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PRACTICING UNCERTAINTY IN R&D NETWORKS – EXPLORATIVE EVIDENCE FROM A SEMICONDUCTOR INDUSTRY NETWORK

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INTRODUCTION

In order to manage uncertainty – understood here in line with Knight (1921) as situations when actors face options whose likelihood cannot be estimated in terms of probabilities – an increasing number of organizations collaborate by means of engaging in interorganizational networks of three or more organizations that pursue joint activities for a common objective (Grabher & Powell, 2004; Provan, Fish, & Sydow, 2007). This observation holds particularly true for innovation-related activities, where the actors attempt to lower complexity and share the high costs for research and development in the face of increasingly shorter product life cycles. The environment, in this case in particular the technological environment, turns out to be a central source of uncertainty to which organizations and, increasingly, interorganizational networks have to respond. Frequently environmental or technological uncertainty is analyzed from a transaction-cost perspective, focusing upon issues like contract design or investing in suppliers in order to control partner uncertainty in general and relational risk in particular (Beckman, Haunschild, & Phillips, 2004; Das & Teng, 1996). The complexity of this endeavor is aggravated when it comes to engaging with partners along the supply chain, possibly even crossing industry boundaries, or of different societal spheres, i.e. governmental and for-profit actors. This appertains in particular to science-based industries like the biotechnological, telecommunications or semiconductor industries where different types of actors along complex, often global supply chains and from different societal spheres need to be aligned or persuaded to pursue joint activities for mutual benefits.

Given this observation, it is striking that despite the relevance and ubiquity of uncertainty for science-based industries, previous research has by and large focused upon governance-related issues, e.g., how to design contracts by means of adopting a transaction-cost economic stance. However, the way uncertainty is actually faced in and by particular interorganizational systems with what we call uncertainty practices by means of reverting to the literature on strategizing (e.g., Jarzabkowski, 2008), has seldom been subject to discussion. We suggest that comprehending how uncertainty is or can be practiced is critical for our understanding of how interorganizational networks, especially innovation networks like R&D consortia, deal with uncertainty. Against this background, this study's guiding research question is: How do interorganizational networks practice uncertainty concerning the pursuit of differing technological options in science-based industries?

In order to answer this, we elucidate in our phenomenon-driven research the way in which a key innovation network, SEMATECH, in the organizational field of semiconductor manufacturing deals with technological uncertainty. Herein we contribute to the literature on dealing with

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uncertainty in and with interorganizational networks embedded in organizational fields as follows: First, we refine previous research by means of introducing a practice perspective on managing uncertainty, which we call ‘practicing uncertainty’. Hereby networks are not only perceived as reacting to uncertainty; instead, as only few previous (organizational) studies have acknowledged (e.g., Michel, 2007), organizations as well as interorganizational networks may also induce uncertainty. Second, we set forth how the technology development paradox, which semiconductor industry actors face and is obviously already plagued with uncertainty, is tackled – by means of the stretching practice of partnering, understood here as selectively engaging with different present and potentially in-the-future-relevant organizational actors.

THEORETICAL BACKGROUND

A Practice Perspective on Uncertainty

In order to analyze how organizational actors practice uncertainty in the SEMATECH network, we make use of Giddens’ (1984) theory of structuration, which has already been applied to the analysis of organizations and interorganizational networks (e.g., Jarzabkowski, 2008; Sydow & Windeler, 1998). In line with Giddens, 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.

In connection with reducing uncertainty it is noteworthy that Giddens (1984: 5-14) presumed that the practices of agents, who are assumed to strive for “ontological security”, are to a large extent routinized and, as routines, considered as 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. Thereby, structuration theory not only allows to analyze this dynamics but with the help of the fundamental theorem of the “duality of structure” (Giddens, 1984), which emphasizes not only the recursive interplay between action and structure, highlights three interrelated dimensions of any action and structure, i.e. signification, legitimation, and domination.

For the purposes of this study, we revert to Knight (1921) in defining uncertainty as those situations when (in our case: organizational) actors face options whose likelihood cannot be expressed by probabilities. This represents a sharp contrast to situations where actors are confronted with risk (in its narrow Knightian sense), as the latter dispose of known alternatives and probabilities which can at least be estimated (“known unknown”).

Practicing Uncertainty in Interorganizational Networks

Furthermore, we define an interorganizational network as a social system in which the activities of at least three organizations as formally independent legal entities are coordinated in time-space on a repeated basis, i.e. there is some reflexivity involved in the interorganizational division of work and the cooperation among the actors involved in the network domain.

