



RESEARCH CONTRIBUTIONS TO ORGANIZATIONAL
SOCIOLOGY AND INNOVATION STUDIES

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The Sociotechnical Constitution of Fields

**Integrating technology into the conceptualization
of organizational fields**

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Organizational Sociology and Innovation Studies

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Abstract

Technology is an essential component of every modern society. Furthermore, new technological possibilities play a key role as catalysts and drivers of far-reaching socio-economic change. When seeking to analyze and reconstruct such transformations, such as in the context of case studies, for example, researchers often use institutionalistic field concepts as heuristic and general frameworks. This is surprising, since technology, as an important engine of change, is virtually absent from such field concepts. This paper discusses the role of technology in the structuring, organization, and transformation of fields. It explains how technology can be integrated into the conceptual framework of organizational fields and why the latter should be understood and analyzed as sociotechnical units.

Zusammenfassung

Technik ist ein wesentlicher Bestandteil jeder modernen Gesellschaft. Darüber hinaus spielen neue technologische Möglichkeiten eine Schlüsselrolle als Ausgangspunkte und treibende Kräfte für weitreichende sozioökonomische Veränderungen. Institutionalistische Feldkonzepte werden oft als Heuristik und Analyserahmen verwendet, um solche Veränderungen zu analysieren und zu rekonstruieren, beispielsweise im Rahmen von Fallstudien. Das ist erstaunlich, da Technik als wichtiger Motor des Wandels in solchen Feldkonzepten praktisch nicht vorkommt. In diesem Beitrag wird die Rolle von Technik für die Strukturierung, Organisation und Transformation von Feldern diskutiert. Es wird herausgearbeitet, wie Technik in den konzeptionellen Rahmen von organisationalen Feldern integriert werden kann und warum letztere als soziotechnische Einheiten verstanden und analysiert werden sollten.

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1 Introduction: Technology as a blind spot of institutionalist field theories (2024)

It should be undisputed that technology is a constitutive element of any modern society. Whether as artifacts, as large-scale industrial facilities, as large technical infrastructure systems, as software, methods or process technologies, or as everyday technologies: technology enables and influences a diverse range of societal relations and interactions. No reproduction of economic sectors, no production process or service provision, no financial transaction, no administrative procedure, no transportation or logistical operation, no communication, no war, and virtually no everyday event would be possible without technology. Technology penetrates deeply and broadly into society, structuring it and regulating it.

In addition, new technological possibilities such as digitalization in all its forms and facets, algorithmic control, renewable energy sources, or electromobility tend to play a key role as catalysts and drivers of sometimes far-reaching socioeconomic transformations—for example in changing transport and energy infrastructures, in stock and currency trading, in retail, in the area of transport services, travel and room bookings, or in entire economic sectors such as the automotive, energy, or media industries (Dolata 2009). Institutional field concepts (and especially the concept of ‘strategic action fields’ by Neil Fligstein and Doug McAdam) are often used as a heuristic and general framework to analyze and reconstruct such sociotechnical transformations. What is remarkable about this is that technology, as an important driver of change, plays virtually no role in these concepts of fields.

From an institutionalist perspective, fields are typically conceptualized as purely *social* entities. Firstly, they are actor-oriented, with a focus on “the totality of relevant actors” in the field (DiMaggio/Powell 1983: 143). Secondly, they are interaction-oriented, here, the researcher places the actors in relation to one another and identifies typical patterns of interaction characterizing the field. And thirdly, they are institution-oriented, meaning that the actors are understood to act and interact against the background of identifiable social rules and within a specific institutional framework that characterizes the respective field.

All that is well and good. However, there is the one crucial gap that needs to be filled. Fields of any kind are not constituted solely of social actors and social institutions, but always also have their own specific technological profile or design, which significantly influences the possibilities for action and the institutional framework. No field functions without technology. And field dynamics (such as in the case of driving services or room rentals, the automotive industry, or the energy sector) cannot be adequately depicted without systematically drawing on the specific characteristics and the transformative role of new technological possibilities. The rise of Uber or

Airbnb, for example, would have been unthinkable without all the new possibilities in matters digital networking and algorithmic control. In short: fields of any kind have to be conceptualized as *sociotechnical* entities.

The following text is an attempt to narrow this gap, namely by dealing with the role of technology in the structuration, organization, and transformation of fields—a concept I refer to as the *sociotechnical constitution of fields*. That said, apart from this brief introduction, this text is not a new one. It was written in the early 2010s—a time when the discourse around fields and technology was still in its infancy—and was initially published as a chapter in my book *The Transformative Capacity of New Technologies* in 2013 (Dolata 2013: 7–21). In a way, the argument made was ahead of its time and is worth revisiting to this day, as it linked institutionalist field concepts with the question of what role technology can play in the conceptualization and transformation of fields. This vintage paper from the vault explores this using the example of economic sectors as an almost archetypical and thoroughly generalizable type of sociotechnical field.

