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# **Technological Innovations and the Transformation of Economic Sectors**

**A Concise Overview of Issues and Concepts**

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## **Abstract**

The paper examines two main questions: First, how are economic sectors changing under the influence of new technological opportunities that bear an enormous potential for development and deployment for them? And second, how might this kind of sectoral transformation be analyzed? To pursue these questions, it first presents selected approaches to the topic, followed by a pragmatic concept for analyzing technology-related sectoral transformation processes.

## **Zusammenfassung**

Der Aufsatz geht der Frage nach, wie sich Wirtschaftssektoren unter dem Eindruck grundlegend neuer technologischer Möglichkeiten, die dort ein enormes Entwicklungs- und Einsatzpotenzial haben, verändern und wie sich ein solcher sektoraler Wandel durch Technik analysieren lässt. Dazu werden zunächst ausgewählte Zugänge zum Thema vorgestellt und daran anschließend forschungspragmatische Überlegungen zur Untersuchung technikgeprägten sektoralen Wandels vorgestellt.

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## 1 Introduction

The main focus of social science-based innovation research is the examination of the origin, spread and establishment of technological innovations, and more recently also of social innovations. It looks at, in particular: the different actors, social relationships and social practices in which innovations are spawned and consolidated; the structural or institutional framework conditions and national, regional or sectoral contexts that promote or constrain innovation dynamics; the regulation of innovation processes, such as in organizations and networks or through policy; as well as the assessment of their potential consequences (Windeler 2016; Rammert 2010; Lüdtko 2016). In contrast, this paper will examine how processes of socioeconomic change take place that are substantially triggered and supported by new technologies or broader technology clusters. More specifically, it looks at how economic sectors as larger socio-technical fields are changing under the impact of fundamentally new technological opportunities, and how such sectoral transformations can be analyzed.

There is no dearth of examples: Since the mid-1970s, genetic engineering has profoundly expanded the technological profile and knowledge base of the pharmaceutical sector; changed pharmaceutical products and markets; triggered a significant reorientation of the established companies; necessitated the establishment of systematic cooperative relationships between pharma companies, start-ups and research facilities; and led to substantial changes in the regulatory framework of the sector (Henderson et al. 1999). Similarly, recent years have seen the considerable socioeconomic effects of digitalization, data compression and the internet on various media sectors (Küng et al. 2008; Dolata and Schrape 2013); changes in the communication technology sector through the development of mobile phones and smartphones (Giachetti and Marchi 2017); and transitions triggered by digitization in the production and product structures of the automotive industry and other classical industry sectors—changes, or trends, that have been labelled “Industry 4.0” and the “smart factory” (Athanasopoulou et al. 2016).

In this way, the following discussion validates a shift in perspective that has already been proposed, in the German research community, by Raymund Werle (2005, 2012) in the first half of the 2000s. According to this new perspective, research is to focus not only on the formation and dissemination contexts but also on the socioeconomic effects of technological innovations. To this end, I first present selected approaches to the topic, followed by pragmatic considerations on the analysis of sectoral transformations that have I developed since the end of the 2000s (for more details, see Dolata 2009, 2013). Of interest here are, in particular, the effects of technology fields with a high transformative capacity, understood as effects with an enormous potential for development and deployment in those fields—yet that can only be realized by means of major socioeconomic or socio-technical transformations in those sectors.

## 2 Current state of research: Periods of mismatch, selection pressures, adaptive capacities

The overall link between radical technological innovations and associated social and socioeconomic adaptation processes had already been pointed out by Heinrich Popitz (1992, p. 39f.):

“Technical innovations of a certain scale are accompanied by social changes, or ‘social correlates,’ of varying character. Two types of social correlates are of interest here. One, social innovations understood as the necessary condition for technical innovations: a new technology (e.g., metallurgy) can only be introduced when a particular social transformation has taken place (e.g., division of labor). Two, the consequences invariably resulting from the requirements of modern production technology (e.g., the spatial concentration of the workforce in industrial production) or the inevitable consequences of new products (e.g., new ways of obtaining information in the age of television).” (Our translation)

In a similar vein, Herbert Kitschelt, albeit with a view to economic sectors, referred to what Popitz called social correlates as *match*. He emphasized, in particular, the need for compatibility between the existing technologies and their socioeconomic structures and institutions, arguing that “industrial sectors, identified by core technologies, efficiently operate only if governance structures match technological constraints” (Kitschelt 1991, p. 468).