RESEARCH CONTEXT AND METHODS

The organizational field of *semiconductor manufacturing* was selected as the setting of this study because it is characterized by both a dominance of interorganizational networks, and an extremely high degree of technological uncertainty stemming mainly from the inability to predict,

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which technologies – and accompanying organizational actors – will succeed the current CMOS-related technology path, an arena typically referred to as Beyond CMOS. At present the organizations from the field of semiconductor manufacturing invest in improving the efficiency of current CMOS technologies – labeled 'scaling' and referring to Moore's 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 also plagued with uncertainties, it is not at all comparable in this respect with the Beyond CMOS alternative, which questions almost every technological layer that is known from the CMOS path.

In this organizational field, the originally U.S.-born *SEMATECH* consortium is of outstanding importance, as its organizational members now represent around 50% of the worldwide production output. Since we employ structuration theory to analyze stretching practices, we adopt an *interpretative research methodology* (Lincoln & Guba, 1985) that allows us to capture practices that are at the center of any structurationist inquiry from the respondents' perspective.

Data Collection

Our data has been collected for 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, four main sources were utilized for triangulation purposes in order to heighten construct validity, as well as preventing post-hoc rationalization and potential biases (Lincoln & Guba, 1985): field documents, 120 semi-structured interviews, an annual panel and participant observation during on-site visits and in particular from visiting conferences.

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, whereby our analysis is based upon the 'raw data' of 150 pages of field notes, approx. 2,000 pages of interview transcripts and roughly triple the amount of archival as well as conference data. Stage two consisted of writing up condensed descriptions of how the uncertainty practices are enacted within SEMATECH. In stage three we condensed our empirical data. 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.

PRACTICING UNCERTAINTY BY MEANS OF STRETCHING PRACTICES

Partnering as a Stretching Practice to Reduce the Technology Development Paradox

We identified a number of stretching practices that the SEMATECH members as well as other participants from the field of semiconductor manufacturing use to cope with this kind of situation in general and to practice uncertainty in particular. Our analysis suggests that the key practice relevant in terms of practicing uncertainty concerning the SEMATECH network and its members is that of *partnering*, which pervades a set of different practices, namely congregating, interorganizational projecting, collaborating with fellow networks, and roadmapping. Bearing these stretching practices in mind the SEMATECH network – and the entire field – faces what we label a technology-development paradox and which is why we refer to *stretching practices*. Hereby the term stretching is used to highlight two aspects: First, to denote the mindful parallel pursuit of two

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or more (here: technological) options by means of a recurring social activity. The stretching manifests in exploiting an existing established practice concerning comparatively well-understood options in more familiar contexts, while at the same time striving to refine the established practices. This 'optimizing' (in the field of lithography in the form of 'scaling') is done 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 uncertainty and deemed relevant for the future at present. Such a leveraging is aimed for in order to take advantage of capabilities and capacities accumulated in the established and comparatively well-understood domain. This 'optimizing' of the known – which in our case implies already quite a lot of unknown – is complemented by exploring one or more radical alternatives, in the case under scrutiny the technology that goes Beyond CMOS – the unknown unknown. As for Beyond CMOS this 'unknownness' is aggravated as there is not even at this point in time a set of economically and technically attractive technological options on the different layers discernible. 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 as well as relationship.

Although the network and its members successfully coordinate the field of semiconductor manufacturing concerning the comparatively well-understood CMOS technology path, the actors are aware that this path is very likely, even in the face of the success of past path extensions, to reach physical limits as an end of scaling is conceivable. However, a small fraction – i.e. three – of our industry respondents stated that this does not need to be the case, which is why even the end of CMOS scaling is somewhat uncertain. This appertains not only to the time frame when it will terminate, but some industry respondents argue that there will be no end even if the atom level is reached.

Moreover, the SEMATECH members need to pursue alternative technological options at the same time concerning the Beyond CMOS arena. This appears inevitable due to the limits of scaling with regard to CMOS but is highly imbued with technological uncertainty, as neither the technological options are fully understood nor prioritized in regard to their economic attractiveness.

Partnering as Comprising a Set of Stretching Practices

In what follows, we report on the practices that constitute the core of partnering in order to reduce uncertainty. We acknowledge that these categories are not mutually exclusive in praxi.

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 for a limited amount of time in one place in order to exchange technical knowledge face-to-face. It is during these venues that existing ties to fellow partners from the field of semiconductor manufacturing are cultivated while member-company representatives exchange both formally, e.g., by means of presenting research results to each other, or informally.

Interorganizational Projecting. Engaging in projects that involve at least two organizations has been an essential part of SEMATECH's activities from the onset. This can be traced back to the fact that so-called assignees from the different organizations usually engage in testing and measuring technological options with colleagues from other SEMATECH members and also from the field of semiconductor manufacturing in general (who are able to test their equipment at SEMATECH's facilities and pay for this service). SEMATECH provides for these cases its own

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testing facilities, located at its headquarters in Austin, Tx., as well as Albany, N.Y., and also some of the members allow SEMATECH partners to make use of their facilities in turn. It is at these locations that ideas for projects are initiated and executed.

