Open innovation at the interorganizational network level – Collaborative practices in a semiconductor industry consortium

Gordon Müller-Seitz[a]*, Jörg Sydow[a]

[a] Dept of Management, School of Business & Economics, Freie Universität Berlin,

Boltzmannstr. 20, 14195 Berlin, Germany

*Corresponding author. Tel.: +49 30 83856359, fax: +49 30 83856808

E-mail address: gordon.mueller-seitz@fu-berlin.de

ACKNOWLEDGEMENTS

Earlier versions of this paper were presented at the 2011 R&D Management Conference in Norrköping, Sweden, at the 2011 EGOS Colloquium in Gothenburg, Sweden, and at the 2011 Academy of Management Meeting in San Antonio, Texas, where this paper was accepted for the Best Paper Proceedings. We are grateful for the financial support of the Volkswagen Foundation under grant AZ II/80308 and the German Research Foundation (DFG) under grant MU 3070/1-1, as well as for helpful feedback from participants at the venues mentioned. Moreover, we thank Joe Lampel and Frank Piller for helpful advice while preparing this manuscript.

Abstract

Previous open innovation research and practice primarily adopts the perspective of single firms. However, what remains surprisingly unexplored is a phenomenon common in the innovation literature, i.e. networks of three or more organizations. Against this background we shift the unit of analysis and explore how open innovation is managed by a well-known interorganizational network, the SEMATECH consortium. We report how open innovation in this volatile industry is handled at the network level by illustrating how SEMATECH is confronted with a paradox: while exploiting existing technological paths by means of well-established practices, novel and yet unknown future technological landscapes need to be screened and opened up in parallel, even though the necessary expertise is still lacking. Based upon a longitudinal case study, we reveal how the SEMATECH network reconciles contradictory technological demands by its members via the stretching practice of partnering; that is, selectively but repeatedly engaging with different presently and potentially in the future relevant organizational actors to manage technological uncertainty. By identifying a set of collaborative practices that serve to 'stretch' previously successful network activities with different partners on a consensual basis, we contribute to the debate on open innovation on the network level of analysis.

Keywords: open innovation; interorganizational networks; consensual practices; stretching; semiconductor industry

1. Introduction

Ever since Chesbrough (2003) introduced the notion of open innovation, collaborating with external partners – as opposed to closed innovations pursued internally within an organization – to generate innovations has been at the top of the agenda for many firms (Chesbrough, 2003; Chesbrough et al., 2006; Gassmann et al., 2010). One of the key reasons for the broad diffusion of this conception is that the vast majority of publications stress the benefits of open innovation, highlighting the opportunity, among others, to reach out to ideas external to an organization and to reduce development costs and risks (Chesbrough, 2003; Lichtenthaler, 2011). A wide range of sources for such external ideas and collaboration partners has been analyzed, including users, in particular lead users, suppliers, venture capitalists or even competitors (e.g. Enkel et al., 2005; Gassmann and Reepmeyer, 2005; von Hippel, 1986), making the concept applicable to a broad range of levels of analysis and sectors. Bearing these findings in mind, previous open innovation research has advanced our understanding of how organizations can engage with external partners.

Given this observation, it is surprising that interorganizational networks (networks for short) – understood here as three or more organizations undertaking joint activities and constantly pursuing realigned objectives (Grabher and Powell, 2004; Powell et al., 1996; Provan et al., 2007) – are seldom taken into account. This is surprising, given that networks represent a common phenomenon for innovation management (Gassmann et al., 2010; Gomes-Casseres, 1996; Maula et al., 2006; Powell and Grodal, 2005; Vanhaverbeke, 2006; Vanhaverbeke and Cloodt, 2006; West et al., 2006) and are even considered *the* locus of innovation in some industries (Powell et al., 1996). If networks are analyzed at all from an open innovation perspective in line with Chesbrough's (2003) initial conception, the focus frequently lies on how a single organization can benefit from engaging in these networks or systemic innovation contexts (Chesbrough and Rosenbloom, 2002; Dittrich et al., 2007;

Dittrich and Duysters, 2007; Enkel, 2010; Maula et al., 2006; Powell et al., 1999). In this regard, previous research on networks – though not necessarily geared towards the open innovation discourse – has shed light primarily upon constellations led by a “platform leader” (Gawer and Cusumano, 2002; Perrons, 2009), a “hub firm” (Jarillo, 1988), or a “network orchestrator” (Dhanaraj and Parkhe, 2006). Despite widespread network leadership (Müller-Seitz, 2012), such networks, including innovation networks, do not have hierarchic structures, i.e. no single organization can exert hierarchical fiat. This appertains in particular to situations where network partners pursue different (in our case: technological) innovations (Roelofsen et al., 2011). Therefore, the management of interorganizational networks represents an important challenge for open innovation management. Hence analyzing the management of innovation networks at the network level of analysis (Provan et al., 2007) appears timely and relevant for open innovation management practitioners and academics alike (e.g. Gassmann et al., 2010; Vanhaverbeke, 2006; West et al., 2006). It is against this background that the present study is guided by the following explorative research question:

How do networks manage open innovation concerning the pursuit of differing technological innovations?

In order to answer this, in our phenomenon-driven research we elucidate the way in which a key innovation network in the semiconductor industry, the SEMATECH consortium (Browning and Shetler, 2000), deals with technological uncertainty. Based upon a longitudinal case study of this network’s effort to agree upon common research and business agendas, we introduce the concept of stretching practices. We conceive a practice to be an intentionally pursued yet not entirely controllable, recurring social activity that is relatively stable across time-space (Giddens, 1984). The possibility of disposing of the ‘stretched’ character of such activities points to the observation that sometimes actors pursue at least two differing activities that deal with conflicting demands (cf. in a similar vein: Sitkin et al., 2011). In SEMATECH, stretching practices help the network to cope with the contradictory demands of the different network members as well as the foreseeable end of conventional scaling techniques (the so-called Complementary Metal-Oxide-Semiconductor or CMOS for short). At the same time the network and its members need to identify an unknown future technological landscape that will replace the existing CMOS path (often labeled Beyond CMOS). While SEMATECH and its members intend to retain their current dominant industry position, stretching practices between the CMOS and Beyond CMOS arenas become important.

Herein we contribute to the literature on open innovation by genuinely taking the role of interorganizational networks for open innovation into account. More precisely, we shed light upon how innovation networks are managed at the network level of analysis. Closely related, we introduce collaborative practices, refining existing research by highlighting the limits of (re)producing strategic technological uncertainty-related actions within them. The stretching practice of partnering – understood here as selectively engaging with different present and potentially in-the-future-relevant organizational actors – helps networks like SEMATECH to maneuver the conflicting network members' demands to pursue diverging technological options.

The remainder of this paper is structured as follows: we start by positioning our study in the literature on open innovation and how organizational actors deal with technological uncertainty. Subsequently, we introduce our research setting, the global semiconductor industry, and within it the SEMATECH network. Then we delineate our longitudinal explorative case study approach before we present our findings, culminating in a conception of rather consensual stretching practices as simultaneously pursuing differing technological innovations. We conclude by suggesting that the conception of stretching practices not only bears relevance to this semiconductor industry network but is also applicable to other science-based, volatile industries, and by delineating areas for future research ensuing from the limitations of this study.

2. Theoretical background

2.1 Moving beyond the intraorganizational Open Innovation domain

While firm innovations were traditionally pursued by organizations internally, more recent evidence shows that firms rely upon external sources to generate innovations. It is against this background that Chesbrough (2003) coined the term “Open Innovation” to signify a more collaborative approach for pursuing innovations. Following his seminal publication, a large number of studies has confirmed his findings in different sectors and settings (e.g. Chesbrough and Crowther, 2006; Chesbrough et al., 2006; Enkel et al., 2005; Gassmann and Reepmeyer, 2005; Lichtenthaler, 2011) and the theme has gained increasing attention in managerial practice and academia.

One of the key assumptions of open innovation is that “knowledge has become widely diffused” (Chesbrough, 2003: xxix) allowing companies to “rely on external sources to do the job effectively” (Chesbrough, 2003: 49). Though some studies also elaborate upon the challenges and limits of open innovation (e.g. Laursen and Salter, 2006; van de Vrande et al., 2009; West et al., 2006), the vast majority of publications stress the benefits for firms engaging in open innovation, as they are able, among other things, to reduce the costs and risks associated with research and development or launching products in shorter periods of time (Chesbrough, 2003); an aspect meriting particular attention in highly volatile environments (Brown and Eisenhardt, 1998).