2 Business sectors as sociotechnical fields (2013)

I start by clarifying what a sector is, what technology can be, and how the two are related. I will begin with three introductory definitions.

Business sectors such as the automotive, financial, music, or pharmaceutical sectors of course have specific economic cores, but these are embedded in and influenced by their wider social environments. An economic core of a sector is characterized by specific business activities (research and development, production, distribution, services etc.), modes of exchange (markets, networks, competition), and actors (companies). However, from a sociological aspect, a business sector is to be seen as more than merely a branch of industry. Sectors are influenced and structured through actors, environments, and regulatory frameworks that go beyond the mere economic. These include political actors, government agencies, the whole range of media institutions and associations, academic and public research institutions, social movements and communities, consumers, and politically informed individuals all of which can considerably influence the structuring and future course of business sectors in one way or another: by shaping the conditions for research, production, markets, and company activity in both normative and regulative ways; by non-economic actors providing services (e.g. firms collaborating with academic research institutes); by public discourse and protest; or by the purchasing decisions made by individual consumers.

Institutional research has analyzed such entities as *organizational fields* (DiMaggio/Powell 1983; DiMaggio 1986; Powell/DiMaggio 1991), *interorganizational fields*

(Leblebici et al. 1991), *societal sectors* (Scott/Meyer 1991), or as *strategic action fields* (Fligstein/McAdam 2011, 2012). Paul DiMaggio and Walter Powell (1983: 143) provide the standard definition:

“By organizational field, we mean those organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products. The virtue of this unit of analysis is that it directs our attention not simply to competing firms [...] or to networks of organizations that actually interact [...], but to the totality of relevant actors.”

A sector’s shared rules and regulatory framework form the basis for structured and reliable interaction between its actors: “Fields only exist to the extent that they are institutionally defined” (DiMaggio/Powell 1983: 143).

This permits a *first definition*: business sectors are *socioeconomic fields* with distinct rules and regulatory frameworks, actor configurations, and relationships which together constitute a distinct area of economic activity (e.g. the manufacture of cars or machinery, or the provision of financial services). Although sectors are sustained by a core of economic structures and actors they are also clearly influenced by non-economic actors and shaped by social institutions, e.g. statutes, regulations, standards, conventions, routines, values, and prevailing ideas. Markets can likewise be conceived as fields (Fligstein 2001: 67–98; Beckert 2010: 609f.).

But this is not all. No business sector (or any other organizational field or societal subsystem) can function today without technology. Sectors are highly dependent on the availability and use of advanced technological artifacts, highly-automatized production and distribution systems, complex technological infrastructures (e.g. transportation and energy supplies), technological methods, programs and processes, and information and communication networks. Remove technology and every business sector, as well as society at large, would immediately collapse. Technology is not merely an accessory to the dynamism within a sector; it is a central element giving structure to the sector. Without technology no business sector would survive. Therefore, any definition of a business sector must take into account the effects technology has on its specific structuring. A *second and extended definition* therefore characterizes business sectors as *sociotechnical fields* that are constituted not only by specific social actor figurations, structures and institutions but also by distinct technostructures (Rammert 2007).

In the literature, only the concept of sectoral innovation systems has established a systematic relationship between sectors and technology. Since the mid 1990s, this concept has been introduced (predominantly by Franco Malerba) and widely accepted as a variation on the concept of national innovation systems. It focuses on the specific socio-technical conditions a sector possesses for the development and production of technological innovations: i.e. on the sector’s existing knowledge base and underlying technology as well as on its participating actors, networks, and characteristic institutions (Breschi/Malerba 1997; Malerba 2002, 2004, 2005). This focus on a sector’s existing

sociotechnical structuration may explain why one sector is more innovative and competitive than another. However, this approach is too narrow for our purposes here. For one thing, the concept is static: it does not take into account and cannot explain processes of sectoral transformation and the significance technological change has in this. For another, it looks only at those business sectors where processes of technological innovation take place and that invest heavily in the research, development, and production of new technologies.

But when considering technology-induced sectoral transformation, *two types of business sectors* become relevant. On the one hand, there are obviously those sectors that are directly involved in the development, production, and commercialization of new technologies. These sectors can be characterized as having a high degree of innovative activity, examples being the chemicals and pharmaceutical sectors, the automobile industry, the energy and telecommunications sectors, or the aerospace industry. In these sectors, usually referred to as sectoral innovation systems (Malerba 2004), technology-induced sectoral change may derive both from internal innovation processes and from new technologies developed in other sectors—especially new information and communication technologies—which are tailored to the specific demands of the utilizing sector. A typical case in point is the current transition in energy production. It is based on the internal development of new decentralized and flexible energy production technologies, as well as on the implementation of new externally developed information and communication technologies, which at the same time foster new possibilities for the centralized management of complex and distributed energy systems (Rohracher 2008).