Collaborating with Fellow Networks. Moreover, SEMATECH attempts to collaborate with other innovation networks. This represents a historically imprinted feature as semiconductor applications are relevant for a wide range of products, among others, military devices, which was also the reason for SEMATECH's initiation in the mid-1980s. Therefore, SEMATECH has been partnering, among others, with a number of governmental laboratories since its inception in order to develop leading edge CMOS technologies. However, this aspect is not restricted to national governments, but also to local institutions across the globe. For instance, SEMATECH is currently establishing offices in Japan, Taiwan and Korea, acknowledging the need to dispose of regional offices 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.

Roadmapping. SEMATECH is also a key actor with regard to the practice of roadmapping, that is, in our context: setting continuously future technological objectives and milestones in consensus in the form of the International Technology Roadmap for Semiconductors on a field level (ITRS for short). The exchange about technical details takes place in so-called chapters, which are in effect organizational units of the ITRS where interested actors meet on a regular basis to exchange ideas concerning specific future technological challenges regarding the present technological path. These exchanges are complemented by ITRS-wide meetings hosted three times a year; every year there is a spring meeting in Europe, a summer meeting in the U.S. and a winter meeting in South East Asia. Although it represents a field-wide effort, this activity is substantially supported by SEMATECH and its member companies. This influence does not only stem from SEMATECH's membership base while the companies account for about half of the worldwide semiconductor industry output, but also due to being funded by the SIA in close collaboration with SEMATECH in the 1990s; albeit at that time as a U.S.-only endeavor, entitled the National Technology Roadmap for Semiconductors (NTRS for short). Nevertheless, since its inception the overarching objective was to provide "guidance that can be used for R&D investment decisions and selection of roles by R&D organizations" (NTRS, 1994: 1).

CONCLUDING REMARKS

Taken altogether, we deem our findings to be partially generalizable, as other science-based industries like telecommunications or bio- and nanotechnology are likely to experience similar technological paradoxes, i.e. are faced with pursuing diverging technological paths, making our conception of stretching practices in general and partnering as a stretching practice in particular applicable beyond the semiconductor industry setting. We suggest that our contribution is in this connection threefold: First, we offer a first practice-oriented perspective on how to deal with uncertainty – as opposed to risk. Second, in contrast to previous (practice, as well as uncertainty related) research targeting primarily the organizational level of analysis (e.g., Jarzabkowski, 2008), we explicitly address the network-field nexus. Thereby, we even go beyond the present organizational field, which is opened up towards novel and yet unknown actors. Third, we elucidate how partnering as a stretching practice pervades a set of different practices that help the SEMATECH network to practice uncertainty. However, our analysis gives also some hints as to where the network runs the risk of 'overstretching' its (partnering) practices. For instance, congregating and interorganizational projecting might bind too many resources in such a way as to prevent organizations from maintaining awareness of significant developments in both arenas that in effect practices neither the CMOS nor the Beyond CMOS arenas, which are well addressed by the practices employed. 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, while losing its value as a tool for strategic foresight.

Although our longitudinal study offers explorative evidence of how SEMATECH and its members practice uncertainty, more detailed data concerning partnering would help to offer a finer-grained picture of the way SEMATECH practices uncertainty. This, however, as most practice research, would require a more ethnographic methodology (Whittington, 1992; Jarzabkowski, 2008). What is more, research on uncertainty, not only as the unknown unknown is mastered in or with the help of interorganizational networks, is even more distant from an approach that is able to capture the practices of organizational actors coping with extreme uncertainties of different kinds, or in some cases even inducing uncertainty in order to stimulate the invention of radical new solutions (Michel, 2007).

REFERENCES

Beckman, C. M., Haunschild, P. R., & Phillips, D. J. 2004. Friends or strangers? Firm-specific uncertainty, market uncertainty, and network partner selection. **Organization Science**, 15: 259-275.

Das, T. K., & Teng, B.-S. 1998. Between trust and control: Developing confidence in partner cooperation in alliances. **Academy of Management Review**, 23: 491-512.

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

Grabher, G., & Powell, W.W. 2004. **Networks**. Cheltenham: Edward Elgar.

Jarzabkowski, P. 2008. Shaping strategy as a structuration process. **Academy of Management Journal**, 51: 621–650.

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

Lincoln, Y. S., & Guba, E. G. 1985. **Naturalistic Inquiry**. Beverly Hills, CA: Sage.

Michel, A. A. 2007. A distributed cognition perspective on newcomers' change processes: the Management of cognitive uncertainty in two investment banks. **Administrative Science Quarterly**, 52: 507-557.

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.

Sydow, J., & Windeler, A. 1998. Organizing and evaluating interfirm networks – A structurationist perspective on network management and effectiveness. **Organization Science**, 9: 265-284.