While previous research has primarily contributed to our comprehension of open innovation management from the perspective of a single firm interacting with external partners (e.g. Lichtenthaler, 2011; Vanhaverbeke, 2006; West et al., 2006), how open innovation management unfolds at the level of networks remains by and large unexplored. In this paper we focus upon networks of three or more organizations undertaking joint activities and constantly pursuing realigned objectives (Provan et al., 2007). The scarcity of research on this phenomenon is surprising, as their importance has been highlighted across many disciplines and settings (Gomes-Casseres, 1996; Powell and Grodal, 2005; Powell et al., 1996; cf. for exceptions from an open innovation perspective: Enkel, 2010; Gassmann et al., 2010; Vanhaverbeke, 2006; Vanhaverbeke and Cloodt, 2006; West, Vanhaverbeke and Chesbrough, 2006). If networks are observed from an open innovation perspective, the focus still lies in effect upon the single organization, concentrating upon how an organization can benefit from engaging in these networks or more comprehensive innovation contexts (Maula et al., 2006). For instance, Enkel's (2010) study of a European research network explores the personal and organizational attributes required to benefit from engaging in an interorganizational network. Along similar lines, previous research has explained intraorganizational change processes as a result of engaging in networks with differing partners (e.g. Chiaroni et al., 2010, for the case of four Italian firms in different industries; Dittrich and Duysters, 2007, for the case of Nokia; or Dittrich et al., 2007, for the case of IBM).

In this regard previous research on networks has shed light primarily upon the lead firms of the respective networks, labeling these organizations "platform leaders" (Gawer and Cusumano, 2002; Perrons, 2009), "strategic center" (Lorenzoni and Baden-Fuller, 1995) or "network orchestrator" (Dhanaraj and Parkhe, 2006). As empirical evidence, these studies revert by and large to large scale organizations like IBM (Dittrich et al., 2007), and Japanese keiretsu like Toyota (Dyer and Nobeoka, 2000) or Nokia (Dittrich and Duysters, 2007). However, networks are not necessarily hierarchic in nature (i.e. led by a single firm), but they might also be more heterarchic in nature where no single organization can exert power as is possible organization-internally, and consensus is needed to pursue future technologies (Powell et al., 1996; Roelofsen et al., 2011). Though not only focusing upon innovation networks as defined above, Gomes-Casseres (1996) underscores our core idea when he discusses the competition across groups of organizations and the need to manage these groups cautiously, resembling our idea of open innovation management on the network level of analysis. Thus, the management of innovation networks represents an important challenge to achieve as many mutual benefits for the network and its members as possible. Hence analyzing the management of networks at the network level of analysis (Provan et al., 2007) appears timely and relevant for open innovation management practitioners and academics alike (e.g. Gassmann et al., 2010; Maula et al., 2006; Vanhaverbeke, 2006; West et al., 2006).

2.2 A practice perspective on dealing with technological uncertainty

In order to analyze how organizational actors actually practice technological uncertainty in networks, which is omnipresent in most innovation contexts and particularly prevalent in science-based industries like the manufacturing of semiconductors, we anchor our study in recent research on practice-based phenomena and organizing activities (Whittington, 2011). In line with Giddens (1984) structuration theory, we perceive *practices* to be ordered, recurring social activities that are relatively stable in time-space and do not represent single and isolated occurrences, but are part of an ongoing stream of activities in a particular context. The major advantage of such a practice conception is that it allows us to consider (re)produced social activities (here: uncertainty practices) and, in particular, to focus on practice-immanent dynamics and contradictions (which are particularly relevant to stretching practices) rather than on stability and equilibrium. This approach makes our study commensurable with other studies that have also applied Giddens' conception to organizations and network settings (Sydow and Windeler, 1998; Whittington, 2011).

In connection with practicing uncertainty, it is noteworthy that Giddens (1984: 5-14) presumed that the practices of agents like organizations or networks are routinized to a large extent and, as routines, considered to be rooted in the practical rather than the discursive consciousness. Only if triggered by an unexpected event or problem or the intervention of a third party is the routine character of practices likely to be questioned, and consequently the issue brought into the discursive realm (here: pursuing practices concerning CMOS and in particular Beyond CMOS).

As pointed out, semiconductor industry actors are faced with the challenge to invest in technologies related to the CMOS and Beyond CMOS arenas at the same time, each of which is imbued with technological uncertainty. Therefore, uncertainty in the semiconductor industry is the raison d'être for the stretching practices of SEMATECH, its members and other actors from the industry. Herein, our conception disposes of parallels to the intraorganizational approaches of March (1991; cf. also Enkel and Gassmann, 2010) with regard to exploitation (here: concerning CMOS) and exploration (here: regarding Beyond CMOS) as well as more recent notions of ambidexterity (Tushman and O'Reilly, 1996; cf. Simsek, 2009, for a review and Schreyögg and Sydow, 2010, for a critical assessment), the latter comprehended as skillfully pursuing both exploitation and exploration. However, informed by a structuration theoretical interpretation of practices, we assume a middle ground between the more individual behavior-oriented and the more structure-oriented conceptions geared towards ambidexterity.

The term 'stretching' has been employed elsewhere with different connotations. Perhaps closest to our conception is that of strategy as stretch (Hamel and Prahalad, 1993), although the authors relate to the differences between resources and goals rather than, as in our case, between differing goals. O'Mahony and Bechky (2006) also make use of the term when they refer to individual career aspirations in terms of bridging existing competencies to extend them into new areas. Also noteworthy are Sitkin et al. (2011), who focus upon stretch goals, understood as not necessarily two or more differing objectives, but future conditions that are difficult to obtain. Our notion of stretching practices is quite similar, but differs as the key interest is in two competing – and in particular with regard to the Beyond CMOS realm – yet unknown and ever evolving objectives, rather than already known and clearly specifiable objectives.

3. Research context and methods

The *semiconductor industry* was selected as the setting of this study because it is characterized by both a dominance of innovation networks (Browning and Shetler, 2000) and an extremely high degree of technological uncertainty. The latter stems mainly from the inability to predict which technologies – and accompanying organizational actors – will succeed the current CMOS-related technology path, i.e. the arena typically referred to as Beyond CMOS.

At present, the organizations from the semiconductor industry are investing in improving the efficiency of current CMOS technologies – labeled 'scaling' and referring to Moore's (1965) law that states that the number of transistors that can be placed on an integrated circuit doubles approximately every 18 months. Although this development is definitively plagued by technological and organizational uncertainties, it is not at all comparable in this respect with the currently envisaged Beyond CMOS alternatives, which question almost every technological aspect that is known from CMOS technologies and, in consequence, also the current activities of SEMATECH and the member composition itself. Moreover, the actors involved – in particular those engaging substantially in both arenas, like SEMATECH – desperately watch out to maintain their current dominant CMOS-related position in the industry and fear becoming obsolete or at least marginalized due to as yet unforeseen changes in the technological landscape concerning Beyond CMOS. Therefore, they engage in partnering to reduce technological uncertainty.

The originally U.S.-born *SEMATECH* consortium is of outstanding importance for the industry, as its organizational members now represent around 50% of the worldwide production output. SEMATECH represents an innovation network that can be described as being a ‘whole network’ (Provan et al., 2007), as the members are linked to one another by being enrolled at SEMATECH, by maintaining multi-lateral relationships, and by utilizing the same pre-competitive testing facilities as other consorts; that is, they have reflexively agreed upon an interorganizational division of labor and cooperation (Browning and Shetler, 2000). The operations are continuously conducted on a global scale, as now half of the currently 13 SEMATECH member organizations are from the U.S. and the other half from South East Asia; while 12 of them are for-profit firms and one is a public research institute. As we will show, one of the key challenges SEMATECH faces is the continuation of open innovation activities among SEMATECH members, which is ensured by a variety of joint activities geared towards the migration from CMOS to Beyond CMOS-related technological options.

Since its inception in 1987 SEMATECH has “needed consensus on its structure from [then] all fourteen members” (Browning and Shetler, 2000: 32) and “freedom from internal domination by a single company” (Browning and Shetler, 2000: 79). The members are linked to each other formally by being enrolled at SEMATECH and actually by coordinating pre-competitive research and development activities and by utilizing the same testing facilities. The heterarchical character of this network is embodied first and foremost in the ‘One member one vote rule’ (Spencer and Grindley, 1993). Therefore, decisions about and allocations of the annual budget of approximately U.S. $ 140 million are made on a consensus-basis or, in the case of disagreements and deadlocks (resulting from the ‘one member one vote rule’), ‘favors’ are reciprocated (Browning et al., 1995).

Since we employ structuration theory to analyze stretching practices, we adopt an interpretative research methodology that allows us to capture practices from the respondents' perspective (Sydow and Windeler, 1998). Such a methodology is, moreover, most appropriate for exploring a phenomenon that, like uncertainty-related practices in innovation networks, is understudied and dynamic by nature. A longitudinal case-study approach was chosen, as this allows us to generate novel insights into how stretching practices are enacted over time (Yin, 2009). Subsequent to pre-studies in optical technologies that sensitized us to the challenges that the semiconductor industry is facing, our present study is part of two projects (2004-2010, completed, and 2010-2013, ongoing) into the way complex system technologies are extended and created in the semiconductor industry with the help of networks in search of novel manufacturing technologies. Such an approach is indispensable in any analysis of social practices as recurrent activities that are enabled and constrained by structures and contribute to either the (re)production or transformation of those very structures over time (Giddens, 1984).