The *literature on innovation economics* of the late 1980s, for its part, examined technological dynamics and their attendant socioeconomic changes, underscoring the increasing difficulty of finding any kind of compatibility, or match, in times of major technological transitions. Since the end of the 1970s, these transitions have been characterized by the broad spread and radical ongoing development of new digital information, communication and networking technologies as well as by genetic engineering and nanotechnologies. According to the argument, the more substantial or incisive new technological opportunities are, the more difficult it is to develop and utilize them within the framework of established organizational patterns, structures and institutions. These authors see major technological transitions as leading to a situation where “the established social and institutional framework no longer corresponds to the potential of a new techno-economic paradigm” (Dosi et al. 1988, p. 11). This engenders, they claim, periods of mismatch, accompanied by major crises of adjustment, understood as long(er) periods of time needed to search for, experiment with and engage in new organizational patterns, structures and institutional arrangements that might match the new technologies. Further, such adaptive processes and crises are seen to culminate in a new functional relationship between technology, socioeconomic structures and institutions:

“Social and institutional changes are necessary to bring about a better ‘match’ between the new technology and the system of social management of the economy – or ‘regime of regulation.’” (Freeman and Perez 1988, p. 38; see also Rip and Kemp 1998)

This stylization of socio-technical transformation processes is characterized by three main points: technologies are not viewed in isolation from the socioeconomic contexts in which they are developed and implemented; major technological transitions and substantial changes in organizational, structural and institutional frameworks are put into relation to one another; and, importantly, such restructurings are seen as “period[s] of considerable confusion” (Henderson and Clark 1990, p. 12) that generally take a longer time before a new and relatively stable match between technology and the socioeconomic context is established.

While this approach has merits, it remains unsatisfactory in various respects. First, it has a strong economic bias, whereby social contexts and changes within the framework of technological transitions remain underexposed. Second, it refers primarily to the meta-level of economic systems or societies, thereby losing sight of the differentiating, or different, sectoral impacts of a new technology field. Third, it remains vague as to questions about the typical variants and patterns of such periods of mismatch and how exactly they evolve and unfold.

Some of these open questions have been addressed by the more recent research on *socio-technical transformation*. This field of research sought to identify different transformation contexts and, building on those, to distinguish between various socio-technical transition paths (Smith et al. 2005; Geels und Schot 2007; Geels und Kemp 2007; Geels 2007). Adrian Smith et al. (2005), for example, presented a model that explains the transformation of a socio-technical regime on the basis of the interplay of two processes: the selection pressure, which a regime is always exposed to (for whatever reasons), and its adaptive abilities, in other words, the capacities and resources with which it can respond to the selection pressure.

“We understand regime change to be a function of two processes: 1. Shifting selection pressures bearing on the regime. 2. The coordination of resources available inside and outside the regime to adapt to these pressures.” (Smith et al. 2005, p. 1494)

The selection pressure that a regime is exposed to can be as different as the perception and processing of this pressure.

“More adaptive regimes will be those whose membership can most effectively reproduce regime functions in the face of prevailing selection pressures.” And conversely: “When the adaptive capacity of the regime is weak, it can be outside groups who build up the functions that generate the alternatives needed for change.” (Smith et al. 2005, p. 1496)

Distinct transition variants, then, result from differences in how a given selection pressure interacts with a regime and its adaptability (see also Geels and Schot 2007).

