



Technological innovations and sectoral change Transformative capacity, adaptability, patterns of change: An analytical framework

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ABSTRACT

Following up on recent debates about sectoral systems of innovation and production, the paper introduces a heuristic framework for analyzing and explaining distinct patterns of technology-based sectoral change. The concept is based on two interrelated influencing factors. The first is the sectoral-specific transformative capacity of new technologies themselves, that is, their substantial or incremental impact on socioeconomic and institutional change in a given sectoral system. The second is the sectoral adaptability of socioeconomic structures, institutions, and actors confronted with the opportunities presented by new technologies. The first factor—the sectoral transformative capacity of new technologies—enables us to identify the technology-based pressure to change and adjust the structural, institutional, and organizational architectures of the sectoral system. The second, complementary factor—sectoral adaptability—helps us to discern the distinct social patterns of anticipating and adopting this technology-based pressure. The specific interplay between the two influencing factors creates distinguishable modes of sectoral transformation, ranging from anticipative and smooth adjustments to reactive and crisis-ridden patterns of change. Even processes of radical sectoral change continue over longer periods of mismatch and are characterized by numerous and mostly gradual organizational, structural and institutional transformations.

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1. Technology-based socioeconomic and institutional change: starting points

Since the late 1970s, the advanced capitalist societies have been marked by a continuing period of significant technological change, which is characterized to a great extent by the diffusion of numerous new information and communication technologies and, to a lesser extent, new biotechnologies. In the course of the social shaping of these new technologies, the strategies and organizational fits of the involved actors, as well as the socioeconomic and institutional settings in which they are embedded, have also undergone significant changes. Although they are the contingent results of actor-based social processes, new technologies have at the same time contributed to the restructuring of existing economic, political, and social surroundings: they have promoted organizational change and new patterns of inter-organizational collaboration, created leeway for new actors, and constituted entirely new or reshaped existing economic sectors, markets and patterns of competition. They often required far-reaching readjustments of

legal frameworks, have modified lifestyles and consumption, and sometimes provoked sharp disputes about their benefits and risks (Dolata and Werle, 2007).

Meanwhile, this general interrelation of technological, socioeconomic, and institutional changes is to be found in various scientific concepts on the co-evolution of technology and institutions or in recent sociotechnical system approaches. In one way or another they raise the question of “how technology is shaped by social, economic, and political forces alike; and how, in the same process, technologies and technology systems shape human relations and societies.” (Rip and Kemp, 1998, 328; Kemp et al., 2001; Kitschelt, 1991; Nelson, 1994; Lynn et al., 1996; Geels, 2005). Although the general interrelations between technology and society or, more specifically, between technology, socioeconomic structures, and institutions are of interest in these approaches, they still aim to study and explain the processes and modes of *technological change*. However, there have rarely been answers to the second part of the question concerning processes of *socioeconomic and institutional change* provoked by emerging new technological opportunities and constraints (Werle, 2005; recent exceptions are the contributions in Hage and Meuus, 2006). How and to what extent are the involved socioeconomic structures, institutions, and actors changing under the influence of new technologies?

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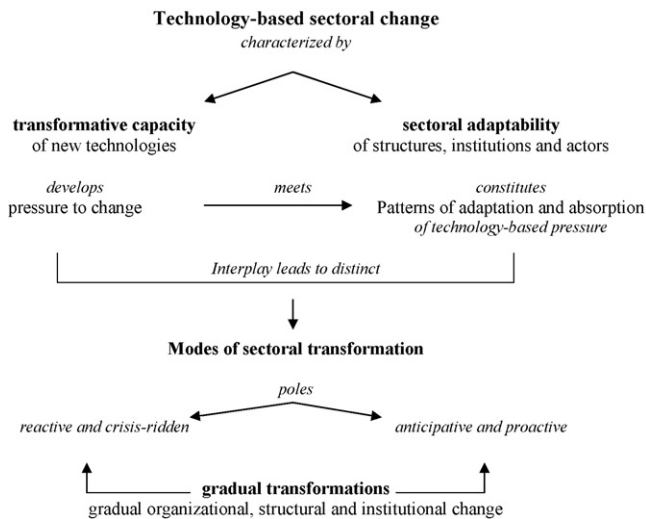


Fig. 1. Technology-based sectoral change: basic categories.

And how do they react to such a technology-based pressure to change?

These questions are discussed in the following with regard to the technology-based transformation of existing economic sectors. This focus on the meso level of economic sectors makes allowance for the observation that, in particular, new multi-purpose technologies affecting different sectors do so in distinguishable ways. In each case they exert a specific pressure to change on the structures, institutions, and actors of the various existing sectoral systems. In addition, this pressure to change is perceived and handled in distinct ways within each given sector.