3.1 Data collection

Our data has been collected to cover a 23-year period since the inception of SEMATECH in 1987, 16 years of which (1987–2003) were retrospective and seven years of which (since 2004) have been in 'real-time'. Apart from initial data collection from secondary sources (e.g. scholarly and non-scholarly publications), four main sources were utilized for triangulation purposes in order to heighten construct validity, as well as preventing post-hoc rationalization and potential biases (Yin, 2009).

INSERT TABLE I ABOUT HERE

First, we analyzed a broad range of field documents (Table I). Such data as a form of secondary data are deemed to be useful, as they allow a reconstruction of practices employed on different levels of analysis and from multiple angles; here, the network and field levels of analysis.

Secondly, to date 136 semi-structured interviews have been conducted with semiconductor industry experts as well as with senior executives in Europe, the U.S. and Japan. Among them were representatives from SEMATECH (54), suppliers (35), chip manufacturers (17) and other consortia (8), as well as senior civil servants (6), representatives of research laboratories (10) and consultants (1). At first, we identified interviewees by 'snowball sampling' and initial contact partners were asked to identify other potential respondents relevant in practicing uncertainty concerning CMOS and Beyond CMOS. This process converged into a set of key respondents that we contacted and interviewed. The interviews took place primarily during on-site visits, and were recorded and transcribed verbatim for subsequent analyses. Except for seven, all interviews were conducted by at least two members of the research team, allowing us to benefit from more adequate information gathering and recollection after the interview took place. Each interview (on average: 60-90 minutes) was based on an interview guideline supplemented by follow-up and clarifying questions. The interviews were divided into themes geared towards developing future technological options and the way interactions are managed, both formally and informally, at SEMATECH. While we concentrated throughout the first 90 interviews upon the way SEMATECH and the industry are engaged in innovating a new technological path, Extreme Ultraviolet Lithography (EUV for short; which is still CMOS-related), the focus of the later interviews was geared increasingly towards what lies Beyond CMOS as it started to become increasingly important for SEMATECH throughout the course of our projects. This led in effect to refining the focus of this study and culminated in the stretching practices identified, which address both CMOS and Beyond CMOS-related technologies.

Thirdly, an annual panel was used between 2007 and 2010. Five semiconductor industry experts were interviewed with the help of an interview guideline that contained, by and large, the same content as that of the semi-structured interviews. Four of the panellists are members of SEMATECH.

Fourthly, we draw extensively upon material from participant observation during on-site visits and in particular from conferences, in the latter case both from participating at conferences (by members of the research project in 2001, 2005, 2009–2011) and by analyzing archival data like conference presentations and public announcements around these meetings (cf. also Table I). This is in line with Giddens' (1984) view on conducting field research, as attending such public conferences serves to strengthen the validity of our claims by formal and informal conversations and data gathering (e.g. roster listings, conference slides) in the course of such venues (Lampel and Meyer, 2008). Hereby, we were able to conduct an additional 15 impromptu interviews, which were between 5 and 60 minutes in length and were not transcribed. In order to capture most of the impressions adequately, as suggested by Yin (2009), extensive notes were taken and results were discussed with members of the project within 24 hours after the visit in each case. Finally, we conducted follow-up interviews and e-mail correspondence with key respondents as a form of member validation (Yin, 2009).

3.2 Data analysis

Although our data analysis did not occur in a linear fashion, it can be roughly divided into the following three stages: in the first stage we collected all data in a case study database to heighten reliability (Yin, 2009), whereby our analysis is based upon the 'raw data' of 150 pages of field notes, 1,934 pages of interview transcripts, and roughly triple the amount of archival (including media coverage, both by online journals and trade periodicals via the LexisNexis database) as well as conference data (e.g. SEMATECH hosted conference presentation slides). Written comments and reports were compiled on SEMATECH and its members, as well as on the practices pursued in the field to engage in open innovation. Cyclical rereading formed a basis for comprehending the way future technological options are evaluated and pursued and, in effect, SEMATECH's uncertainty practices are initiated and executed.

Stage two consisted of writing up condensed descriptions of how the uncertainty practices are enacted within SEMATECH. The resulting detailed descriptions were discussed by the research team, sensitizing us to the way in which SEMATECH practices uncertainty. Throughout the course of this, partnering as a stretching practice became manifest as the decisive practice to manage technological uncertainty.

INSERT FIGURE 1 ABOUT HERE

In stage three we condensed our empirical data. For this purpose we converted all 'raw data' for a combined analysis in atlas.ti, a software program for analyzing qualitative data. Figure 1 depicts the emergent data structure. Initial coding resulted in first-order categories observed or offered in vivo by informants. At first, some observations were placed in multiple categories to allow for a rich interpretation of data. In what followed we constructed mutually exclusive second-order themes and grouped them hierarchically, which led to the collapse of first-order categories into second-order themes that represent researcher-induced interpretations. Then we identified the stretching character conceptually, acknowledging the complexity of the different practices. For instance, we collected information about roadmapping and realized that this practice serves both CMOS and Beyond CMOS-related efforts. Thereafter, the second-order themes were subsumed under the third-order themes that represent partnering.

For construct validity purposes, the analytical themes were reviewed by key informants in the course of re-entering the field parallel to the three stages. By means of conducting focused interviews, ambiguities in our comprehension of practicing uncertainty were resolved. When these practices were clarified as an overarching analytical framework of stretching practices, we compared our results with previous open innovation research to highlight similarities (e.g. the role of networks, Vanhaverbeke, 2006; West et al., 2006) and differences (e.g. analyzing open innovation at the network level of analysis), which strengthened the internal validity of our findings and served to match data and theory.

INSERT TABLE II ABOUT HERE

Table II shows examples from different sources, from which we identified and verified the theme of partnering as a stretching practice. It is worth noting that only those perspectives were integrated that were shared by interviewees with differing types of occupation and hierarchical levels in order to strengthen the internal validity of our claims (Yin, 2009). Despite our efforts to conduct this research as rigorously as possible, we are fully aware that we reduce the complex reality to what seems inter-subjectively consistent to our interviewees and to us.

4. Practicing uncertainty by means of stretching practices

4.1 Partnering as a stretching practice in the face of technological uncertainty

Our analysis suggests that the key practice relevant in terms of open innovation at the network level of analysis concerning the SEMATECH network and its members is that of *partnering*. While partnering is characteristic of any network, we comprehend it as a *stretching* practice only when it implies engaging recurrently with fellow actors from the existing “organizational field” (DiMaggio and Powell, 1983) while *at the same time* attempting to collaborate with actors from beyond the present industry who may be potentially relevant in the future. The latter activity is pursued in order to identify potentially relevant organizations with complementary expertise and collaborate with them regarding the Beyond CMOS technologies, which is why our analysis concentrates upon the network levels of analysis. This practice is of chief importance for SEMATECH members as they attempt to maintain their leading role within the existing organizational and/or technological field, while at the same time trying to defend their impact in face of the uncertain composition of the future industry – due to as yet unknown technologies and industry actors.

INSERT FIGURE 2 ABOUT HERE

Thus, we use the term stretching practice to highlight two aspects (cf. Figure 2): first, to denote the mindful parallel pursuit of two or more (here: two technological) options by means of a recurring social activity (here: partnering); secondly, to sensitize to possible overstretching.

The stretching is manifest in exploiting an existing established practice concerning comparatively well-understood options in more familiar contexts (here: CMOS). A Vice

President of SEMATECH mentioned in this regard that the network's and also industry's conservatism is manifest in the saying 'Don't change something until it's broken' (I-103). At the very same time, most actors strive to refine the established practices in order to bypass a lack of capabilities or capacity that is needed and aspired to concerning alternative (here: technological) options that are highly imbued with technological uncertainty and deemed relevant to the future at present (here: Beyond CMOS). Such leveraging is aimed for in order to take advantage of capabilities and capacities accumulated in the established and comparatively well-understood domain. The management of this kind of technological uncertainties is complemented by exploring one or more radical, much less understood alternatives, in the case under scrutiny the technology that addresses Beyond CMOS. An Intel CEO put it succinctly as follows:

> The philosophy has always been twofold: one is, you continue to run at 400 km/h towards […] the end of scaling, you don't slow down, you continue to run. And then in parallel to that you invest in, well what would be the options beyond the CMOS transistor? (I-115)

As for Beyond CMOS this 'unknownness' is aggravated, as there is not even a set of economically and technically attractive technological options on the different layers discernible at this point in time.

Second, and alluding to the metaphorical meaning of stretching, the actors pursuing this practice might be in danger of 'overstretching' their capabilities or capacities while pursuing two or more separate (here: technological) options that each require substantial resources – here in terms of financial capital, technological expertise, and relationships.

INSERT FIGURE 3 ABOUT HERE

Although the network and its members successfully collaborate concerning the comparatively well-understood CMOS technology path, the actors are aware that this path is very likely, even in the face of successfully extending past technological paths, to reach its physical limits, as an end to scaling is conceivable (I-120). Thus, at the same time the SEMATECH members need to pursue alternative technological options concerning the Beyond CMOS arena, indicated by the grey arrow. This appears inevitable due to the limits of scaling with regard to CMOS, but the Beyond CMOS technological landscape is even more highly imbued with technological uncertainty, as the organizations producing the potentially relevant technological options are neither fully understood nor prioritized with regard to their economic attractiveness. Therefore, SEMATECH engages extensively in partnering, including the screening and influencing of the existing industry, in order to maintain its dominant position in the future regarding the Beyond CMOS technological landscape.