However, what is lacking in this research stream is a more systematic elaboration on these considerations. Thus, beyond rather generic conclusions, it remains unclear how selection pressure is created, what exactly comprises it, and how it affects a socio-technical regime. The same applies to the adaptive capabilities of a regime. At times

these are portrayed as strong and at times as weak, with no explanation for why and when one or the other might be the case. Finally, the attempts at classifying regime transformations remain unsatisfactory. The presented variants are not systematically derived from the interplay of selection pressure and adaptive capabilities, nor are they distinguished from one another on the basis of ideal types.

Nonetheless, these considerations also have some merit. This applies in particular to their basic premise that socio-technical transformation processes become manifest through the interplay between a distinct selection pressure and the similarly distinct adaptive capacity, understood as the opportunities which the field under investigation (regime, sector) has to perceive, take up and deal with that pressure.

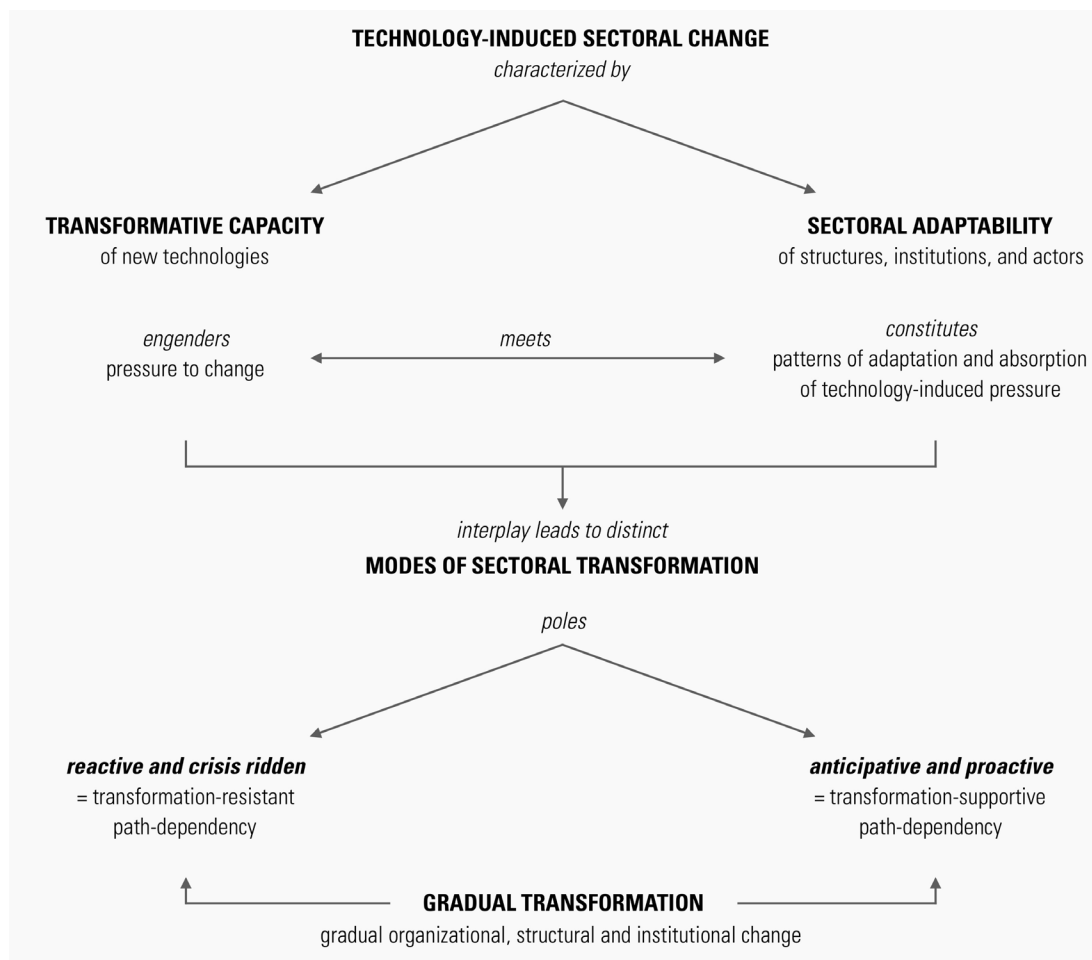
In contrast to these instructive approaches to the topic, the concept of *sectoral systems of innovation*, introduced in the second half of the 1990s (mainly by Franco Malerba) as a variant of the national innovation systems approach, has contributed comparatively little to the analysis of technology-related transformation at the meso level of economic sectors. This was due to the fact that it concentrated primarily on sector-specific characteristics of the development and production of innovations, which were decisively influenced by the prevailing knowledge and technology base, their respective actors and networks, as well as the predominant institutions (Breschi and Malerba 1997; Malerba 2002, 2004, 2005, 2006). To its credit, the concept did offer a well-manageable heuristic framework for the comparative empirical analysis of stable sectoral innovation systems and processes (Mowery and Nelson 1999). However, it did not, or not for the longest time, pursue the questions of when and how economic sectors themselves become unstable; what role the emergence of fundamentally new technological opportunities can play therein; and the way(s) in which sectoral transformation processes take place—not only in sectors that are characterized by an independent technological innovation activity but also in those that primarily use technologies that were developed outside of their system and used in a system-specific way.