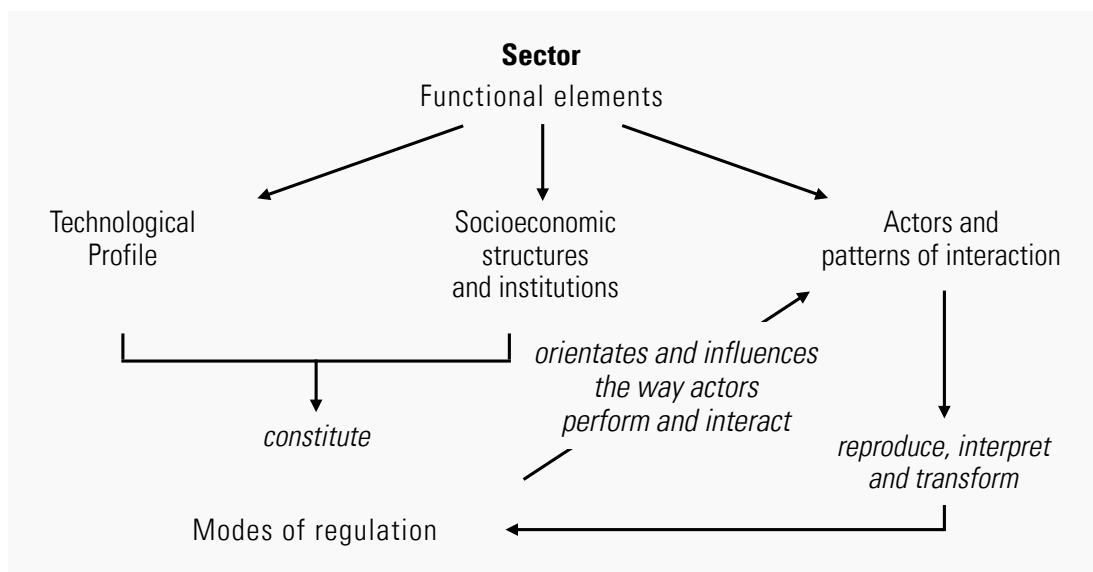
On the other hand, there are other important economic sectors that cannot be characterized as innovation systems. Instead, these sectors mainly use technologies developed elsewhere and adapt them through processes of co-invention in a sector-specific way (Greenstein/Prince 2006; Goldfarb 2005; Oudshoorn/Pinch 2003). This is characteristic of the music and media industries or banking and finance, where new technologies, inducing sectoral change, primarily seep into the sector from the outside. Since these sectors predominantly use externally developed technologies, their functioning may also be severely altered by the new technological opportunities. Once again, it is the information and communication technologies in particular that can trigger substantial processes of sectoral restructuring.

A *third definition* of what a business sector is therefore has to take into account these *two basic types of sectors* that become evident when examining technology-induced sectoral transformation: those sectors characterized by their active involvement in processes of technological innovation; and those that utilize predominantly externally developed technologies. However, the following applies to any business sector (including those that predominantly utilize technology): as sociotechnical fields all sectors are characterized by distinct technological profiles, socioeconomic structures, institutional arrangements, specific actor figurations, and patterns of interaction.

3 Surveying and mapping the functional elements of sectors

Before dealing with the issue of technology-induced sectoral transformation, a precise explanation is required of the functional elements that make up a business sector (or any other field), and how these elements relate to each other. This involves conceptualizing a sector's technological profile, its structural and institutional context, its actors and patterns of interaction, and the ways in which these elements interact to reproduce and transform a sector's performance (see *Figure 1*).

Figure 1: Business sectors as sociotechnical fields



Source: Dolata 2013: 20

3.1 Technological contexts: Types of technology and technological profiles

Business sectors, like other fields or societies in general, are not just socially based systems but are also sociotechnical entities (Geels 2004). They are comprised not just of social relationships but also of the technologies that they develop, produce, and use. Any business sector—whether automotive, engineering, aerospace, chemicals, pharmaceuticals, telecommunications, the media, or electronic components—has its own specific technological profile.

To profile a sector's technological basis first requires a definition of what technology actually is (or might be). In explaining technology, I emphasize three different aspects.