4.2 Partnering as comprising a set of stretching sub-practices

We focus on partnering as an abstract category comprising a set of diverse sub-practices as it is attributable to SEMATECH. We are aware that there are other options for dealing with technological uncertainty. However, in this paper we restrict our analysis to those stretching practices that bear most relevance for the SEMATECH network on the network level, based upon our respondents' perspectives. Table III offers an overview of the set of sub-practices that constitute the core of the partnering practice (see Table III). We acknowledge that these categories are not mutually exclusive in reality. For instance, interorganizational projecting is often closely related to collaborations with fellow networks, which is why the two practices are partially overlapping in reality. Nonetheless, we present the four key practices separately for analytical purposes.

INSERT TABLE III ABOUT HERE

4.2.1 Congregating

SEMATECH members benefit from exchanging ideas in the course of SEMATECH's *congregating*, understood here as the repeated engagement in or hosting of conferences or workshops where different participants gather in one place for a limited amount of time in order to exchange technical knowledge face-to-face. It is during these venues that existing ties to fellow partners from the semiconductor industry are cultivated, while member-company representatives exchange ideas and information both formally, e.g. by means of presenting research results to each other, or informally, e.g. in the shape of 'hallway conversations' (I-32) as one interviewee put it.

These venues are used to exchange ideas in terms of how to deal with technological uncertainty concerning CMOS-related technologies when SEMATECH hosts, for instance, the so-called Litho Forum. This is an annual venue devoted solely to the – at present – most promising next-generation lithography candidate that is deemed to be able to prolong and optimize the current CMOS scaling efforts (i.e. EUV). Visiting these venues, we became aware of the specific staging of this event to foster partnering with existing organizations from the CMOS arena. A venue in New York City in 2010, for example, contained diverse formal events (e.g. keynote presentations) and there was ample room for informal opportunities to exchange ideas with fellow colleagues concerning CMOS-related themes. Illustrative evidence was the provision of seats and meeting rooms outside of the main hall, which were reserved for companies and open to informal conversations, and a catering area in the back of the main hall where mostly finger food was served, which enabled additional informal conversations. So it is ‘the interaction with your peers’ (I-103) that makes engaging in congregating valuable (I-01; I-21; I-64).

Notwithstanding these CMOS-related efforts, SEMATECH also hosts venues geared towards Beyond CMOS at the same time. The so-called SEMATECH Symposia serve both audiences, those interested in CMOS and those in Beyond CMOS. For instance, a Vice President of SEMATECH aired, as a keynote speaker during one of these occasions, the view that it is of chief importance for SEMATECH to ‘[d]evelop novel technologies with disruptive scaling potential’ (Jammy, 2009: 6). Such calls are frequently made and usually do not trail off, but are subject to discussion at future meetings and bind time and resources (I-60; I-103; I-113). Thus, these venues often dispose of a stretched character, as SEMATECH hosts them and attempts to accommodate the diverging interests, trying to engage in partnering with actors from both arenas.

Moreover, although some meetings are restricted to SEMATECH members, most of the venues are open to the public. This holds particularly true for those venues geared towards Beyond CMOS, as SEMATECH is trying to be at the technological forefront and attract actors not yet involved in the development of this kind of technology. Therefore invitations to ‘round tables’ (I-121) with actors from other industries, e.g. bio- or nanotechnology, are repeatedly arranged in order to tap as yet uncharted territories cautiously (I-131; I-136).

4.2.2 Interorganizational projecting

Engaging in projects that involve at least two organizations has been an essential part of SEMATECH’s activities from the onset (I-84; I-101; I-115). This can be traced back to the fact that assignees – the name given to member company staff delegated to SEMATECH for usually two years (I-66; I-79) – from the different organizations usually engage in specific testing and measuring of technological options’ innovativeness with colleagues from other

SEMATECH members and also from the semiconductor industry in general. Visiting the SEMATECH facilities in Albany/New York we experienced the fact that organizations are invited to test their equipment at the network's research and development (R&D) facilities and pay for this service. Of probably similar importance, this represents another opportunity to get in touch with other organizations. In addition, some of the members allow SEMATECH partners to make use of their R&D facilities in turn. It is at these locations that ideas for innovative projects are initiated and implemented (I-104; I-108). Often such projects are the beginning of a long-term partnership.

A prominent example whereby SEMATECH and its members engaged in projecting with regard to a CMOS-related technological option was when the semiconductor industry could not agree upon the most likely candidate for a next-generation lithography (NGL) at the turn of the century (I-04; I-16). Due to its prominence and relevance, actors from the industry were waiting for SEMATECH and its members to decide which technological path to follow in order to reduce technological uncertainty. However, the SEMATECH members could not agree upon a single candidate. As a consequence, the SEMATECH member Intel Corporation established the so-called EUV LLC in order to support EUV. Partnering took place beyond those SEMATECH members that favored EUV, as this consortium also included three national laboratories from the U.S. Later on, the semiconductor firms Infineon and Micron joined the consortium in 2000 and IBM followed in 2001, lending further support to EUV, which helped to shape the industry's orientation, thereby lowering technological uncertainty concerning which technological option is most likely to be pursued. When the EUV LLC achieved the critical technological proof of principle in 2001, this eventually turned the balance lastingly in favor of EUV – up to the present day (I-02; I-56). A respondent who worked for the EUV LLC still remembers that as a response to the EUV LLC's technological proof of principle, the successful members of the EUV LLC consortium, together with other members of SEMATECH and the industry, then strategically retransferred resources to the development of EUV. This culminated in partnering between the organizations favoring EUV as a key CMOS option of SEMATECH and those favoring it from the industry and was the desperately sought-for indication of how to proceed; in effect lowering technological uncertainty.

As for Beyond CMOS, an interorganizational projecting effort has been the establishment of a new organizational unit, exclusively dealing with challenges arising from Beyond CMOS. Hereby, SEMATECH installed a Vice President of Emerging Technologies as an acknowledgement of the need to closely collaborate with other partners in the course of projects. This represents another (here: personnel- and finance-related) aspect whereby the stretching becomes discernible, as resources need to be geared towards both CMOS and Beyond CMOS-related projects in order to deal with the extreme uncertainties involved in their development. A Vice President mentioned that Beyond CMOS themes can be understood as opening up the SEMATECH activities to non-members, serving to sensitize SEMATECH members to previously unacknowledged or disregarded partners who deal with technologies that might bear relevance in the future. The activities of SEMATECH are thereby, for instance, discernible in terms of the so-called Front-End Processes Program, which supports ‘projects aimed at ensuring that critical materials, tools and processes are available in time for effective scaling to the limits envisioned’ (SEMATECH, 2011). This is done in order to achieve joint objectives and reduce uncertainty concerning emerging research devices – that is, Beyond CMOS-related technological options – that do have disruptive potential for the existing semiconductor industry (I-95; I-103; I-132; I-133).

4.2.3 Collaborating with fellow networks

SEMATECH attempts to collaborate with other innovation networks on a repeated basis to (re)produce its overarching strategic objectives (I-101; I-118). This represents a historically imprinted feature, as semiconductor applications are relevant for a wide range of products, including military devices, which was also the reason for SEMATECH's initiation in the mid-1980s (I-104). Therefore, SEMATECH has been partnering, among others, with a number of governmental laboratories since its inception in order to develop leading edge CMOS technologies (e.g. Lawrence Livermore Laboratories; I-105). Nowadays, this aspect is not restricted to national governments, but also extends to local institutions across the globe. For instance, a senior SEMATECH member (I-103) mentioned that the network is currently establishing offices in Japan, Taiwan and Korea, acknowledging the need to source expertise and being, or rather, remaining an attractive consortium for its existing as well as potential members in the face of Beyond CMOS technologies (I-100).

In this context, according to the CEO and President of SEMATECH, the network and its members have acknowledged that it is necessary to collaborate 'on a new scale' to address challenges that are global, and cut across industry sectors (I-106). This stems from the need to reduce technological uncertainty and offer global guidance for innovation activities. In an official document he therefore touts accordingly:

> I believe the shared risk model that emerged from our EUV collaboration will be repeated in other emerging technologies […] With today's industry structure, it is inevitable that major technology transitions will have to be addressed by the full supply chain in unaccustomed collaborations. SEMATECH's role will be to help organize and consolidate competing views, identify top challenges, and champion programs to overcome the technical and financial roadblocks that are critical to our industry's future (Armbrust, 2010: 3).

