producing the technology development in the field of semiconductor manufacturing. Both practices are crucial for the institutionalization of the field and are best understood as forms of institutional work (Lawrence and Suddaby 2006). Neo-institutional theory emphasizes the cognitive and normative dimensions of institutions (Meyer and Rowan 1977; Scott 2008), particularly the relevance of shared cognitive frames, schemes, and taken-for-granted assumptions. An important aspect of institutional work, hence, is the "socialization of new participants" (DiMaggio 1988: 13). Berger and Luckmann (1976) describe this as the third and final step (in their words 'internalization') in the creation and institutionalization of shared beliefs. The ITRS and conferences in the semiconductor industry are used exactly for this purpose. We have emphasized the fact that institutionalization in not merely a mental process, but one of collectively and strategically creating artifacts such as the ITRS and locales like the SPIE conference. Combined with a lack of regulation by states or state-like actors, coordination through roadmapping and conference organizing are primary forms of reproducing this field. These two practices serve selective information collation and control. When working collaboratively, strategically placed actors are able to reflexively coordinate the transnational field to some extent through these two practices. They shape the cognitive structure of the field's participants.

Our central argument is that roadmapping and conference organizing are forms of institutional work used to reduce uncertainty and to coordinate actions and relations among actors in an organizational field that lacks more direct forms of regulation.

Therefore both described practices are strategic forms of reflexive coordination, not aiming at the setting of formal rules, but at influencing cognitive and normative institutionalization and using concrete artifacts and settings. They are the medium and result of collective institutional work by groups of actors representing different organizations. The ongoing organization of conference series and meetings to adjust roadmaps, as well as the conferences and roadmaps as concrete entities, are keys to the constitution of *institutional life* in the semiconductor industry.

Thus, roadmapping and organizing conferences are to be understood as institutionalized as well as crucial practices of institutional work. Herein, we contribute to the literature as follows:

First, we have shown that maintaining specific forms of *institutional life* is a crucial factor in the industry's robust economic success and steady rates of innovation. This can be explained by the field's ability to adapt its internal regulation, the rules of signification and legitimation as well as the resources of domination according to the fast pace of complex technological developments.

Second, both the roadmap as an artifact and the conference as a specific event with a particular location in time-space are institutionalized themselves. Their immense impact results from the processes by which they are repeatedly organized and (re-)created. It is this combination of constitutive artifacts, institutionalized events and practices that facilitates the transnational reflexive coordination of the field.

Third, it turns out that the different aspects of institutional work – creation, maintenance and disruption – are inextricably interwoven and bound up with the material conditions of innovating complex technologies. As such they are separable only on an analytical level. Both roadmapping and conference organizing combine these three elements. To achieve a deeper understanding of institutional work it is therefore necessary to perceive all three aspects as a *single* process of structuration. For example, engineers actively involved in the production of the ITRS *create* institutions in the sense of industry-wide shared understandings, orientations and norms. But by doing so, they also *maintain* them by renewing and adjusting the data and overall orientation through an annually recurring procedure. In addition, continuous data adjustments and major chapter revisions result in the *disruption* of established views and norms.
In the same way, the reflexive organization of conferences, by creating events, and especially defining 'hot topics', keynote speakers, and so on, contributes to the creation and maintenance of a shared perspective of the industry's situation and future options and also the disruption of others. Information is filtered and controlled in an institutionalized way that is elemental for the reflexive coordination of the field.

On the *field level*, aspects of maintenance are expressed, for example, in the continuation of Moore's law. This "meta-narrative" (Zilber 2009), which is never seriously questioned, provides an important institutional basis for the reflexive coordination of the field. Only its actual implementation in concrete activities is examined and changed. Institutional work is aimed at

changing the field and its institutional structure in a way that allows for the continuation of technology development in accordance with the business models of the main field actors. When continuous improvement of manufacturing technology is no longer seen as viable, the whole supply chain is likely to be changed to maintain the basic industry dynamic. With both practices of institutional work, it is apparent that institutional creation, maintenance or disruption are *always* based on and interwoven with the two other aspects of institutional work.

Nevertheless, this distinction is useful for the analysis in at least two ways. First, one can analyze the relation of the three elements to characterize specific forms of institutional work. And second, even if all three forms are present in all instances of institutional work, different forms can be distinguished depending on if and to what degree one of the three aspects is dominant.

Forth, the level of the organizational field is a crucial for the analysis of complex technology development on a transnational scale (Hoffman 1999). Fields like NGL are based on a specific issue shared by all actors within the field. Such fields are areas of interorganizational cooperation, but also of conflicts and power struggles which (re-)produce field regulations. Field level activities such as roadmapping and conference organizing can bridge different levels: Activities of small groups of actors influence dynamics and structures at the field level – and vice versa. Strategic forms of institutional work like the ones discussed here are initiated to regulate the entire organizational field by influencing taken-for-granted assumptions, frames, schemes, etc. of all individual or organizational actors in the field.