First, technology today can be many different things. As well as being individual artifacts, technology can also be large-scale facilities or large technical infrastructure systems, new cross-sectional technologies, or methods, processes and programs (like software). Furthermore, much of today's advanced technology—robotics, software, or

multi-agent systems—are not just passive objects but also ‘act’ in one way or other. Advanced technology has become active, interactive, and intelligent and its operations can no longer be entirely predetermined and controlled (Rammert/Schulz-Schaeffer 2002; Rammert 2003). However, technologies differ not only in their purely technological attributes but also in the distinct forms of their social organization, regulatory requirements, and socioeconomic effects. The organizational, structural, and institutional characteristics of a sector are highly affected by the specific properties of the basic technologies that sectors develop and use, whether these are large-scale technologies, technical infrastructure systems, new cross-sectional technologies, or personal, everyday technologies. Charles Perrow (1984, 1986), in his examination of complex organizations and technology’s failure-risk, came up with a basic two-dimensional typology that distinguishes between technology’s coupling (loose versus tight) and complexity (complex versus linear interaction). He was then able to assign these ‘appropriate’ governance structures. Herbert Kitschelt (1991: 492) also revealed a close correlation between a technology’s properties and a sector’s organizational and regulatory frameworks: “Technological features are one of the major factors shaping the institutions of industrial sectors.” Technologies therefore need to be classified into different types according not only to their *technical* characteristics but also, in a wider sense, to their distinct *sociotechnical* features.

A *second* aspect of technology is that business sectors are not just influenced or shaped by those technologies that have solely or primarily emerged within the sector itself. These days, sectors are more likely to be affected either by a combination of internally and externally developed technologies, or by technologies that are generated only externally. Even the technological profiles of the many sectors that develop and produce new technologies—such as the automotive, engineering, or pharmaceuticals sectors—include externally developed technologies which have then been tailored to a sector’s specific requirements. An obvious example is the multitude of new information and communications technologies that can be applied in almost any sector. These technologies play a major role in research and development (e.g. in active-agent research or the decoding of the human genome), are often a central component in manufactured products (e.g. as electronic components in vehicles and machinery), form the backbone in complex networks of production, logistic, distribution, and services, and can redefine an entire sector’s structure and methods of operating (e.g. as shown by the effect data compression, digitalization, and the internet technologies have had on the music and other media sectors).

A *third* aspect is that technology not only affects the structuring of a sector but can also be the initiator of that sector’s transformation. Since the mid-1970s, modern biotechnologies, for example, have been the triggers for wide-ranging change, primarily within the pharmaceutical sector (Orsenigo 1989; Henderson/Orsenigo/Pisano 1999; Dolata 1996, 2003). Since the beginning of the 1980s, digitalization has enabled the telecommunications sector to decentralize and liberalize. This would not have been

possible without the associated technological innovations (Werle 1990). Since the end of the 1990s, the internet has brought about radical restructuring processes, initially within the music sector and then, from the mid-2000s, the film, newspaper, and book sectors (Küng/Picard/Towse 2008; Dolata 2011; Currah 2006, 2009; OECD 2010). Radical technological innovations can penetrate deeply into a sector's research, production, and distribution structures; they can support and increase existing knowledge and competencies or make them obsolete; they can create, eradicate or transform markets, initiate the development of new forms of organization and practices, and trigger new consumer preferences or the need for new regulations (Lynn/Reddy/Aram 1996; Freeman/Perez 1988; Henderson/Clark 1990). In other words, major change to a sector's technological profile also generally brings about change to its underlying organizational, structural, and institutional conditions.

It follows from the above that it is futile to search for a general term for technology that can be applied to all business sectors. I suggest that a sector's technological profile and technology's effect on a sector's structuration can be better understood by answering the following questions (from Dolata 2003: 93–102):

- *Technology type.* What type of technology characterizes the sector under investigation? Is it based on large-scale technologies or large technical infrastructure systems that require high levels of organization and capital? Or does it concern knowledge-based and decentralized cross-sectional technologies? Or is it a fundamentally commonplace, everyday type of technology?
- *Usage and requirements.* Is the technology consumer-oriented and capable of personal use? Or is it large-scale and suited only to business applications?
- *Knowledge base.* Is it a field of technology that is deeply rooted in academic research, or one that is based on more practice-oriented, engineering expertise? How accessible is the knowledge and to what extent can it be applied?
- *Endogenous and exogenous technology.* What is the relationship between a sector's internally- and externally-developed technologies? In particular, how and to what extent do new information and communication technologies affect sectoral processes of development, production, and organization?
- *Developmental dynamics.* Is sectoral development being affected by paradigmatic new technologies and radical innovations that have far-reaching socioeconomic effects? Or is it characterized primarily by established technologies and incremental innovations?

Responding to these questions enables inferences to be made about a sector's technological profile and how technology may affect sectoral structuring. The type of technology that characterizes a given sector promotes specific patterns of industrial organization, of market and consumption constellations, of competitive and collaborative relations, and of regulative environments. For example, large-scale technologies

that demand high levels of organizational and financial input (as in aircraft, aerospace, and nuclear technologies) cannot be developed, organized, and applied in the same decentralized and market-oriented way that small-scale, cross-sectional, and open-application technologies can (as in biotechnologies or internet-based technologies). Interaction between academia and industry is much more likely to occur in sectors characterized by science-based technologies (such as the pharmaceuticals sector) than in sectors using technologies that are more application-oriented and engineering-based (such as manufacturing systems). Sectors that develop and produce personal, everyday technologies (e.g. those sectors involved in consumer electronics or communication technologies) are influenced much more by individual consumers arbitrarily applying these technologies than those sectors producing large-scale technologies for use by business (e.g. in plant engineering and construction). In contrast to established technologies, paradigmatic new technologies generally require not only major industrial transformations but also new forms of social or ethical valuation and regulation. This pressurizes the affected sectors to undergo significant change.