These questions were only taken up recently, namely in the context of the observation that economic sectors and firms from latecomer countries are capable of successfully catching up and of joining the ranks of internationally leading industries and companies that are challenging the until then dominating sectors from leadership countries (Malerba and Nelson 2012; Lee and Malerba 2017). Yet, two conditions must be met for such a catching up to take place. One, there must be windows of opportunity that the latecomers proactively seize. These may include, for example, fundamentally new technologies or radical innovations which economic sectors in latecomer countries reorient themselves to early on and in an adaptive manner. Two, the chance to actually catch up is also increased if the internationally leading sectors and their actors turn out to be incapable of adapting. “The incumbent then continues to use the current technology and tends to ignore the possible destructive potential of new technology or new products” (Lee and Malerba 2017, p. 334). In short, the eco-



economic sector of one country can prove to be more adaptable to new technological framework conditions than the same sector in another country, and can improve its international competitive position during catch-up cycles. However, the conditions under which this may occur and how it might take place remains unclear, whereby these more recent studies, too, are wanting.

Figure 1: Technology-induced transformation—main analytical categories



Since the late-2000s, I developed a heuristic framework for analyzing and explaining distinct patterns of technology-based sectoral change (Dolata 2008, 2009, 2011, 2013). It is based on three related concepts (Figure 1).

According to the *first concept*, the (potential) range of technology-driven sectoral restructurings depends on the extent to which new technological opportunities affect the functioning and reproduction conditions of an economic sector. In short, the more relevant a fundamentally new technology, or bundle of new and complementary technologies, becomes for the future reproduction of a sector, and the less it can be fitted into the framework of the organizational patterns, structures and institutions established

there, the greater the selection pressure that it exerts on the sector and its stakeholders. I refer to this phenomenon as the sectoral *transformative capacity of new technologies*.

However, this first concept does not allow deriving clear sectoral restructuring policies and patterns. The *second concept*, then, states that the way in which a significant selection pressure is dealt with that builds up from substantially new technological opportunities, and the concrete patterns which the sectoral change assumes, depend on how new technologies and their potentials are anticipated, taken up, transformed and implemented into concrete changes under such circumstances. This is what I call *sectoral adaptability*, which is not simply understood as a reactive adaptability to already established new technological conditions but as a way of dealing with initially incomplete and ambiguous new technological opportunities, themselves subject to ongoing change and whose potential socioeconomic effects are likely to be long-term.

This brings us to the *third concept*. Sectoral change processes that are triggered by radical technological transitions do not, even where the selection pressure is high, occur as a series of more abrupt and drastic restructurings that then make way for a distinctly new period of socio-technical continuity. Instead, technology-driven sectoral change regularly takes the form of long-term—as in one or two decades—socio-technical search and selection processes that can dramatically change the structures, institutions and actor configurations of a sector—albeit not in the form of unique and radical breaks but as the result of a multitude of organizational, structural and institutional changes that are drawn out over a longer period of time. I refer to this process as *gradual transformation*.