This goes as far as turning SEMATECH into a kind of meta-network, whose task is to coordinate across very heterogeneous innovation networks addressing unknown technologies on different levels of the supply chain (I-106). Hereby, it is worth noting that close ties exist, for instance, to the Semiconductor Industry Association (SIA), which consists of about 60 companies representing roughly 90% of the U.S. semiconductor industry's productive output and voicing the mission to 'unite an industry of innovators' (SIA, 2011). In the early 1980s this organization lobbied successfully for the establishment of SEMATECH, making SEMATECH in effect an 'offspring' (I-99) of it, enabling partnering from its inception. Ever since SEMATECH's inception, collaborating with fellow networks has become increasingly important due to this science-based industry's volatility and accompanying uncertainty regarding future technological developments (I-56; I-98). Current activities comprise, among others, joining resources to align the industry infrastructure needed for both CMOS and Beyond CMOS-related technologies (SIA, 2010). The rationale for this is the perceived need to stretch and devote resources to both arenas.

4.2.4 Technological roadmapping

SEMATECH is also a key actor with regard to the (sub-)practice of roadmapping, that is, in our context: continuously setting future technological objectives and milestones in consensus in the form of the International Technology Roadmap for Semiconductors (ITRS) on an industry level. The ITRS is in effect affiliated and largely steered by SEMATECH (I-106; I-109), and the key output is a roadmap as a written artifact by the same name. The exchange of information about technical details and collaboratively defined future milestones takes place in so-called technical working groups, which are in effect organizational units of the ITRS, where interested actors meet repeatedly to exchange ideas concerning specific future technological challenges.

Similar to SEMATECH, the ITRS started as a U.S.-only endeavor in the early 1990s, at that time termed the National Technology Roadmap for Semiconductors (NTRS). From the start, the NTRS and ITRS were geared towards CMOS-related scaling and offering 'guidance that can be used for R&D investment decisions and selection of roles by R&D organizations' (NTRS, 1994: 1). This guidance usually takes the form of setting technological milestones in consensus, which transform non-calculable technological uncertainty into calculable technological risks from the actors' perspectives (I-118; I-136). To date, offering guidance represents a key mechanism, as the actors need to stay in line with Moore's law in order to maintain their innovative image and to handle the immense technological uncertainties already involved in following this path. Consider, for instance, the still uncertain introduction of EUV despite this technology being currently the most favorable NGL (I-84; I-129; I-136). This is critical, insofar as falling behind Moore's law would have severe financial implications because shareholders and industry observers would punish the actors lacking the necessary innovativeness (I-98). As a result, it is not surprising that now the industry actors are exchanging knowledge in this pre-competitive arena globally in the form of roadmapping, in order to align the infrastructure necessary to stay in line with Moore's law. It is to this very practice that substantial financial resources are devoted, and SEMATECH is co-hosting events surrounding ITRS meetings, eagerly maintaining its close ties to the ITRS organization and the practice of roadmapping. This close connection can also be grasped insofar as the headquarters of SEMATECH and the ITRS organizations are co-located, which is not by chance according to senior respondents (I-88; I-101). Another indication is that the SEMATECH President and CEO has a single expert on his staff who is permanently engaged with the ITRS organization to allow an improved information flow between the two organizations and the practices employed (I-87; I-101).

However, roadmapping in the form of the ITRS is not bound solely to engaging with organizations working on CMOS-related technologies. A stretching is discernible here due to the observation that the actors also recognize the need to open up the research agenda towards Beyond CMOS and collaborate with partners not yet engaged in the development of the technology. One of our respondents highlighted the need to open up, as well as the difficulties implied in doing so when he pointed out that

> I would like to see much more dynamism in many ways […] It is still the old club [i.e. existing and established semiconductor industry actors] which I perceive to be behind the times. Everyone has found his role […] everyone knows how everything works [concerning CMOS-related technologies] and they focus upon that […] it would really need some 'fresh blood' (I-118).

It is for this reason that the ITRS organization introduced two chapters devoted entirely to Beyond CMOS-related challenges in 2000/2001, entitled Emerging Research Devices and Emerging Research Materials. Both chapters are considered 'incubators for future potential technology solutions' (Herr, 2011: 26). This is done as the SEMATECH and other ITRS actors acknowledge the inherent technological uncertainty while not even being able to categorize these devices or materials more specifically, which is why they use such broad categories for their chapters. Thus their aim is to

> Determine which, if any, current approaches to providing a "Beyond CMOS" information-processing technolog[ies are] ready for more detailed roadmapping and enhanced investment (Hutchby, 2008: 5).

5. Stretching practices to enable open innovation for CMOS and beyond CMOS at the network level

The stretching practice of partnering is pursued by SEMATECH and its members in order to maintain its current dominant position as the leading innovation network in the semiconductor industry. At the same time the network is also trying to gain a similar position for itself and its members in the highly uncertain future arena of Beyond CMOS-related technologies at a still unknown point in the future.

Thus, by answering our guiding research question when elucidating how a network deals with technological uncertainty in the face of conflicting (here: technological innovations to be pursued) demands, we contribute to the literature on open innovation as follows: we offer a first step towards a genuine open innovation perspective at the network level of analysis. More precisely, we do not concentrate upon how a single organization as a unit of analysis can benefit from engaging in open innovation related activities with external partners in a network form, as most studies on open innovation have done so far. Take, for instance, Enkel's (2010) study in which she researches how organizations participating in a European research network benefit from it. The focus remains the same, that is, the interaction with the network from a single organization's perspective. Along similar lines, Dittrich and colleagues (2007) highlight how IBM changed its overarching strategy from exploitation to exploration (March, 1991) while repositioning by means of its alliance networks (cf. also Dittrich and Duysters, 2007 reporting similar findings for the case of Nokia). Instead, we echo the calls by open innovation researchers (e.g. Maula et al., 2006; Vanhaverbeke, 2006; West et al., 2006) when we focus upon how open innovation is pursued at the network level of analysis (Gomes-Casseres, 1996; Provan et al., 2007), which appears justified given the prevalence of this organizational constellation in today's business world and its importance as the locus of innovations (Powell et al., 1996).

In this connection we also pay specific attention to the way a network and its members actually deal with the technological uncertainty involved in exploring innovative technologies whose basic shape, as well as the necessary network of interorganizational partners to develop it, is quite unclear, pointing towards partnering as a stretching practice. Such a practice lens also differs from the ambidexterity debate, since it does not artificially distinguish between structural ambidexterity on the one hand and behavioral or contextual on the other (Simsek, 2009).

Closely related, the networked context underscores the need for a consensus-based character of the stretching practice of partnering. This resonates with the overarching idea of open innovation in terms of jointly pursuing innovation-related activities across organizational boundaries (Chesbrough, 2003; Lichtenthaler, 2011). Further support stems from research targeting research consortia underscoring the necessity to seek for consensus when pursuing emerging technologies (e.g. Roelofsen et al., 2011), not least SEMATECH (Browning et al. 1995; Browning and Shetler, 2000).

Finally, we submit that the stretching practice of partnering represents a phenomenon-driven contribution, insofar as this very practice enables and constrains SEMATECH in its ambitions to maneuver the conflicting demands of pursuing differing technological options. In this connection we also argue that the set of different sub-practices that help the network to practice uncertainty give some hints as to where the network runs the risk of 'overstretching' its (partnering) practices; an aspect not considered in previous stretching conceptions like that of stretch work (O'Mahony and Bechky, 2006). For instance, congregating and inter-organizational projecting might bind too many resources in such a way as to prevent organizations from maintaining awareness of significant developments in both arenas, which might in effect make the network ill-prepared for CMOS and Beyond CMOS challenges. In a similar vein, partnering in the form of collaborating with fellow networks might overstrain SEMATECH's capacities, and roadmapping as a planning procedure might become too formalized (e.g. by concentrating upon measureable technological outputs), while losing its value as a tool for strategic foresight when true uncertainties are not covered. Herein, a parallel can also be drawn to the ambidexterity discourse (Tushman and O'Reilly, 1996) that elaborates upon balancing exploitation (here: similar to CMOS) and exploration (here: similar to Beyond CMOS; Enkel and Gassmann, 2010; March, 1991).

6. Concluding remarks

Our research objective was to explore how open innovation can be managed at the network level of analysis in the face of technological uncertainty. The empirical setting is further characterized by technological options with contradictory, possibly even paradoxical demands. The results of our study suggest that the consensual stretching practice of partnering allows the exploitation of existing practices and their transfer to as yet uncharted territories. In this connection we have identified a set of sub-practices that constitute partnering.

Though our findings certainly exhibit features specific to the semiconductor industry and large scale corporations, we deem our findings to be partially generalizable, as other science-based industries like biotechnology or telecommunications are likely to experience similar situations with conflicting demands when pursuing open innovation by means of networks (Chiaroni et al., 2010; Gassmann et al., 2010; Maula et al., 2006; Powell et al., 1996; Powell et al., 1999; Vanhaverbeke, 2006; West et al., 2006). More precisely, they are also likely to face the pursuit of diverging technological innovations, making our conception of stretching practices in general and partnering in particular applicable beyond the semiconductor industry setting. The sub-practices identified also bear relevance to other industries. Take, for instance, roadmapping as a practice increasingly employed by other industries in need of pooling joint resources to face uncertainty, e.g. transportation, health care or fossil fuels (cf. Phaal, 2011 for an overview). In a similar vein, interorganizational projects and collaborating across networks are by no means activities solely idiosyncratic to the semiconductor industry (e.g. Boland and Lyytinen, 2007). Congregating has also gained increasing scholarly attention, where conferences also play a pivotal role (e.g. Garud, 2008).