Fifth, the search for new technological paths is an inherently political process: technology options are not only chosen based on technological criteria. They are also evaluated in terms of their influence on the structure of the field, for example how a certain technology might influence the structure of the supply chain or where competencies are located. *Domination* can be observed on at least two levels: Strategically placed actors with the necessary resources influence the field and the concrete usages of the institutionalized packages of actor-action relations, thus further stabilizing their own position(s). In other words: Already in the past, technologies have been refused and abandoned by actors because of competencies located with other companies in other regions.

REFERENCES

Abrahamson, E., & R. Rosenkopf 1993. Institutional and Competitive Bandwagons: Using mathematical modeling as a tool to explore innovation diffusion. The Academy of Management Review 18:487-517.

Ahrne, G., Brunsson, N. 2008. Meta-organizations. Cheltenham: Elgar.

Berger, P. L., and T. Luckmann. 1967. The social construction of reality: a treatise in the sociology of knowledge. London,: Penguin P.

Borodovsky, Y. 2006. Marching to the beat of Moore's Law. San Jose, SPIE Microlithography plenary talk slides. http://download.intel.com/technology/silicon/Yan_Borodovsky_ SPIE_2006.pdf.

Browning, L.D., Shetler, J.C. 2000. Sematech: Saving the U.S. semiconductor industry. College Station/Texas: A&M University Press.

Brunsson, N. 1982. "The Irrationality of Action and Action Rationality - Decisions, Ideologies and Organizational Actions." Journal of Management Studies 19:29-44.

DiMaggio, P. (1988): Interest and agency in institutional theory. In: Zucker, L. G. (ed.): Institutional patterns and organizations. Culture and environment. Cambridge: 3-21.

DiMaggio, P. J.; Powell, W. W. (1983): The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. In: American Sociological Review, 48: 147-160.

Dyer, J. H.; Nobeoka (2000): Creating and managing a high-performance knowledge-sharing network: the Toyota case. In: Strategic Management Journal, 21: 345-367.

Fujimura, J. H. (1988). "The molecular biological bandwagon in cancer research. Where social worlds meet." Social Problems 35(3): 261-283.

Galvin, R. (1998). Science Roadmaps. In: Science, 280(5365): 803-805.

Giddens, A. (1979). Central problems in social theory. Action, structure and contradictions in social analysis. Houndmills et al..

Giddens, A. 1984. The Constitution of Society: Outline of the Theory of Structuration. Cambridge: Polity Press.

Glaser, B. G. & Strauss, A. L. (1967). The discovery of grounded theory. Chicago: Aldine.

Gurvitch, G. (1958). Traité de Sociologie. Paris.

Hoffman, A. J. (1999): Institutional Evolution and Change: Environmentalism and the U.S. chemical industry. In: Academy of Management Journal, 42 (4): 351-371.

Hoffman, A. J., and W. Ocasio. 2001. "Not all events are attended equally: Toward a middle-range theory of industry attention to external events." Organization Science 12:414-434.

ITRS 2010. International technology roadmap for semiconductors. 2009 Edition. Executive summary. http://www.itrs.net/Links/2009ITRS/2009Chapters_2009Tables/ 2009_ExecSum.pdf, accessed 2010-01-18.

Jarzabkowski, P. 2008. Shaping Strategy as a Structuration Process. Academy of Management Journal, 51(4): 621-650.

Jarzabkowski, P., Seidl, D. 2008. The Role of Meetings in the Social Practice of Strategy. Organization Studies, 29(11): 1391-1426.

Jarzabkowski, P., Spee, A.P. 2009. Strategy-as-practice: A review and future directions for the field. International Journal of Management Reviews, 11(1): 69-95.

Knight, F.H. 1921. Risk, Uncertainty, and Profit. Boston: Houghton Mifflin.

Lampel, J., Meyer, A.D. 2008. Field-Configuring Events as Structuring Mechanisms: How Conferences, Ceremonies, and Trade Shows Constitute New Technologies, Industries, and Markets. Journal of Management Studies, 45(6): 1025-1035.

Lawrence, T. B.; Suddaby, R. (2006): Institutions and Institutional work. In: Clegg, S. R. (ed.): The Sage handbook of organization studies. London etc.: XXII, 215-245.

Lee, J.H.; Kim, H.; Phaal, R. (2011): An Analysis of Factors improving Technology Roadmap Credability: A Communication Theory Assessment of Roadmapping Processes. Technological Forecasting & Social Change, XXX.