Based on this consideration, the paper aims to introduce and empirically substantiate an *analytic framework* for studying and explaining technology-based sectoral change. The framework depends on two interrelated influencing factors:

- The first is the sectoral-specific *transformative capacity of new technologies* themselves. While a technology may have a supplemental and sustaining impact on the existing structures and institutions of one economic sector, it may be disruptive in others and provoke major adjustment crises and changes.
- The second and complementary factor is the *socioeconomic adaptability* of the established sectoral structures, institutions, and actors confronted with the challenges presented by new technologies. While some sectoral systems and its established actors may, at an early stage, ignore and underestimate even serious technological challenges, others may possess institutionalized mechanisms that even facilitate path-deviant transformations.

The first concept—the transformative capacity of new technologies—enables us to identify the technology-based pressure to change and adjust the structural and institutional architectures of a given sectoral system (part 3). The second, complementary concept—sectoral adaptability—helps us to discern the distinct social patterns of anticipation and absorption of this technology-based pressure. The specific interplay between these two influencing factors creates distinguishable *modes of sectoral transformation*, ranging from anticipative and smooth adjustments to reactive and disruptive patterns of change (part 4). However, even processes of radical sectoral change continue over longer periods of mismatch and are characterized by numerous and mostly *gradual organizational, structural, and institutional transformations* (part 5). Fig. 1.

2. Sociotechnical systems and periods of mismatch

Sectoral systems such as the automobile industry, the aircraft and aerospace industries, the chemical and pharmaceutical industries, and the music and media businesses are not simply socially based systems; they are sociotechnical entities (Geels, 2004). Characteristic of the constitution of sectoral systems as organizational, institutional, and technological fields are not only distinct socioeconomic structures and institutions, typical constellations of actors, and patterns of actor-based interaction, but also the specific technologies being developed, produced, or used (Leblebici et al., 1991). The types of technologies that characterize a given sector promote specific patterns of industrial organization, of market and consumption constellations, of competitive and collaborative relations, and of regulative environments. Large-scale and capital-intensive technologies (such as aircraft and aerospace technologies) cannot be developed, applied, and organized in such a decentralized and market-based way, for instance, as can small-sized and cross-sectional technologies (such as biotechnology). Far into the 1980s, the decentralization and liberalization of large technical systems, such as telecommunication or energy supply, remained limited, especially because of technology-based boundaries. Science-based sectors, such as the pharmaceutical industry, are characteristic of strong academic–industrial relationships, whereas other sectors depending on application-oriented knowledge, such as manufacturing systems engineering, are not. Finally, sectors that develop, manufacture, or depend on individually useable consumer technologies, such as entertainment electronics or the music and media industries, are largely shaped by their idiosyncratic utilization by private consumers, whereas sectors producing large-scale technologies and industrial goods are not.

Thus, the distinct technological profiles appear to be one of the major factors influencing and shaping the socioeconomic structures, institutions, actors, and interactions of sectoral systems. Freeman and Perez (1988) have conceptualized this interrelation as a *match*: To operate successfully, sociotechnical systems of any kind have to show compatibility between the peculiarities of their technological profile, their socioeconomic structures, and their institutions. With regard to the development of large technical systems, Renate Mayntz (Mayntz, 1993) points out that their socioeconomic structures and institutions are highly dependent on the respective technological attributes characteristic of the sociotechnical system. Kitschelt (1991, 468) considers this *match* to be a prerequisite for efficiency: “Industrial sectors, identified by core technologies, efficiently operate only if governance structures match technological constraints.”

Whereas incremental or sporadic radical innovations can normally be integrated into existing contexts without major socioeconomic and institutional modification and do not fundamentally challenge the existing sociotechnical match, the well-rehearsed interplay between established technological profiles and socioeconomic structures, markets, institutions, and activities becomes unsettled in times of paradigmatic and systemic technological change. Both fundamentally new and substantially enhanced technologies challenge not only dominant product designs and related market conditions (Utterback, 1994), but also the operational viability of existing sociotechnical constellations as a whole. They necessitate far-reaching organizational and institutional adjustment processes, and are effective as discrete incentives of socioeconomic and institutional change. Freeman and Perez conceptualize such far-reaching states of flux as *periods of mismatch*: as longer phases of searching for, experimenting and struggling with new structural and institutional arrangements that correspond with the new technological opportunities and constraints. As a result of such adjustment processes, a new equilibrium between

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