The above classifying questions enable a sector's technological profile to be precisely defined. A technological profile functions as a distinct element within a sector and significantly influences its structures, institutions, and actor figurations. Similar to a sector's established social structures and institutions, its technological profile also affects sectoral patterns of organization and regulation and generates opportunities and restrictions for action—but in a non-deterministic way. For one thing, actors always have leeway, though not arbitrarily, to seek out appropriate organizational and institutional patterns that match technological requirements. For another thing, a technological profile is anything other than an ahistorical and static entity. Distinct technological features come with a history and, in conjunction with processes of innovation, often undergo incremental, at times even substantial change.

3.2 Social contexts: Socioeconomic structures and institutional arrangements

A technological profile is an important and often under-estimated functional element of a business sector. Of course, it is not the only element; sectors are also characterized by genuine social structures and institutions.

Every sector has specific *socioeconomic structures* which over time have become stable. These include:

- *Industrial and corporate structures*, i.e. a sector's internationality and its degree of concentration; the patterns and dynamics of competition and competitor interaction; the relationship between large businesses, SMEs, and technology start-ups; typical organizational features of core businesses; and characteristic inter-organizational patterns of interaction.

- *Research, production, distribution, market, and demand structures*, i.e. the organization and intensity of industrial research and development; the type of products or services being delivered; the characteristics of production and distribution; the structure of demand; and the targeted markets (e.g. capital goods or consumer markets).
- The *socioeconomic embeddedness of a sector*, i.e. the interaction with other sectors and non-economic actors (e.g. research institutions) and the significance of this for sectoral (re-)production; the field's political and regulatory structuring; the significance of innovative fringe activities for a sector's formation and dynamism; the role of civil-society actors.

Using the above enables a sector's socioeconomic topography to be identified. The game rules that are effective within a sectoral field are represented through specific *institutional arrangements*. These include the social rules, norms, conventions, routines, values, and prevailing ideas that shape and give stability to the activities of actors and the relationships between them within a given field of action (North 1990, 1991; Scott 2001; Scharpf 1997). Institutional arrangements may also be legally enforceable frameworks—such as legislation on drug and gene technologies or patent and copyright law—and common norms and routines shared by actors—such as agreed spheres of responsibility, the acceptance of lines of power, authority and dependency, the trust and confidentiality expected within economic networks, or political bargaining. And finally, these institutional arrangements may be the overall guiding principles and shared beliefs that characterize a sector (e.g. the life-sciences approach within the pharmaceutical sector).

Together, a sector's socioeconomic structure, institutional arrangements, and technological profile form the basis from which all sectoral activity takes place. But this basis is not at all static and deterministic. It initially forms and emerges through social interaction. And even when stabilized, a sector's structures, institutions, and technologies undergo continual re-interpretation and re-adjustment through its social actors and the ways they interact. Although actors might keep to the rules and defer to the status quo, existing rules and structures are permanently re-interpreted, violated, bypassed, circumvented, and even dismantled (Ortmann 2003). This takes place as processes of rivalry or cooperation, of industrial or social self-regulation, of bargaining between state and non-state actors, as social disputes or power struggles, or as the sovereign actions of government agencies. A sector's technological, structural, and institutional conditions undoubtedly stabilize its actor figurations and patterns of interaction, and influence the way actors perform. However, these conditions are “continuously created and recreated by a great number of actors with divergent interests, varying normative commitments, different powers, and limited cognition” (Streeck/Thelen 2005: 16; also: Mayntz/Scharpf 1995; Giddens 1984).

For our purposes here, this means that sociotechnical fields—such as business sectors—are in no way characterized by homogeneous identities, i.e. unanimously agreed and common structures, regulations, norms, and values. They are more likely to be shaped in a process of diverging interpretations, repudiations, and debates that take place continually between actors. These actors can be highly heterogeneous, representing differing interests with differing powers and influence. Business sectors are therefore not characterized simply by existing structures and institutions to which actors defer. They are instead characterized by processes of structuring and de- and re-institutionalization that are continuous and borne by a range of interests.

This is true even in periods of relative stability when sectoral actors continue to reinterpret, renegotiate, and slightly modify existing structures and institutions (Quack 2005). Such incremental adjustments may take place during a company's internal restructuring or strategic development, or arise from mergers and acquisitions. They might be the result of readjustments to cooperative networks, or emerge from permanent modifications to products, markets and the conditions for demand, or from initiatives to modify existing regulatory or legislative frameworks.