### **3 The transformative capacity of new technologies and sectoral adaptability**

How can these concepts be applied to empirical research? In the following, I will outline the key building blocks of a heuristic that can guide the concrete analysis and reconstruction of technology-induced sectoral change (Dolata 2011, 2013).

#### **3.1 Transformative capacity of new technologies as a relational and dynamic concept**

It is first necessary to identify the specific sectoral selection pressure that may be triggered by major technological transitions. This context raises the questions of the usable potential of radically new technological opportunities in a sector, of how far this potential impacts the existing socio-technical profile of that sector, and of the extent to which sectoral restructurings are necessary for the development and imple-

mentation of that potential. Subsequently, the research must examine the extent to which these new technological opportunities:

- change the technological profile of the sector; or expand or destroy existing knowledge base and competencies;
- influence existing research and development, production, distribution and market structures;
- put established players under selection pressure; promote the emergence of new actors; and question the sectoral actor configurations as a whole;
- enable, or impose, new forms of cooperative interaction and competition; as well as
- necessitate institutional adjustments (e.g., in the form of new legal-regulatory frameworks or in the form of changed sectoral norms, rules and guidelines).

Transformative capacity is thus not an autonomous concept, derived solely from the technology in question, but a *relational* concept. It is determined by the developmental and application opportunities which a new technology field can offer a sector *and* by the structural and institutional composition of the sector on which the new technology has an impact. Indeed, in and of themselves, technological innovations are merely opportunities whose potential can, if at all, be realized only if the socio-technical constellations of the sector change substantially. The transformative capacity of new technologies and the resulting selection pressure then emerge from this tension between what is technologically possible and what is doable under the given socioeconomic conditions.

In addition, the transformative capacity of new technologies is a *dynamic* concept. New technological opportunities do not appear *ex nihilo* to produce a one-time sectoral selection pressure that is then processed. Instead, they emerge, become concrete and change in the interplay of technological innovation dynamics and socioeconomic search, selection and appropriation processes, often over a longer period of time. In other words, the pressure on a sector that is triggered by new technological opportunities gradually builds up. It then enters a period of more or less far-reaching and successful socio-technical reshuffling in the sector, during which its technological base as well as its socioeconomic foundations gradually change. The pressure then drops in the course of this stabilization and socioeconomic incorporation of the new technologies, as exemplified by the transformation of the pharmaceutical sector initiated by genetic engineering from the mid-1970s to the mid-1990s (Dolata 2003, pp. 143–237).

### 3.2 Adaptability of the actors and institutional adaptation conditions

The way in which such a transformation takes place in practice, what actually changes and who makes these changes are dependent on social processes of perception, re-

ception, appropriation, debate and (re)use, in other words, by the concrete way in which a sector and its actors engage with the new technological opportunities.

Examining this requires, first, taking the *adaptability of the established core actors* into account. It is by no means unusual for the saturated actors in a sector to initially underestimate or ignore the socio-technical potentials for change coming from new technologies and to, once a significant selection pressure has built up, continue to thwart efforts toward change by means of more subtle types of resistant attitudes and strategies for defending the status quo, such as sluggishness in delivering adaptation measures and getting caught up in an incumbent trap. This topic, or phenomenon, has been studied by works on structural inertia and the failure of established organizations (Chandy and Tellis 2000; Christensen 1997; Hannan and Freeman 1977, 1984; Mellahi and Wilkinson 2004). That said, on the other end of the spectrum, established actors can also act upon fundamentally new technological opportunities early on, openly and proactively, take initiative in developing them, and build new areas of activity and business around them.

