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Innovation processes in large technical systems: Market liberalization as a driver for radical change?

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Abstract

Electricity supply is a large technical system, which exhibits strong path dependencies and high barriers for radical innovations. Recent market liberalization, however, has initiated a fundamental restructuring. The paper analyzes how liberalization has altered innovation processes in the field of electricity supply. We examine three radical innovations under monopoly conditions and contrast the findings with the results from a survey on the innovation behavior of electric utilities in liberalized markets. We argue that the selection environment for innovations has changed in various respects. In our sample, new options open to innovation activities have emerged at the level of the firm and utility strategies turn out to be more heterogeneous. This may be interpreted as an increase in the variety of search processes, which may lead to a mid-term decrease of path-dependencies.

Keywords: Radical innovation; Large technical systems; Market liberalization; Electricity supply

1. Introduction

Large technical systems like the electricity supply system encompass a capital-intensive infrastructure, a broad range of technical components and technologies and a variety of actors and institutions. Most system components are closely interrelated and various kinds of technical norms, organizational practices and institutional procedures have emerged to guarantee a smooth joint operation of all these components. As a consequence the development of the electricity supply system tends to be strongly path-dependent. Innovation processes are more of the incremental than of the radical type (e.g. Hughes, 1987).

Radical innovations are confronted with considerable barriers as they have both to overcome prevailing standards and to compete against the network externalities of established products or technologies. Nonetheless, radical innovations sometimes take place in large technical systems. Such innovation processes may be triggered by factors or 'events' from outside the system including new preferences on the political agenda or technological breakthroughs in other sectors. Radical innovations may also emerge in the course of continuous expansion and growth of a technical system. If reverse salients, i.e. frictions in specific parts of the system hinder its further expansion, innovation activities will be concentrated at these points (Hughes, 1987). Reverse salients that cannot be overcome within the context of the existing system may bring about radical innovations and a shift in prevailing technological regimes.

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In the field of electricity generation, we can in fact observe several cases, in which radically new technologies were driven by external stimuli and government action in order to overcome reverse salients. For instance, nuclear or wind power were supported by policy instruments in the light of public debates about the security of supply in the aftermath of the oil crises and a reduction of environmental pollution (Hadjilambrinos, 2000). The diffusion of combined cycle gas turbines as baseload power plants represents another example for a radical technological change in electricity supply. Here, significant innovation impulses can be traced back to the advances in gas turbine technology in the aircraft industry (Islas, 1997; Patterson, 1999, p. 73). The main driving factors can be classified as external in all three cases because the internal resistance of the electricity supply system confronted with these innovations proved to be considerable (Jacques et al., 2001; Patterson, 1999; Sine and David, 2003).

The recent introduction of market liberalization in the electricity sector may also be interpreted as an external stimulus to the electricity system. Electric utilities, which used to operate on the basis of regulated, territorial monopolies over many decades, now have to compete for customers in the fields of power generation, trading and sales. However, unlike the before mentioned driving factors, the impact of market liberalization has no specific impact on a certain technology but changes the selection criteria in a general way. More importantly, market liberalization has a considerable impact on the organizational structures of electricity supply (Joskow, 1998; Sioshansi, 2001a). As a consequence, we may expect that forms of resistance towards radical innovations are likely to change under the new market rules: new players enter the market, new roles are assigned to electricity consumers and new rules for investment decisions and technology choices emerge.

This paper addresses the question how market liberalization has altered the way innovations are handled in the electricity supply system. Our focus is on radical innovations and we ask whether recent changes have increased the options open to innovative activity, thus broadening the range of development paths pursued and decreasing the path dependency of the sector. On a conceptual level, the article contributes to the analysis of particularities of radical innovation processes in large technical systems.

In the field of science and technology studies there are several studies dealing with the basic attributes of large technical systems (Gökalp, 1992; Hughes, 1987; Joerges, 1998) but only few scholars have explicitly addressed the characteristics of innovation processes and radical innovations (Davies, 1996; Godoe, 2000). With our analysis, we want to enrich this body of literature. We furthermore relate our study to economic analyses of technological change and radical innovations (Mascitelli, 2000; Teece, 1996; Tushman and Anderson, 1986). We particularly refer to lock-in phenomena, the path-dependency of innovation and the notion of technological regimes, which guide innovation processes (David, 1985; Dosi, 1988; Rip and Kemp, 1998; Rosenberg, 1982).

The paper is structured as follows. Section 2 shortly presents the theoretical concepts of large technical systems and technological regimes on which our analysis is based. In Section 3 we introduce the electricity supply system and discuss how various kinds of interdependencies and standards impede radical innovations. Section 4 elaborates on three radical innovations in the field of power generation. On this basis, we examine key drivers for radical innovation under monopoly conditions. Section 5 deals with the consequences of market liberalization for innovation processes. It starts with an analysis of the transformation of the selection environment for innovations. Then, electric utility innovation strategies and the underlying motivations are illustrated on the basis of a case study on stationary fuel cells. Section 6 concludes that market liberalization has increased the scope of variation for innovation activities at the level of the firm and of the sector. However, it remains to be seen whether these opportunities, in fact, lead to radical technological changes or not.

2. Particularities of innovation processes in large technical systems

2.1. Key characteristics of large technical systems

Technical systems like infrastructures for the supply of energy and water, railway systems, telecommunication networks or military defense systems show similarities in their structure and in their innovation characteristics. In the literature on science and technology studies, the notion of *large technical systems* has been developed together with a conceptual framework to describe the general features and the dynamics of such systems (e.g. Gökalp, 1992; Hughes, 1987; Joerges, 1998). Large technical systems can be defined as

> "... complex and heterogenous systems of physical structure and complex machinery which (1) are materially integrated, or 'coupled' over large spans of space and time ... and (2) support or sustain the functioning of very large numbers of other technical systems ..." (Joerges, 1998, p. 24)