In contrast, in periods of substantial technological change, a sector's existing socioeconomic structures and institutional arrangements may undergo substantial transformation. Such periods often force established actors into a process of major strategic repositioning. Opportunities appear for new actors to expand, and new interest groups and power structures emerge. These then contribute to changes in a sector's markets and in the ways a sector competes, cooperates, and interacts. Established relationships between industry and science may undergo significant realignment, new lines of sectoral demarcation may emerge, or networking with other sectors may intensify. Periods of substantial technological change may also impose new instrumental and regulative demands on politics and may seriously question, reinterpret, complement or even replace the institutions that have shaped a sector and influenced the way its actors have performed. In the chemical and pharmaceutical sector, for example, this concerned the sector's guiding principles (from chemical syntheses to biotechnological paradigms), its companies (from large concerns that broadly diversify to specialist life-science companies), their corporate culture (from hierarchical and autonomous concerns to networked and cooperative companies), the regulatory framework (from conventional drug legislation to new forms of regulation on genetic research and production), and the broader societal discourse and debates (e.g. labeling laws for foodstuffs or issues concerning the ethics and restrictions on biomedicine).

Typical for such periods of substantial technology-induced change is the emergence of fundamentally new technological opportunities that cannot be exploited and fully developed within existing socioeconomic structures and institutions, structures and institutions whose ongoing functioning is then called into question. Initially, this increases both uncertainty and contingencies for action, and triggers search processes

that aim at identifying appropriate readjustments at the organizational, structural, and institutional level. These processes are characterized by major uncertainty, open up opportunities for differing interpretations, and may initially result in different and at times contradictory perceptions of problems, strategies, and guiding principles (Beckert 1996; van Lente/Rip 1998). Furthermore, these processes are often associated with wide-ranging debates and power struggles between actors who are compelled to reformulate their interests and strategies, to counter opposition, and to hold their own against competitors (such processes around the VHS and Betamax video standard have been well documented; see Cusumano et al. 1992). And finally, these processes of search and readjustment often emanate not from the sector's economic core but rather from its periphery.

“Radically new practices that may evolve into conventions are most likely to be introduced by parties from the fringes of an interorganizational field who are looking for ways to solve the problem of realizing value from transactions. These players are the newer and/or less powerful participants, for whom experimentation is less costly in final outcomes and who are less likely to be sanctioned by more central players. [...] The powerful parties who had vested interests in the institutionalized conventions used their resources to maintain the status quo or introduced practices that confirmed established conventions.” (Leblebici et al. 1991: 358; similarly Utterback 1996: 160–165)

This view is extremely important in being able to understand business sector structuration as well as in identifying the dynamics of sectoral transformation. Business sectors do not generally share homogeneous identities, structures, and institutions, especially at times of substantial change. Debates about socioeconomic and institutional restructuring do not usually remain within, and rarely even emerge from, a sector's established core and its actors. The impetus for change often comes instead from a sector's fringes, from actors who until now have not been at the sector's core. What emerges at these fringes are often new milieus with their own structures and rules that often diametrically oppose those of the sectoral core. An example here is the new non-commercial and non-market methods of transferring music via the internet, which from the early 2000s on were provided by peer-to-peer-networks and utilized by countless non-organized file-sharers. These dynamics and activities from the fringes placed the sectoral core of the music industry under immense pressure (Dolata 2011). Another example is renewable energy. In Germany, renewable energy has made progress and over decades has reached consolidation while remaining on the fringes of the fossil fuel and nuclear energy sector (Fuchs/Wassermann 2012). A final example concerns new biotechnologies. Before being adopted by the pharmaceutical sector's core, the development and early commercialization of new biotechnologies emerged on the sector's periphery, within academic research and biotechnology start-up firms (Orsenigo 1989).

To bring the point to a close, it is not sufficient to concentrate on a business sector's existing core and its established actors when considering sectors as dynamic sociotechnical fields in order to portray and explain their socioeconomic and institutional transformation. A major transformation rarely extends from the core of a sector but rather from innovations and dynamics at its fringes where new technological opportunities

are tested out, new and unknown actors can meet, and innovative environments can develop which possess their own qualities and which follow their own rules. Charting the transformative activities of a sociotechnical field must include not only its core structures, institutions, and activities but also its fringes: a playground for new cutting-edge actors, often in a fluid and dynamic state, and equipped with alternative sets of mainly informal guiding principles and rules.

3.3 Actors and patterns of interaction: Competitive and cooperative figurations

The same applies to a field's actors and its patterns of interaction. To observe a business sector's "totality of relevant actors" (DiMaggio/Powell 1983: 143) usually requires going way beyond the industrial core of actors. A field includes a multitude of social actors who relate to each other in figurations that are specific to the field. These actors are: producers, suppliers, and industrial consumers; political agencies that regulate and promote; technology companies that serve the market; technology-savvy sub-communities; scientific and research institutions; interest groups; media and social movements; and individuals who purchase and use technology for their own ends. In the following I will distinguish *three different types of actors* (Dolata 2003: 21–33).