Although our longitudinal study offers empirical evidence of how SEMATECH and its members deal with technological uncertainty, further data concerning partnering on the organizational or even industry level would help to complement our understanding of the way SEMATECH and its members face technological uncertainty, as we have focused upon the network level of analysis. Another future research avenue might be capturing the practices of organizational actors coping with extreme uncertainties of different kinds, e.g. when they are intentionally inducing uncertainty – instead of reducing uncertainty as primarily observed in our study – in order to stimulate the invention of radical new solutions (Michel, 2007). In sum, we submit that further explorations of how networks face technological uncertainty and the practices they employ are needed in order to comprehend this timely and important open innovation management topic more adequately.

References

Armbrust, D. 2010. Collaboration across the industry supply chain making EUV lithography a reality, in: *SEMATECH TECH report*, Edt. 9, 2-3. Austin/Texas.

Boland Jr., R. J., Lyytinen, K. 2007. Wakes of Innovation in Project Networks: The Case of Digital 3-D Representations in Architecture, Engineering, and Construction. *Organization Science*, 18(4): 631-647.

Brown, S. L., K. M. Eisenhardt. 1998. *Competing on the Edge: Strategy as Structured Chaos*. Harvard Business School Press, Boston.

Browning, L. D., Beyer, J. M., Shetler, J. C. 1995. Building cooperation in a competitive industry: Sematech and the semiconductor industry. *Academy of Management Journal, 38*: 113-151.

Browning, L. D., Shetler, J. C. (2000). *Sematech: Saving the U.S. Semiconductor Industry*. College Station, TX: University Press.

Chesbrough, H. 2003. *Open Innovation. The New Imperative for Creating and Profiting From Technology.* Boston: Harvard Business School Press.

Chesbrough, H., Crowther, A. K. 2006. Beyond high tech: early adopters of open innovation in other industries. *R&D Management*, 36(3): 229-236.

Chesbrough, H. W., Rosenbloom, R. S. 2002. The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and Corporate Change*, 11(3): 529-555.

Chiaroni, D., Chiesa, V., Frattini, F. 2010. Unravelling the process from Closed to Open Innovation: evidence from mature, asset-intensive industries. *R&D Management*, 40(3): 222-245.

Dhanaraj, C., Parkhe, A. 2006. Orchestrating innovation networks. *Academy of Management Review, 31*: 659-669.

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

Dittrich, K., Duysters, G. 2007. Networking as a means to strategy change. The case of open innovation in mobile telephony. *The Journal of Product Innovation Management*, 24(6): 510-521.

Dittrich, K., Duysters, G., de Man, A. 2007. Strategic repositioning by means of alliance networks: The case of IBM. *Research Policy,* 36: 1496-1511.

Dyer, J. H., Nobeoka, K. 2000. Creating and managing a high-performance knowledge-sharing network: The Toyota case. *Strategic Management Journal*, *21*: 345-367.

Enkel, E. 2010. Attributes required for profiting from open innovation in networks. *International Journal of Technology Management*, 52(3/4): 344-371.

Enkel, E., Gassmann, O. 2010. Creative imitation: exploring the case of cross-industry innovation. *R&D Management*, 40(3): 256-270.

Enkel, E., Perez-Freije, J., Gassmann, O. 2005. Minimizing Market Risks Through Customer Integration in New Product Development. Learning from Bad Practice. Creativity and Innovation Management. Vol. 14 No. 4, pp. 425-437.

Garud, R. 2008. Conferences as Venues for the Configuration of Emerging Organizational Fields: The Case of Cochlear Implants. *Journal of Management Studies*, 45(6): 1061-1088.

Gassmann, O., Enkel, E., Chesbrough, H. 2010. The future of open innovation. *R&D Management*, 40(3): 213-221.

Gassmann, O., Reepmeyer, G. 2005. Organizing Pharmaceutical Innovation. From Science-based Knowledge Creators to Drug-oriented Knowledge Brokers. Creativity and Innovation Management. Vol. 14 No. 3, pp. 233-245.

Giddens, A. (1984). *The Constitution of Society.* Cambridge: Polity Press.

Gomes-Casseres, B. 1996. *The alliance revolution. The new shape of business rivalry.* Cambridge: Harvard University Press.

Grabher, G., Powell, W. W. (2004). *Networks*. Cheltenham: Elgar.

Hamel, G., Prahalad, C. K. (1993). ‘Strategy as stretch and leverage’. *Harvard Business Review*, 71(3-4), 75-84.

Herr, D. J. C. (2011). ‘New technologies & devices structures’. *Future Fab International*, 36(1), 26.

Hutchby, J. A. (2008). Emerging research devices. http://www.itrs.net/Links/2008Summer/Public%20Presentations/PDF/ERD.PDF (accessed on 6 January 2011).

Jammy, R. (2009). Materials, Process and Integration Options for Emerging Technologies. http://www.sematech.org/meetings/archives/symposia/8845/07a_EmergingTech_Jammy_handout.pdf (accessed on 22 October 2010).

Jarillo, J. C. 1988. On strategic networks. *Strategic Management Journal, 9:* 31-41.

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, 1025-35.

Laursen, K., Salter, A. 2006. Open for Innovation: the Role of Openness in Explaining Innovation Performance Among U.K. Manufacturing Firms. *Strategic Management Journal*, 27: 131-150.

Lichtenthaler, U. 2011. Open innovation: Past research, current debates, and future directions. *Academy of Management Perspectives*, 25(1): 75-93.

Lorenzoni, G., Baden-Fuller, C. 1995. Creating a strategic center to manage a web of partners. *California Management Review, 37(3):* 146-163.

March, J. G. (1991). ‘Exploration and exploitation in organizational learning’. *Organization Science*, 2, 71-87.

Maula, M. V., Keil, T., Salmenkaita, J. 2006. Open Innovation in Systemic Innovation Contexts. In H. W. Chesbrough, W. Vanhaverbeke, & J. West (Ed.), *Open Innovation. Researching a New Paradigm:* 241-257. Oxford: Oxford University Press.

Michel, A. A. (2007). ‘A distributed cognition perspective on newcomers’ change processes: The management of cognitive uncertainty in two investments banks’. *Administrative Science Quarterly*, 52, 507-57.

Moore, G. E. (1965). ‘Cramming more components onto integrated circuits’. *Electronics*, 38, 114-17.

Müller-Seitz, G. 2012. Leadership in Interorganizational Networks: A Literature Review and Suggestions for Future Research, in: *International Journal of Management Reviews*. DOI: 10.1111/j.1468-2370.2011.00324.x.

NTRS (1994). *The National Technology Roadmap for Semiconductors 1994*. San Jose: SIA.

O'Mahony, S., Bechky, B. A. (2006). ‘Stretchwork: Managing the career progression paradox in external labor markets’. *Academy of Management Journal*, 49, 918-41.

Perrons, R. K. 2009. The open kimono: How Intel balances trust and power to maintain platform leadership. *Research Policy*, 38(8): 1300-1312.

Phaal, R. (2011). Public-Domain Roadmaps. http://www.ifm.eng.cam.ac.uk/ctm/trm/documents/public_domain_roadmaps.pdf (accessed on 25 November 2011).

Powell, W. W., Grodal, S. 2005. Networks of Innovators. In J. Fagerberg, D. C. Mowery, & R. R. Nelson (Ed.), *The Oxford handbook of innovation:* 56-85. Oxford: Oxford University Press.

Powell, W. W., Koput, K. W., Smith-Doerr, L. (1996). ‘Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology’. *Administrative Science Quarterly*, 41, 116-45.

Provan, K. G., Fish, A., Sydow, J. (2007). ‘Interorganizational networks at the network level: A review of the empirical literature on whole networks’. *Journal of Management*, 33, 479-516.

Roelofsen, A., Boon, W. P. C., Kloet, R. R., Broerse, J. E. W. 2011. Stakeholder interaction within research consortia on emerging technologies: Learning how and what? *Research Policy*, 40: 341-354.

Schreyögg, G., Sydow, J. 2010. Organizing for fluidity? On the dilemmas of new organizational forms. *Organization Science*, 21 (6): 1251-1262.

SEMATECH (2011). Materials and emerging technologies. http://www.sematech.org/ research/materials/ (accessed on 7 January 2011).

SIA (2010). SEMATECH, SIA and SRC Team to Establish New Collaborative Program for Enabling 3D ICs. http://www.sia-online.org/cs/papers_publications/press_release_detail? pressrelease.id=1841 (accessed on 20 December 2010).

SIA (2011). Mission statement. http://www.sia-online.org/cs/about_sia/mission_statement, (accessed on 8 January 2011).

