



The means of managing momentum: Bridging technological paths and organisational fields

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ABSTRACT

This paper examines how technological and organisational changes are mediated through different means of mutually monitoring and collectively coordinating technological developments in the field of semiconductor manufacturing. As collective practices, both monitoring and coordinating aim at generating momentum in order to stabilise or redirect technological paths in organisational fields. The empirical analysis of innovation practices in the field of semiconductor manufacturing technology shows that the means of managing momentum, above all roadmaps, conferences, and R&D consortia, influence and transform the development of new technologies as well as the social relations within the organisational field. The transformative capacity of these means is elaborated conceptually using Giddens' theory of structuration.

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1. Introduction

Technologies drive organisational change as much as organisations influence the development of technologies. Hence it comes as no surprise that the interaction between technological and organisational change is a central object of organisation research in general and of research on technology and innovation in particular. For instance, research on socio-technical systems (Trist and Bamforth, 1951), strategic management (Chandler, 1977), evolutionary economics (Nelson and Winter, 1977), the social construction of technological systems (Pinch and Bijker, 1984) and, more recently, on the structuration of organisational technologies (Orlikowski, 1992) has highlighted the deep interrelation of social and technical components within and among organisations. At the level of industries or organisational fields, research on technical change (Rosenberg, 1963) and, more specifically, on dominant designs (Abernathy and Utterback, 1978; Dokko et al., 2012; Kaplan and Tripsas, 2008; Tushman and Rosenkopf, 1992) have emphasised the fusion of technological and organisational structures in a process of mutual adaptation.

Even though the mutual shaping of technologies and organisations has been widely addressed, their relation is still not well understood, particularly in terms of their process dynamics. Moreover, on the level of the organisational field – and especially in science-based industries – technologies and organisations are not only linked directly through processes of technological innovation, but also through intermediate agencies such as collaborative ventures (Barley et al., 1992), cooperative technical organisations (Rosenkopf et al., 2001), and new forms of management (Pisano, 2010). In this paper, we will analyse the role of specific means of cooperation and coordination like technological roadmaps, conferences and consortia in the mutual shaping of technologies and organisations. Such means are, at least in the field of semiconductors, widely used for managing “technological momentum” (Hughes, 1994). This is because in this field, but also in many others where standards matter, important technologies may constitute a dominant design or even a technological path (Arthur, 1994; David, 1985). By drawing on the empirical case of innovating novel semiconductor manufacturing technologies (SMT), we will show that the management of technological momentum is inseparably related to the specific organisational means of cooperative R&D.

High-volume SMT provides an excellent case for studying not only the constitution of a dominant design, but even more so of a technological path, since the entire industry seeks to identify one, and only one, technological option among several competing alternatives to become the global standard for high-volume chip manufacturing in the future (Sydow et al., 2012). Adopting a process perspective, the notion of technological paths allows us to

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account for the contingent stabilisation of a technological option over time. To analyse the constitution of technological paths in more detail, we draw on the concepts of path dependence (Arthur, 1989; David, 1985) and path creation (Garud and Karnøe, 2001; Garud et al., 2010) and adopt a social-constructivist and gradualist approach towards path constitution (Meyer and Schubert, 2007; Sydow et al., 2012; Windeler, 2003), which informs us as to how technological options become stabilised both through undirected processes of change, as well as the strategic activities of knowledgeable agents in the field. We look at these dynamics on the level of the organisational field (DiMaggio and Powell, 1983) in order to account for the collective nature of managing technological paths and interorganisational change.

The means of managing momentum are one important aspect in the relationship between technologies and organisations more generally, and in accounting for the dynamics between them in particular, because they help to 'bridge' the development of technological paths on the one hand with the transformations of organisations and organisational fields on the other. By introducing new ways of collectively developing novel technologies, these means transform not only the technologies of chip manufacturing, but also (inter-)organisational structures in the field. Even though these means are employed by powerful field actors, they cannot be fully controlled by them; instead, they occasion the contingent emergence of interrelated arrangements of technologies and organisations.

In order to conceptualise the transformative capacity of such means, we take up ideas from the pragmatist tradition (Dewey, 1958, pp. 121–165) which – in stark contrast to utilitarian or functionalist notions – understands means not as *mere means to ends*, but as *transformative agencies* that enable and constrain, and thereby shape courses of action. We refine Dewey's emphasis on the inherently contingent, practical and mediated nature of human experience with Giddens' (1984) theory of structuration by conceptualising the means of managing momentum to simultaneously produce and re-produce technological paths and organisational fields – i.e. they constitute and transform the relations in which they are embedded. In particular, we will develop our argument along three lines of inquiry that bridge technological paths and organisational fields by combining insights from (a) evolutionary economics, (b) organisational research, and (c) science and technology studies.