Whether incumbent actors—in our context, above all the leading companies in the sector—are capable of adapting or not depends very much on their internal structure and their relationships to the outside. Among the conditions and factors shown to promote adaptation are:

- the systematic integration of spaces allowing for creative activity in the organizational context, such as through the establishment of autonomous entities within the organization or in the form of spin-offs (Ahuja et al. 2008, pp. 51–59);
- communicative permeabilities within the organization, that is to say “a lateral rather than a vertical direction of communication through the organization, communication between people of different rank, also, resembling consultation rather than command” (Burns/Stalker 1961, revised edition 1994, p. 121);
- the cognitive openness within the organization’s management for taking creative activity seriously and for proactively taking up its results and recommendations—albeit without leading to excessive arbitrariness or organizational fluidity (Schreyögg and Sydow 2010); and
- the establishment of systematic cooperations with innovative new actors such as start-up companies, which are open and receptive to new (technological, economic, social) developments beyond those already established (Rothaermel 2001).

However, a look at a sector’s core actors is not enough when seeking to understand the adaptability of a sector. In their capacity to anticipate and adapt, the well-established actors are also influenced by the existing institutions and structures of their sector and country of origin—such as distinct industry, market and research structures, innovation styles, (im)permeabilities and networking patterns between het-

erogeneous actors, legal and regulatory framework conditions, collectively shared rules, standards, routines and guidelines—that may encourage, impede or block the perception and processing of fundamentally new technological opportunities (Hollingsworth 2000, pp. 626–630).

Sectors whose industrial structures are characterized by the coexistence of different types of companies (e.g., large companies, medium-sized companies and technology-oriented start-ups) that have systematically integrated niches for creative activity (e.g., through venture capital-based corporate finance systems or substantial government subsidies for not yet marketed technologies and specialized stakeholders) and that are characterized by formalized as well as informal networking patterns between heterogeneous actors (e.g., between industry and academia; between large companies and start-ups; between manufacturers and technology suppliers; or between producers, customers, maverick users and subcommunities) have institutional and structural mechanisms that enable adaptability and the proactive handling of new technological opportunities (Mowery and Nelson 1999; O’Mahoney and Bechky 2008; Ahuja et al. 2008; Mazzucato 2013).

These specific *structural and institutional adaptation conditions* likewise determine whether or not a sector and its actors can (or cannot) proactively embrace new technological challenges. Here, the crucial factor is the extent to which these conditions not only guarantee the stability of a sector but also support and positively sanction path-deviant developments and new actors (such as risk-friendly entrepreneurs or start-up companies). Sectors unable to adapt are characterized especially in the early phase of socio-technical transitions, both as regards the core actors and the existing structures and institutions, by rigid organizational, structural and institutional lock-ins, which initially block or constrain adaptations coming from the sector (*transformation-resistant path dependency*). This is different in sectors capable of adapting. Of course, they too have carved out specific socio-technical development paths without which they could not function. However, their core actors or their structures and institutions are simultaneously equipped with transformation mechanisms whose impact is not merely situational or coincidental but also generalizable and which promote technology-induced change from within the sector and which facilitate targeted path modifications or switches (*transformation-open path dependency*).

### 3.3 Sectoral core structures and their peripheries

That said, the initially posed research questions require looking beyond the established core structures and actors of a sector. Particularly in sectors that initially proved incapable of adapting, actors who were not initially a part of their core are often the early drivers of technology-induced change. Such actors might include those who were already established in other sectors and who are expanding their business

on the basis of new technologies and entering into a new sector (e.g., Apple in entertainment, communications and music) as well as non- or hardly organized collective actors seeking to explore the new technological opportunities beyond the framework of existing institutions and structures, using these opportunities unconventionally and enhancing them independently (e.g., subcommunities and outlaw innovators in information technology, Flowers 2008).

Above all, however, they include newly founded companies that form around a new technology field and who are breaking up, or disrupting, existing structures and actor configurations with their activities. In new high-tech sectors, it was regularly not the saturated large-scale enterprises but rather the start-ups that were the pioneers and that first explored the commercial use of fundamentally new technological opportunities and triggered sectoral change. Accordingly, the upswing of the US-American PC and software industry in the late 1970s and early 1980s was driven by the emergence of a large number of new research-intensive companies (Bresnahan and Malerba 1999; Mowery 1999; Cloudt et al. 2010). Similarly, the main impetus for the commercial development of genetically engineered drugs, vaccines and diagnostics did not come from established corporations but from start-up companies (Henderson et al. 1999; Roijackers and Hagedoorn 2006). Finally, a decade later, in the mid-1990s, the internet was commercialized primarily by start-ups, who were the first to explore new opportunities, such as network-based trading or advertising, and who put the saturated actors in these sectors under adaptation pressure (Dolata 2017).