Simsek, Z. (2009). 'Organizational ambidexterity: Towards a multilevel understanding'. *Journal of Management Studies*, 46, 597–24.

Sitkin, S. B., See, K. E., Miller, C. C., Lawless, M. W., Carton, A. M. (2011). 'The paradox of stretch goals: Organizations in pursuit of the seemingly impossible'. *Academy of Management Review*, 36, 544-66.

Spencer, W. J., Grindley, P. 1993. SEMATECH after five years: High-technology consortia and U.S. competitiveness. *California Management Review*, *35(4):* 9-32.

Sydow, J., Windeler, A. (1998). 'Organizing and evaluating interfirm networks – A structurationist perspective on network management and effectiveness'. *Organization Science*, 9, 265-84.

Tushman, M. L., O'Reilly, C. A. (1996). 'The ambidextrous organization: managing evolutionary and revolutionary change'. *California Management Review*, 38, 1-23.

van de Vrande, V., de Jong, J. P. J., Vanhaverbeke, W., de Rochemont, M. 2009. Open innovation in SMEs: Trends, motives and management challenges. *Technovation*, 29: 423-437.

Vanhaverbeke, W. 2006. The Interorganizational Context of Open Innovation. In H. W. Chesbrough, W. Vanhaverbeke, & J. West (Ed.), *Open Innovation. Researching a New Paradigm:* 205-219. Oxford: Oxford University Press.

Vanhaverbeke, W., Cloodt, M. 2006. Open Innovation in Value Networks. In H. W. Chesbrough, W. Vanhaverbeke, J. West (Ed.), *Open Innovation. Researching a New Paradigm:* 258-281. Oxford: Oxford University Press.

von Hippel, E. 1986. Lead Users: A Source of Novel Product Concepts. *Management Science*, 32(7): 791-805.

West, J., Vanhaverbeke, W., Chesbrough, H. 2006. Open Innovation: A Research Agenda. In H. W. Chesbrough, W. Vanhaverbeke, J. West (Ed.), *Open Innovation. Researching a New Paradigm:* 285-307. Oxford: Oxford University Press.

Whittington, R. (2011). ‘The practice turn in organization research: Towards a disciplined transdisciplinarity’. *Accounting, Organizations and Society*, 36, 183-6.

Yin, R. K. (2009). *Case Study Research*. 4th ed., Thousand Oaks: Sage.

APPENDIX

TABLE I: Field Documents.

Document type	*Documents analyzed*
Documents issued by organizations	Annual reports and press releases from SEMATECH and its member companies (e.g. Intel and IBM), industry associations (e.g. Semiconductor Industry Association) and consortia (e.g. International Technology Roadmap for Semiconductors)
	Hewlett Packard Journal / Digital Technical Journal
	IBM Journal of Research and Development
	Intel Technology Journal
Media coverage	Online: Compound Semiconductor, Electronic Design News, EE Times, Semiconductor International, Semiconductor FabTech, Semiconductor Today, Silicon Strategies, Solid State Technology
	Databases for the reproduction of printed documents: LexisNexis (English language)
Semiconductor specific outlets	Future Fab International, IEEE Transactions on Semiconductor Manufacturing, Journal of Semiconductor Technology and Science, Journal of Semiconductors, Materials Science in Semiconductor Processing, Microelectronic Engineering
Conference Proceedings	1995 – today: Proceedings of SPIE conferences 1997 – today: NGL Workshop papers and presentations
	2001 – today: SEMATECH (later with SELETE and EUVA) hosted International EUVL Symposium papers and presentations
	2001 – today: Workshops on EUVL masks, resists and source papers and presentations
	2004 – today: SEMATECH, IMEC and SELETE hosted International Symposium on Immersion Lithography papers and presentations
	2004 – today: SEMATECH hosted Lithography Forum (biannually) papers, presentations and surveys

TABLE II: Illustrative data for the subset of consensual practices identified.

Subpractice	Data source	Illustrative evidence
Congregating	*Archival data*	At SEMATECH's Litho Forum […] semiconductor business leaders and technology experts gained valuable insight into the industry's perceptions about and intentions for lithography development. The Forum, a three-day gathering of global lithography experts, featured an impressive line-up of senior executives and technical experts in the semiconductor industry, who shared perspectives on why collaboration is imperative for semiconductor innovation and what challenges the development of next-generation technologies must tackle to make lithography successful […] Dan Armbrust, president and CEO of SEMATECH [mentioned] "For the industry to evolve, business models need to take into account collaborations to control costs and extend current technologies while building the infrastructure for future solutions" (SEMATECH 2010c)
	Conference data	*Observation* : I asked him [a respondent] why he shows up at this venue while he is the representative of a rather minor player. In his reply he points out that he has attended several conferences over time, which is the way it frequently starts for every company "up until people learn to recognize you" and if you "buddy up with one of the 'big ones', then you're in the club and will be recognized" (notes taken during the Litho Forum in New York City, U.S.A., 2010-05-11) *Presentation slide* : A workshop on EUV Mask Infrastructure attended by high-level decision makers from over 20 EUV stakeholders including chip manufacturers, mask houses, mask blank suppliers, scanner suppliers, metrology equipment suppliers. Workshop goal: to highlight the lack of commercial actinic mask metrology infrastructure and obtain consensus on a path to close the gap [with regard to the objectives formulated in the ITRS]' (Rice 2009, 2; EUV Symposium in Prague / Czech Republic)
	Interview data	If you take a look at how many papers are submitted for the different areas [technological options] then you are able to interpret how large the activities with regard to specific technological options actually are […] This implies that you simply need to take a look at the number of submissions and the joint activities taking place in order to realize that EUV is at present the most likely [NGL] candidate (I-1)
Interorgan. projecting	*Archival data*	Filling an industry need considered too costly for individual companies to develop independently [...] the new EUVL Mask Infrastructure Partnership has drawn strong interest from six semiconductor industry entities. Additional members are being sought for the consortium, which will pursue an ambitious metrology program to enable defect-free EUVL masks for high-volume manufacturing by 2013 (SEMATECH Tech Report 2010, 8)
	Conference data	*Observation* : An Intel employee who is currently a SEMATECH assignee mentioned in his presentation that there is a 'Clear mandate' for SEMATECH to guide the EUVL mask infrastructure [...] He deems it to be too capital intensive for one company alone to support the EUV mask infrastructure [...] Therefore he calls for support for an EUV related project, the so-called EUV Mask Infrastructure Consortium, which is supported by SEMATECH and other funders; to be set up soon (in early 2010); the official call for participation is between 2009-11-01 and 2009-12-31 (i.e. hardly a month left; asked about this issue, a participant aired later on confidentially to me that this is an indication of already having a fixed number of relevant actors; however, in order to appear unbiased and open to participation for every organization interested, this is done as a form of lip service) (notes taken during the EUV Symposium in Prague / Czech Republic, 2009-10-20) *Presentation slide* : Key direction #1: Maintaining relationship between ITRS […] and National Projects by sharing working group members (Hutchby 2008, 19, ITRS Winter Conference in Seoul / South Korea)
	Interview data	In the beginning these were really secret projects and there were really no discussions between very much competing companies, but I think right now everything is already much clearer to the whole community, I think there are a lot of similarities in the way they approach things […] SEMATECH is indeed kind of outsourcing a number of projects, which are typically at the front end of the development of the technology – so very early on (I-15)

