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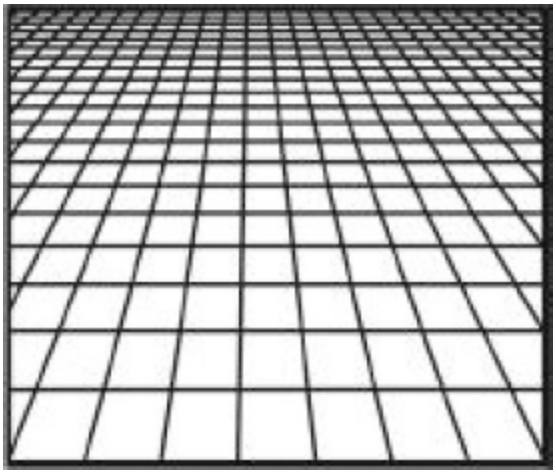
Understanding Technological Innovation

Enabling the Bandwagon for Hydrogen Technology



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1. Synopsis

This thesis aims to give a comprehensive survey of the ongoing technological change in automotive propulsion technology.[1] It attempts to substantiate current technological developments with theoretical approaches and to show current market developments at the same time. Combining both the theoretical and the practical points of view this thesis should lead to a deeper understanding of technological innovations within the field of hydrogen technology for vehicular applications[2] by (i) showing that this technology is embedded in other technological systems, (ii) analysing the actual stage of its diffusion, (iii) showing, on base of a case study, that hydrogen technology is close to market but needs to overcome several obstacles in order to enter large scale commercialisation, and (iv) describing the consequences for further development. It will conclude by suggesting potential market entry strategies and presenting some topics for further discussion.

Keywords: *innovation, diffusion, network effects, hydrogen, fuel cell, automotive –*

Schlüsselworte (deutsch): *Wasserstoff, Brennstoffzellen, Innovation, Technologiewissenschaften, Netzwerkeffekte, Automobil, Diffusion*

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[1] I thank Andreas Reinstaller for his patient guidance and very helpful comments.

[2] 'Hydrogen technology' is synonymously used for 'fuel cell technology' throughout this thesis.

2. Introduction

The complexity of an innovation is not yet fully understood although it is widely acknowledged that innovations are the primary driving force for economic development[3]. Given the great variety of phenomena involved, the interrelations are often too manifold to allow a precise portrayal of this process. While an innovation itself (both in the sense of the process and the result)[4] is difficult to capture, there can be made distinctions between different types of innovations. Among others, Bessant et al. (2001) describe a distinction between product, process, and social innovations as well as innovations in service and conditions. Another distinction can be made between incremental and radical innovations: Incremental innovations implicate minor changes where the socio-technical framework remains stable while radical innovations, by definition, lead to major changes in the existing regime so that markets and whole sets of beliefs are being changed towards another paradigm.[5]

Technological change which is often associated with innovation - can be described as the shifting methodology through which wealth is predominantly created. Technological change also describes the larger framework in which innovations take place. Economists accordingly study - besides its creation - also the distribution of wealth. The study of past changes in technology has contributed to a deeper understanding but does by no means indicate that ongoing changes become well-structured and predictable. According to Schumpeter, an innovation is the entirety of all purposeful actions of an entrepreneur that leads to new combinations.[6] Innovations are inherently uncertain and involve human creativity, they offer chances and – in case of

success – can enable the survival of a company in the long run.

The capability of development and the success of technological innovations play a crucial role in organizations[7]. Technological innovations can open up new markets where certain user groups might be interested in buying a new developed product. The study of innovation is quite new and still suffers from a flood of highly specialized studies and a lack of integrative and comprehensive approaches in the literature. Many case studies from the last decades show that the ability to innovate is far away from being a routine procedure and still represents a big obstacle for virtually all organizations, independent from their market position or size. Even industrial giants like IBM, GM, or Kodak have had to change significantly in order to stay in the market, and have gone through very challenging stages[8]. The mortality of industries and companies can be demonstrated by looking at the top 12 firms which made up the Dow Jones Industrial Average Index of the American stock exchange around 1900. Only one company – General Electric – is still in the market today while all the others have merged or went bankrupt. Some decades ago, an innovating firm could bank on gaining significant competitive advantages whereas today innovation is a necessity of even staying in the marketplace.