These “parties from the fringes of an interorganizational field” (Leblebici et al. 1991, p. 358) proactively use windows of opportunity (Perez and Soete, 1988) that present themselves through the new technological opportunities; no longer orient themselves to a sector’s existing technologies, institutions and structures but instead challenge them in varying degrees; develop and follow new rules and conventions; form independent communication and interaction contexts; and contribute directly or indirectly to a modification of the existing actor configurations, institutions and structures of a sector, especially if their established core initially proves to be incapable of adaptation. It is therefore important to consider the “totality of relevant actors” (DiMaggio and Powell 1983; p. 143) in the analysis of technology-related change and to distinguish between the adaptive capacity of the core and that of the periphery of a sector.

### 3.4 Initial and processual adaptability

Adaptability, too, is not a static but a dynamic concept. The established actors (and with them the existing institutions) generally do not remain passive and resistant to change over an extended period of time. With increasing adaptation pressure, which mounts through new technological opportunities, they too regularly try to find their way into the new playing field with their own restructuring initiatives. They engage,

learn, orient themselves and successively align their actions to the new technologies. In other words, they too can become capable of adapting over time (Cohen and Levinthal 1990). The inverse scenario, which takes place time and again, is also possible: Initially adaptable actors underestimate or ignore new developments occurring during a transformation process and thereby lose their adaptive capacity. In order to analyze such perceptual and processual shifts in the course of time, it is useful to distinguish between *initial and processual adaptability*.

*Initial adaptability* refers to the perception and processing of the potentials and challenges of new technologies in their formation phase, when their (sectoral) opportunities and structural effects first become apparent. The manner in which a new technology is taken up and processed during this phase by the various actors and institutions of a sector sets the conditions for and influences the subsequent process of technology-induced transformation.

*Processual adaptability* refers to the actual establishment and institutionalization of new socio-technical constellations, in other words, the phase during which the development and application perspectives of the new technologies, together with the associated organizational, institutional and structural changes, become successively concretized and consolidated. From that point on, high adaptability is not only a matter of the early anticipation and acceptance of thus far unspecific possibilities in the context of equally non-specific search processes but becomes more and more of a matter of intentional institutionalization: the ability to organize, communicate and execute targeted socio-technical selection and implementation processes.

As a rule, the capability to institutionalize and establish a new socio-technical match is then no longer exclusive to the new actors from the fringes but is actively shaped also by the initiatives of established actors who have survived the initial phase. Thus, while new players are often the catalysts of sectoral transformation processes—with some of them (such as Microsoft, Intel, Amgen, Amazon, Apple) even figuring among the relevant or dominant players in the newly structured core of the respective sector—there is generally no radical exchange of actors, even in less adaptable sectors, as was suggested in the early work on organizations saturated with structural inertia (Hannan and Freeman 1977, 1984). Under the pressure of the periphery and the dynamics engendered by it, established actors no longer react to the new technological opportunities in a primarily conservative way, such as with mitigation strategies. Instead, they become proactive, bring their own initiative and use all the resources available to them to catch up. Often, it is only through this that transformation processes gain in breadth and legitimacy, achieve stability and bring about concrete institutional and structural change (Leblebici et al. 1991).

## 4 Sectoral change as gradual transformation

Even radical socio-technical change is, as already suggested in the above-mentioned concept of the periods of mismatch, often a multi-layered, gradual transformation process. *Transformation* is understood as the radical reorientation of a sector, through which both the sectors' technological profile and, as part of that, its social correlates are substantially changed. The qualification of a transformation as *gradual* serves to emphasize the essential procedural peculiarity of such transitions, which in principle take place step by step, as an accumulation of numerous transformation activities, and which take place over an extended period of time.