Lente, H. v.; Rip, A. (1998): Expectations in Technological Developments: An Example of Prospective Structures to be Filled in by Agency. In: Disco, C. M., Barend van der (eds.): Getting new technologies together: studies in making sociotechnical order. New York: 203-229.
Lincoln, Y.S., Guba, E.G. 1985. Naturalistic Inquiry. Beverly Hills et al.: Sage.
Meyer, J.W. (2008): Reflections on Institutional Theories of Organization. In: Greenwood, R./Oliver, C./ Sahlin, K./Suddaby, R. (Hrsg.): Organizational Institutionalism. Los Angeles, London, New Dehli, Singapore, S. 790-811.
Meyer, J. W.; Rowan, B. (1977): Institutionalized Organizations: Formal Structures as Myth and Ceremony. In: American Journal of Sociology, 83: 340-363.
Meyer, U., and C. Schubert. 2007. "Integrating path dependency and path creation in a general understanding of path constitution. The role of agency and institutions in the stabilisation of technological innovations." Science, Technology and Innovation Studies 3:23-44.
Möllering, G. 2009. Market Constitution Analysis. A New Framework Applied to Solar Power Technology Markets. Max-Planck-Institut für Gesellschaftsforschung Working Paper, 09/7: Köln.
Moore, G. E. 1965. Cramming more components onto integrated circuits. Electronics, 38(8): 114-117.
Moore, Gordon E. 1996. Some personal perspectives on research in the semiconductor industry, in: Engines of Innovation. U.S. Industrial Research at the End of an Era. Richard S. Rosenbloom and William J. Spencer (eds.), 165-174. Boston: Harvard Business Press.
Munir, K. A. (2005): The Social Construction of Events: A Study of Institutional Change in the Photographic Field. In: Organization Studies, 26 (1): 93-112.
Nishiguchi, T.; A. Beaudet, A. (1998): Case Study: The Toyota Group and the Aisin Fire. In: Sloan Management Review: 49-59.
Peters, S. 2006. National Systems of Innovation: Creating High-Technology Industries. New York: Palgrave Macmillan.
Probert, D.R., Radnor, M. 2003. Frontier Experience from Industry-Academia Consortia. Research Technology Management, 46(2): 27.
Radnor, M., Probert, D.R. 2004. Viewing the Future. Research Technology Management, 47(2): 25-26.
Scott, W. R. (2008): Institutions and organizations: ideas and interests. Los Angeles.
Seale, C. 1999. The Quality of Qualitative Research. London et al.: Sage.
SEMATECH 2005. Resists Named Top EUVL Challenge at Symposium Co-Sponsored by SEMATECH, http://www.sematech.org/corporate/news/releases/20051220.htm, accessed 2010-09-22.
SEMATECH 2010. Proceedings Archives. http://www.sematech.org/meetings/archives.htm. accessed 2010-09-22.
Smithson, M. 1989. Ignorance and Uncertainty. New York: Springer.
SPIE 2008. Conferences + Exhibitions. http://spie.org/x306.xml, accessed 2008-12-15.
Strulik, T. 2001. Governance globalisierter Finanzmärkte. Pp. 301-326 in Steuerung von Netzwerken. Konzepte und Praktiken, edited by Sydow, J.; Windeler, A., Opladen.
Sydow, J., A. Windeler, et al. (2012). "Organizing R&D consortia for path creation and extension. The case of semiconductor manufacturing technologies." Organization Studies 33(7): 907-936.
Weick, K. E. 1995. Sensemaking in organizations. Thousand Oaks: Sage Publ.
Windeler, A., & Sydow, J. 2001. Project Networks and Changing Industry Practices - Collaborative Production in the German Television Industry. Organization Studies, 22(6): 1035-1060.
Wooten, M., and A. J. Hoffman. 2008. "Organizational Fields: Past, Present and Future." Pp. xviii, 822 p. in The SAGE handbook of organizational institutionalism, edited by Royston Greenwood, Christine Oliver, Kerstin Sahlin, and Roy Suddaby. Los Angeles; London: SAGE Publications.
Yin, R. K. 2009. Case Study Research. 4th eds. Thousand Oaks et al.: Sage.
Zilber, T.B. 2007. Stories and the Discursive Dynamics of Institutional Entrepreneurship: The Case of Israeli High-tech after the Bubble. Organization Studies, 28(7): 1035-1054.
Zilber, T. B. 2009. "Institutional maintenance as narrative acts." Pp. 205-235 in Institutional work: actors and agency in institutional studies of organization, edited by Thomas B. Lawrence, Roy Suddaby, and Bernard Leca. Cambridge; New York: Cambridge University Press.