First, the focus of inquiry in all these fields of study shifts from the individual to the collective. Since the days of Schumpeter (1912) the number of technological developments driven and controlled by individual entrepreneurs or large integrated companies has steadily declined. This is especially true for the semiconductor manufacturing industry, in which the in-house mode of innovation dominant until the mid 1970s (Mowery and Rosenberg, 1998, pp. 124–166), has been rapidly replaced by collaborative R&D since the mid 1990s (Ham et al., 1998; Sydow et al., 2012). The means of managing momentum are therefore mainly located at the level of the organisational field.

Second, the development of technology in science-based fields is inherently complex, uncertain, and dynamic. Current high-volume SMT combines leading-edge applications in physics, chemistry, and mechanics, and closely connects technological and industrial dynamics (cf. Langlois, 2000; Malerba et al., 2008). The complexity, uncertainty, and dynamics of these developments resonate with the industry's widely shared understanding that no single company is capable of handling these processes individually. This includes supplying the necessary financial resources as well as technological knowledge. The very task of aligning the required components of this science-based technology is so demanding that the limits of established organisational forms of technology development quickly become apparent (Chuma, 2006).

Third, and a key focus of our paper, is that technology development and organisational dynamics in SMT are mediated by different means of monitoring technological progress and coordinating collective R&D. The social construction of technologies and the controversies surrounding competing technological alternatives (Bijker et al., 1987; Pinch and Bijker, 1984) in this area are not only characterised by direct struggle between opposing parties, but also by a collectively mediated process of generating consensus and commitment (Dokko et al., 2012). In line with Giddens (1984), we argue that the means of managing momentum can be understood as collectively organised practices for monitoring and developing technologies that have, over time, become taken for granted within the field and thereby changed the way actors evaluate technologies and organise collective R&D ventures.

Our empirical data stems from an extensive qualitative study in the semiconductor manufacturing industry. The main sources of information are interviews with 68 representatives from the field conducted from 2003 to 2010, with a total of 96 interviews (for more detailed information on the sample see Sydow et al., 2012). Selected key informants were interviewed multiple times and in part on different technological and organisational issues. The interviews were conducted with industry representatives from companies along the SMT supply chain (device makers, tool makers, and component suppliers), test facilities, R&D consortia, university institutes, and government funding agencies. The selected industry representatives are typically in charge of the innovation process within the companies and across cooperative R&D ventures. Interviews were conducted in Europe, the US, and Japan in order to account for the global nature of the industry. In addition, we interviewed selected academic experts and carefully analysed the trade press, as well as industry and academic publications from the past twenty years. The qualitative data allows for an inside perspective on technical and organisational change, which we complement with quantitative data for tracing how the changes manifest over time.

Following Giddens' (1984, p. 284) idea of "double hermeneutics", we study the actors as they create shared frames of meaning and combine necessary resources by collectively organising the transition from one generation of manufacturing technology to the next. This gives us the indispensable inside perspective needed to explain the reflexive managing of momentum and the emergent stabilisation of technological paths and organisational fields. Thus, we conceive the innovation practices in SMT, like all other social practices, as inherently "situated activities" (Giddens, 1979, p. 54), in which social structures are not simply complied to, but also created. Such emergent phenomena can only be explained if we understand innovation practices as "going concerns" (Hughes, 1971, p. 52), as continuously made and unmade as the actors struggle for extending and creating technological paths (Sydow et al., 2012). Tracing the institutionalisation of novel means of coordinating and cooperating into shared innovation practices allows us to reconstruct not only how such means are used and shaped by actors, but also how they themselves increasingly shape technologies and organisations in the field. In terms of social theory, we conceive the actors in the field as "knowledgeable" (Giddens, 1984, p. 30), being much aware of relevant features and practices and reflexively using this knowledge to monitor and influence the course of technological innovation. To this we add the idea that the actors in the field do not monitor actual progress directly, but rather through collective means of managing momentum, which then shape the expectations and evaluations of technological solutions.

This approach is particularly helpful to explain the switching from one technological path to another. Taking a novel manufacturing technology from the conceptual level to a proof of principle and finally into high-volume production requires more than a decade

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