Building on the work of Kathleen Thelen and colleagues (Streeck and Thelen 2005; Mahoney and Thelen 2010), various *modes of gradual change* can be identified and used for a more precise analysis of the typical patterns and progression of sectoral transformation. Sectoral transformation can take place, on the one hand, through the *layering* or the gradual *conversion* of the sector's existing organizations, institutions and structures, which adapt to new technological situations by expanding their scope of action and orienting it to the new socio-technical conditions. On the other hand, it can take place through the *expansion* of the pool of new actors who are open to the new technological opportunities and around whom independent hubs with alternative structures, rules and guiding principles develop that challenge the existing circumstances and *displace* them with time. Finally, these forms of gradual change are always accompanied by a more or less pronounced decline of some established organizations, structures and institutions, seeing that the latter lose influence or *drift* and *exhaust* themselves over time as a result of their incapacity for adaptation or obsolescence.

On their own, however, none of these forms of gradual transformation will stand out in a sectoral transition, which generally spans over a decade or two. As a rule, processes of gradual transformation are characterized by the formation and emergence of challenging alternatives as well as by substantial and targeted changes of the established organizations and institutions. These latter changes are regularly associated with a loss of significance or the decline of those actors and institutions who lose their adaptive capacity. If anything, the unique signature of a (sectoral) transition period and specific transformation paths can be worked out on the basis of the specific interplay and the combination and weighting of the various forms of gradual transformation (in detail, Dolata 2013, p. 104–120).

When, then, do such processes of gradual transformation constitute new system qualities? In other words, when do the many technological and socioeconomic changes become so substantial that they are actually replacing the structures and rules that shaped the sector and ensured its stability and reproduction up to that point?



In general, this is the case when a sector's technological profile as well as socioeconomic basis (i.e., organizations, institutions and structures) have not only substantially changed but have also, in their changed form, consolidated into a new sociotechnical reality which is, at least in principle, no longer reversible, thereby becoming a new guideline or status quo for the actors and constitutive of the reproduction (reproducibility) of the sector as a whole. At that point, the relative stabilization of a new or newly arranged sectoral regulation structure or a new sociotechnical match has taken place.

For this to happen, the new technologies in question need not necessarily replace the old ones completely. However, they must have established themselves to the extent of becoming a mainstay in the sector. In addition, the search for suitable organizational, interactive and regulatory patterns must have progressed to the extent of having engendered new binding and effective socioeconomic framework conditions in the sector that cannot simply be reversed and dissolved. This includes:

- the establishment of new sectoral core actors who have emancipated themselves from their niche-existence and become constituent elements of the newly structured field;
- the consolidation of organizational patterns that have been modified to align with the new technologies among the sector's remaining classical actors who have largely completed their reorientation and restructuring process;
- the stabilization of novel, previously non-existent, competitive and cooperative relationships between the actors, which no longer merely regulate the exchange between these actors in a case-by-case manner but which have become constitutive;
- the institutionalization of essentially different rules—laws, norms, standards, guiding principles—which structure the action on a new basis and that henceforth characterize the reproducibility of the sector concerned.

Relative stabilization means, in addition, that the transformation process at such a turnover point does not yet have to end or have been completed. In view of the often sustained technological dynamics, the stabilization of a new sectoral structure does not necessarily have to lead to a new phase of continuity with then only incremental modifications and fine adjustments. Instead, it can, as a temporary stabilization, also form the starting point of a further round of gradual transformation that will yet again change the sector significantly.

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## Further Publications

Research Contributions to Organizational Sociology and Innovation Studies

Neukirch, Mario, 2017: *Die Dynamik des Konflikts um den Stromtrassenbau. Stabilität, Wandel oder Stagnation?* SOI Discussion Paper 2017-04.

Schrape, Jan-Felix, 2017: *Open Source Projects as Incubators of Innovation. From Niche Phenomenon to Integral Part of the Software Industry.* SOI Discussion Paper 2017-03.

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### Books

Dolata, Ulrich, 2013: *The Transformative Capacity of New Technologies. A Theory of Sociotechnical Change.* London: Routledge.

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