Corporate actors, capable of acting strategically, are of course primarily involved in the reproduction and transformation of business sectors (Coleman 1974; Perrow 1991; Mayntz/Scharpf 1995). These actors include first the range of companies which form the backbone of a sector, i.e. multinational enterprises with divisions and subsidiaries, SMEs, and technology-based start-up firms. External companies, such as purchasers or suppliers, may also be significant to a sector's functioning and transformation. This is particularly evident from the major influence that companies from different IT and communications sectors have on the reproduction and transformation processes in other business sectors. Also significant are the non-industrial corporate actors associated with a sector. Among these are: government agencies, responsible for political initiatives and providing support and regulation; universities and scientific institutions, who can initiate processes of innovation especially within science-based sectors; interest groups from industry, trade unions and civil society; and media agencies that publicize the debates and issues surrounding new technologies. To fully understand actor-driven sectoral transformation requires first and foremost an examination of the strategic orientation, resources, and extent of influence of a sector's corporate actors.

But this is not all. The ways that corporate actors perform are neither uniform nor unambiguous. Their strategic (re-)orientations do not develop in a deterministic way as coherent anticipations and best-way-responses to new environmental pressures. Instead they emerge in search and bargaining processes within and between organizations. These processes of adjustment are significantly influenced by power relations, strategies, and the way problems are perceived by the leading individual members involved. Key persons, as *individual actors*, do not just play a major role in the formation

of new organizations. Strategic reorientations in established organizations are also taken forward mainly by executives with idiosyncratic perceptions, interests, strategic aims, and bargaining powers. Furthermore, individual reputations and authority, trustworthiness, and personal networking activities are important as coordinating and stabilizing links in inter-organizational interaction, i.e. in cooperations within industry, between industry and academia, or in processes of political negotiation and bargaining (Burns 1961/62; Cyert/March 1963; Crozier/Friedberg 1980; Ortmann 1995: 29–42). Without recourse to individual actors, personal relationships, and micro-political power relations, conflicts and negotiations, the strategic decisions and structural changes within organizations, as well as those between cooperating or negotiating organizations cannot be analyzed sufficiently and will remain a black box.

A third relevant type of actor exists mainly in sectors supplying products to consumer markets, or in sectors where innovation is controversial. These actors belong neither to the corporate type nor to the key individual actors possessing creative potential, influence, and bargaining power. Instead they can be characterized as *loosely connected and informally operating collective actors*. They gain in importance and power neither as organizations nor as individuals but as collectives with shared perceptions, beliefs, and interests. They may either operate without any organizational background at all and occur as swarms, or as identifiable communities with little formal structure. This heterogeneous type of actor include: maverick users of technology (e.g. file sharers) or technology-skeptic citizens (e.g. opponents to genetic engineering) who, as swarms, form preferences or dislikes for specific technologies; technology-savvy sub communities who, often without any commercial interest, develop alternative technologies (e.g. hackers or open-source communities); specialists in epistemic communities who become involved in public debates around technology (e.g. on the amendment to copyright laws); protest movements who operate beyond parliamentary debate and who oppose technology and its protagonists (Oudshoorn/Pinch 2003; Flowers 2008; Bauer 1995; Dacus et al. 2005; Djelic/Quack 2010; Dobusch/Quack 2010). Although these collective actors do not belong to a sector's core, the sum of their loosely coupled, decentralized, and arbitrary activities can significantly affect a sector's sociotechnical performance and the strategies of its established industrial and political actors.

Actors of different types and significance operate at the core and peripheries of sociotechnical fields. They also interact with each other in different ways by competing, cooperating, and bargaining or simply doing things that affect the others in some way. I identify four main *patterns of interaction* which occur in one form or another across all business sectors.

Competitive interaction. Any sector is of course characterized by specific competitive practices associated with industrial performance, innovation, and modernization. These practices can vary in influence and include: strategies to gain technological advantage in research and product development; attempts to monopolize, at least temporarily, new

knowledge; the acquisition and exclusive use of key patents; or efforts to bind competitors to one's own and proprietary technological norms and standards. Competitive practices also include all the enduring endeavors to optimize systems of production, assembly, and logistics as well as the strategies targeted either at improving existing market positions and competitiveness or at entering new key market segments that have future potential. And finally there are the conflicts, primarily within the internet, between commercial suppliers and markets (e.g. for music, films and books) and new forms of non-market exchange (Currah 2007).