Subpractice	Data source	Illustrative evidence
Collaborating with fellow networks	*Archival data*	We have built a global network of supporting alliances with equipment and material suppliers, universities, research institutes, consortia, start-up companies, and government partners. Working together, we leverage limited R&D dollars in critical programs that help drive the industry's evolution (SEMATECH Annual Report 2009, 13)
	Conference data	*Observation* : People from different organizations meet in rooms close to the halls where presentations are made. Often time slots are officially designated for meetings for SEMATECH members and their counterparts from other organizations. Taken altogether, the venue serves to connect people, which is basically in line with what the SEMATECH CEO and other industry keynotes tout (notes taken during the ITRS Summer Conference 2010, San Francisco, U.S.A., 2010-07-14) *Presentation slide* : The SEMATECH network is global, with membership of industry-leading chipmakers, and partnerships with suppliers, universities, and governments to drive technology commercialization in semiconductors and nanotechnology (Polcari 2008, 11; SEMATECH / ISMI Symposium in Taipei, Taiwan)
	Interview data	We use also the industry [and] government support to make the infrastructure realistic […] especially in EUV and advanced mask technology areas we are working with most of the consortia worldwide. So that will help us to invest in a very early stage for the EUV specific technology. So EUV specific technology […] is quite expensive and needs very huge investments for development […] So it's quite difficult to support it by one company. So we join those consortia and the consortia will support those kind of development (I-58)
Roadmapping	*Archival data*	The ITRS technology working groups (TWGs) meet several times each year to work on the Roadmap together [...] During these workshops, these ITWG members share their working meeting results with the other regional representatives, and decide how best to update the ITRS. The ITRS teams also hold public conferences for the semiconductor community to learn about the teams' progress and, most importantly, to gather feedback from the audience. Researchers, technologists, and strategists from all sectors of the semiconductor industry are encouraged to attend these public forums to participate in the latest updates of the ITRS (ITRS 2011)
	Conference data	*Observation* : Presenters - and even attendees when talking to each other in the breaks - relate to previous ITRS conferences and roadmap items when they discuss the progress they have made or challenges they face. For me [i.e. author #2], it seems as if they revert constantly to the ITRS in order to justify their present and next steps. The presenters even show ITRS data (e.g. Tables or Figures) to substantiate their line of reasoning and how it relates to the ITRS (notes taken during the ITRS Spring Conference 2011, Potsdam, Germany, 2011-04-11) *Presentation slide* : Moore's Law is there to set common goals. The power of Moore's Law observation and prediction was, is and will be for the foreseeable future to provide a common, easily understood quantified metric for everyone in the semiconductor and IT economy to synchronize their efforts toward historically based, well defined, sustainable and mutually rewarding growth goals in the future. 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 the fundamental uncertainty of assessing risks to schedule and yields of ever more complex novel technologies over extending existing "tried and true" approaches beyond their originally defined limits in the absence of data (Borodovsky 2006, 31; SPIE conference in San Jose, U.S.A.)
	Interview data	So you look at Moore´s law, and you wanna [...] double your number of transistors every two years. So you say "Well, I have to double the number of my transistors every two years [and] I have to have a certain thickness, I have to have a certain uniformity" and [...] I say "Hey you´re here today I get to get ... and I wanna be there". "Oh, you´re the only one that wants to be there. You don´t have to pay me, you know in a rate non recovering engineering charges, to get, because you´re the only one", bring me five dollars they say that to me, they say that the other guy, they say that to the other guy and then we finally said: "Hey enough of this! So now if you go, he said o.k. here is the roadmap. This is here, this is here. All I want you to do is stay on the roadmap, so don´t, don´t make, you know, don´t charge us … all for the same (I-79)

TABLE III: Stretching practices of SEMATECH as related to partnering.

Stretching practice	*Description*	*Primarily involved actors*	*Partnering regarding CMOS related uncertainty*	*Partnering regarding Beyond CMOS related uncertainty*	*Danger of overstretching*
Congregating	Repeated engagement in or hosting of conferences or workshops	SEMATECH concerning hosting these venues, SEMATECH members in participating at these venues	Formal talks and informal (hallway) conversations in established venues in order to maintain established relations	Formal talks and informal (hallway) conversations in new, more open venues in order to explore new partners, supplemented by selective invitations	Wasting time and resources, unintended knowledge flows, missing out important potential partners
Interorganizational projecting	Running projects that involve other organizations	SEMATECH and its members	Projects involving in particular own testing facilities, opening up of facilities for non-members that supported EUV	Projects initiated by a unit and program dedicated to the new path, open for participation by non-members	Losing a clear view of the field, while being open to too many existing as well as new and potentially relevant members
Collaborating with fellow networks	Building and maintaining relations with other networks	SEMATECH	With very few other organizations and networks	On a new scale: collaborating across networks with the help of SEMATECH as a meta-network / network broker	Overusing networks as an organizational form
Roadmapping	Revolving plan in which technological objectives and milestones are set in consensus	SEMATECH and its members	Updating the ITRS with the help of chapter meetings and network-wide meetings	Expanding the ITRS into new technological terrains with the help of new, dedicated chapters	Overusing roadmapping as a planning procedure

FIGURE 1: Emergent data structure.

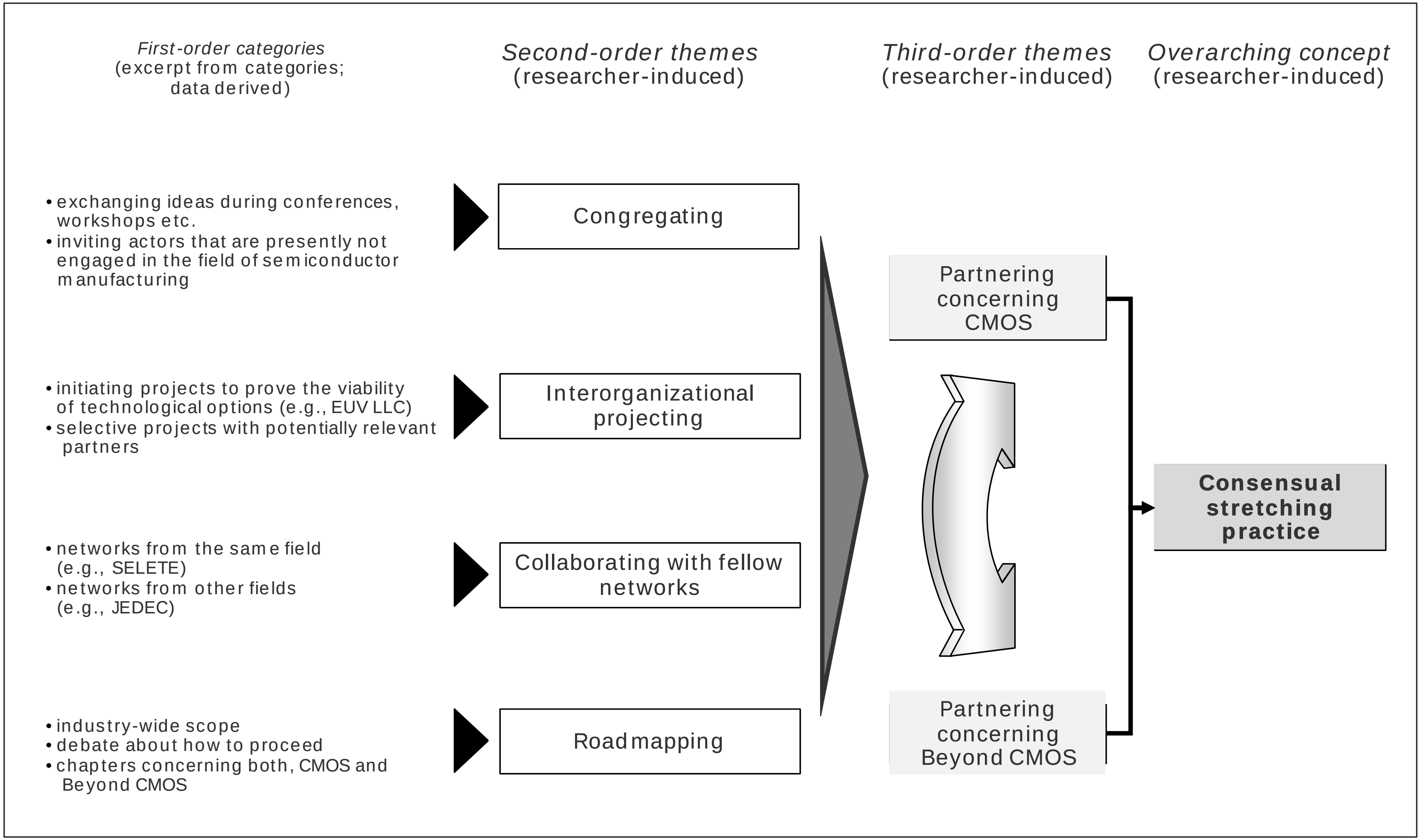

FIGURE 2: Stretching between the CMOS and Beyond CMOS arenas.

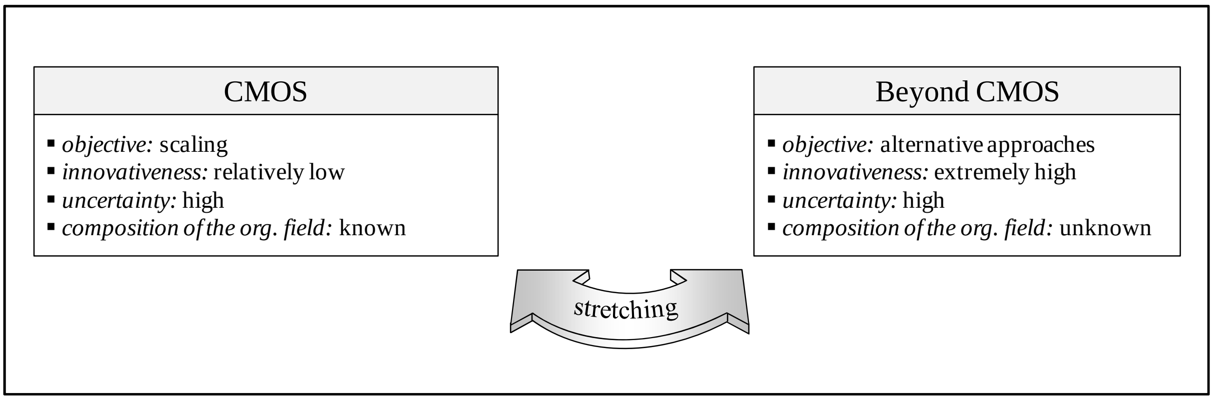

FIGURE 3: Uncertainty-related practices in the case of diverging technological demands.