As Utterback (1994, p. 14) points out, innovation is *'at once the creator and destroyer of industries and corporations'.* Organizations need to innovate through downsizing, reengineering, starting joint ventures, or finding other methods to keep or increase market shares and to survive in the long run. Having to struggle with new circumstances, start-up firms came into monopolist positions and industrial giants fell because they were not receptive for changes in their environment.

Another misleading assumption would be to consider firms as acting alone,

i.e. separated from marketplace and society. Innovation requires much more than a research and development laboratory and can be seen as a creative and highly interactive process involving numerous heterogeneous influences like new production methods, new raw materials or changes in the customers' taste.

This thesis attempts to show how innovations 'occur' and thus the bandwagon for a new technology is set into motion. Although there are several other interesting innovations[9] currently going on, I chose hydrogen technology as framework for my analysis because this particular innovation probably has the most striking influence on our society within the next decades. With the aid of ongoing developments in hydrogen technology, I will apply various models and theories described in chapter

3 throughout my analysis. There are expectations with regard to steady improvements in hydrogen technology accompanied by further reductions of costs within the next decade to allow widespread usage in suitable applications where the technology is applicable. Within the manifold innovation studies the number of close-to-market analysis is very limited as most of the studies have been conducted in retrospective. The retrospective analysis is rather easy to conduct as the development already has come to a closure and thus allows a detailed study on past issues. On the contrary, real-time analyses offer a much more lively and speculative basis and allow an 'educated guess' while markets are being shaped. For this very reason I chose hydrogen technology as the subject for my analysis because it is still far away from being an established technology in our society and thus offers a chance to observe an innovation process in the making.

[3] See Fischer (2001, p. 199).

[4] For a detailed definition of ‘innovation’ see *chapter 3.1.*

[5] A ‘paradigm’ is, according to Kuhn (1970, p.175), the ‘entire constellation of beliefs, values, techniques, and so on shared by the members of a given [scientific] community’. In this case the paradigm is built around the raw material (i.e. fossil fuel) which drives vehicles.

[6] See Schumpeter (1934, pp. 155f), further explanations in *chapter 3.1.*

[7] Organizations are according to Gross (1985, p. 5), social units or human groups to seek specific goals. Corporations, armies, interest groups, hospitals, etc. are included in that definition as they share a common belief, divide labour, power, and communication responsibilities. The terms ‘company’ and ‘firm’ are synonymously used for ‘organization’.

[8] See Bessant et al. (2001), p. 17ff for a detailed description of ‘innovation history’.

[9] See for example developments in diode, chip, laser, or biotechnology.

3. THEORETICAL FRAMEWORK

In this chapter I am presenting the framework for my analysis. After defining the basic terms, I am going to explain the underlying concept and clarify the idea of network externalities as well as technology diffusion rounded off by a critique on conventional innovation models which leads to the introduction of a more comprehensive and interactive approach.

Competitive markets are essential but not imperative for innovativeness while network externalities and economies of scale are key factors of increasing returns, ensuring the survival of organizations in the long run. Technology has been the crucial factor for lasting economic growth which is undoubtedly the backbone of modern industrial societies. Before explaining the theories in more detail some expressions which are used throughout my thesis need to be explained.

The collective terms *science* and *technology* should by no means be simplified but at this point they are used abstractly to clarify the difference between introvert and extrovert activities. Books and articles by various authors (e.g. Kuhn 1967, Rosenberg 1982, Bijker 1992, 1995) have explained these terms sufficiently so that only some main findings with respect to innovation shall be presented here.

Technological development is not socially neutral but shaped and affected by the social structure embracing it. Literature from the field of science-technolo-gystudies[10] attempts to bring together studies in science, society, and technology to thereby counteract the drifting apart of these fields. It is furthermore a rather simplified and deterministic view to believe that technology changes merely as a result of new scientific findings or follows a logic of its own. A so