Cooperative interaction. Specific forms of cooperative interaction also typically occur in sectors. They include: producer-supplier relationships (e.g. in the automotive industries) or producer-industrial customer relationships (e.g. in manufacturing systems engineering); large industrial consortia with a multitude of subcontractors (e.g. in the aerospace sector or in major traffic infrastructure projects); cooperation between large companies and technology start-ups as well as between science and industry (primarily in high-tech sectors such as pharmaceuticals; Dolata 2001). Cooperative interaction also includes the “large-scale collaboration among strangers or loosely affiliated users” which emerges mainly on internet communication platforms and social networking sites (Benkler 2006: here 84). Powell suggests that cooperative interaction is typical for virtually all sectors because “sources of innovation do not reside exclusively inside firms, instead, they are commonly found in the interstices between firms, universities, research laboratories, suppliers, and customers” (Powell et al. 1996: 118; also Freeman 1991; Powell/Grodal 2005).

Interaction through negotiation. The basic regulatory aspects of sectors, such as their legal and regulative frameworks, common values, norms, and generally accepted standards, are not just the outcome of competitive and cooperative interaction but arise from politically coordinated negotiations or non-governmental bargaining processes. In principle, this includes all the formal and informal types of negotiation and bargaining that a modern state is able to offer. These range from informal talks and formalized networks between political authorities and non-political actors such as key individuals, associations (e.g. employer associations or labor unions), and other corporate actors (e.g. major companies), through to regulated forms of exchange (e.g. commissions, hearings, task forces) which might involve additional non-governmental actors (e.g. environmental or consumer associations). Also included here are the negotiations that exclude state-authority participation, e.g. agreements between interest groups, between companies, or between actors from industry and civil society (Scharpf 1997).

Civil society interaction. Finally, there are the specific patterns of interaction taking place among swarms of non-organized actors—e.g. citizens, voters, consumers. These actors are not directly involved in the development, production, and marketing of new technologies, and nor involved in the policy and decision-making processes around technology. They may nevertheless actively influence the way a sector's corporate

actors behave—provided that the shared preferences of such non-organized actors, their misgivings, rejections, and the ways they apply technologies become mass phenomena. Civil society interaction also includes technology-savvy sub communities—e.g. those involved in the open-source movement or in the non-market trading of music over the internet. They develop or modify technologies as outlaw innovators (Flowers 2008), organize their own non-commercial working and user groups, and communicate and interact in informal and self-regulated milieus at the periphery of established structures. With their deviant technological and political activities, they can also put pressure on a sector's established actors and institutions and force far-reaching change.

4 The full picture: sectoral modes of regulation

Although business sectors are characterized by the specific products and services they deliver, it should now be clear that they are more than mere branches of industries. Sectors of course do have core structures that are purely economic. But they are at the same time socially embedded fields where, for example, political actors and frameworks are of significant influence; where academic research institutes and the knowledge they produce are relevant for the sector's reproduction; and where civil-society actors such as citizens, customers, or sub communities may unsettle and pressurize established actors. A sector's core structures, institutions, and actors indeed shape the field and the rules by which it operates. But this core often has an innovative periphery that is made up of its own actor figurations, structures, rules, and projects. This periphery may operate in parallel to the core, but the periphery's actors and innovative activities may also become serious challengers to the established actors and structures of a sector. In periods of substantial technological change, the trigger for transformation often comes from these fringes and not from the sector's core.

What should also now be clear is that business sectors are sociotechnical fields rather than mere social fields. They are defined not only by their structural and institutional characteristics but rather by their technological properties. Sectors obviously possess socioeconomic core structures and institutions that organize the field and formulate rules for its players. But sectors, whether they are pursuing their own technological innovation or applying technology from outside, are also always characterized by specific technostructures without which they would not survive. Both—the technological and the social constitution of a sectoral field—are not mutually exclusive. A sector's technological profile, its structures, and its institutional arrangements are intertwined and have to achieve a match for sectoral reproduction to take place efficiently.

A sectoral field's 'signature' emerges from the interplay between a sector's technological profile and its corresponding socioeconomic structures and institutions. This interplay constitutes specific sociotechnical conditions, rules, and opportunities which actors need to engage with in one way or another in order to become active and

successful players. This overall sociotechnical structuration is relatively stable and characterizes the normal functioning of a sector. It forms a recognized area of *socio-technical* life (to slightly modify the opening citation by DiMaggio and Powell) and constitutes what I refer to as a sector's *mode of regulation*, i.e. a framework that orientates, rather than determines, the way actors perform and interact (see *Figure 1*).

A sector's actors are of course not passive and do not defer unconditionally to existing structures and institutions. They pursue their own interests and have specific power resources at their disposal. They constantly reinterpret rules and structures, adapting them and changing them. A sector's mode of regulation, its underlying technological, socioeconomic, and institutional basis, generally remains stable and resilient over longer periods of time. Otherwise the sector would not function efficiently. But this does not mean that a sector remains static. Even under normal conditions, it is constantly reproducing or undergoing incremental modification through the independent and frequently unforeseen way its actors perform and operate. And in times of major technological change, sectors can even undergo radical transformation.

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