Journal of Cleaner Production 18 (2010) 14–20

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Exploring innovation in the automotive industry: new technologies for cleaner cars

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ARTICLE INFO

Article history:
Available online 17 September 2009

Keywords:
Innovation
Automotive industry advances
Brazilian ethanol experiences
Biofuels
Ethanol
New automotive powertrains

ABSTRACT

The concept of innovation has been used in a wide range of contexts and the theoretical development has proven to be extremely valuable to provide important insights into intra-market competition, strategy and regulatory policy. The automotive industry offers a fertile terrain for progress of the uncompleted theory building process of innovation, especially with the introduction of alternative fuels and alternative powertrain technologies.

This paper investigates the concept of innovation in the context of the modern automotive industry, by focusing on the notion of regulatory innovation of alternative fuels and alternative powertrain technologies. For the purpose of analysing this issue, special attention is given to the concepts of radical and incremental innovation, which are applied to existing alternative fuels and alternative powertrain technologies, including hybrids, biofuels and hydrogen power. The article explores these three categories looking at representative case studies: the Brazilian ethanol experience with biofuels, the development of the Toyota hybrid vehicle and the technological development of hydrogen fuel cells. These categories have been selected because they represent the most important advances in cleaner production for the automotive industry.

1. Introduction

Despite of the economic importance of automobile, incumbents have been suffering from pressures that threaten the economic long term sustainability of the majority of traditional automobile manufacturing firms. Not only has the product been questioned on environmental and safety grounds but the financial and economic situation of incumbent firms has been the subject of great concern. Despite the fact that this paper focusses upon the application of alternative fuels and alternative powertrains to the innovation discussion, the economics of producing vehicles, in large scale, plays a fundamental part in the modern competitive terrain.

The mass production automobile is characterized by the all-steel-body structure and the use of petrol fuelled internal combustion engines. These technologies constrain firms to extremely large initial capital investments, which are mostly sunk costs that need to be recovered with the annual sale of high numbers of units. This constitutes a trap as each competitor has to sell a large amount of vehicles in order to reach a break even point. Another fundamental point is that the global automotive market has very high barriers to entry for new competitors, making it a high concentration market. The recent trend of acquisitions and mergers has contributed to form larger groups that blindly rely on the economies of scale.

2. Innovation

The wide variety of definitions of innovation has resulted in vagueness of terms and explanations [9]. With the intent of avoiding misunderstandings, we had opted to build on the core approach originally presented by the Motor Industry Research Unit within the detailed state aid regulatory context of the European Community [2].

The well established notion of the *Christensen's effect* is illustrative of the potential threat that incumbent firms are exposed in a market with innovations [7]. Christensen work is focused on a description of how successful firms fail with the introduction of disruptive innovations. In this context the distinction between sustaining and disruptive technologies is crucial. Sustaining technologies are the ones that improve the performance of established products, along the dimensions that mainstream customers in major markets value. Disruptive innovation refers to a new

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doi:10.1016/j.jclepro.2009.09.009

technology that emphasizes innovative attributes and qualities that are significantly different from those valued by the mainstream market segment. When disruptive innovations are first supplied to the market, they only appeal to a small share of consumers. With further technological development and greater information, mainstream consumers change their preferences and the conventional products that once were the most satisfying ones become less attractive [6]. This process leads, in due course, to the innovator's dilemma, where incumbents have to decide if they should allocate their resources to the traditional processes and technologies that they are familiar with or to invest in new technologies that could be potentially disruptive.

Another fundamental concept is radical innovation. Utterback [22] defines radical innovation as a discontinuous change that sweeps away much of the firm's existing investment in technical skills and knowledge, designs, production techniques, plant and equipment. The significance of radical innovations is that they do not address a recognised demand but they create a demand previously unrecognized by the consumer, resulting in a new market infrastructure [5]. Radical innovations present both macro level innovativeness characteristics as the product is new to the world, the market and the industry, and micro level characteristics, as it is novel to the firm and to the consumers [9].

Rogers [24] presents aspects that distinguish disruptive innovations from those that are radical in nature but are not disruptive. The radical nature of the innovation is related to the technological dimension while the disruptiveness is related to the market effect to the incumbents. Disruptiveness can be technologically less-radical or technologically more radical but is necessarily related to the phenomenon of the consumer changing tastes and switching from the mainstream product to the new one. Christensen's early work, for instance, was focused on low-end disruptions [7].

In this respect, there is a clear difficulty to use analytical tools to identify disruptive technologies since the measure of disruptiveness is ex-post in nature. Danneels [8] points out that it is not possible to clearly provide ex-ante definitions of disruptiveness, following all the characteristics defined by Christensen. The definition is fundamentally influenced by the organizational-level abilities and competences. The most important models do not provide rigorous forecasting capacities [10]. In this sense, in this paper we opted to conduct the analysis on the observable ex-ante characteristics of the nature of the innovations focusing on the radical innovation concept.

2.1. Regulatory innovation

The concept of innovation has been the subject of some debate in the political and regulatory realm. A specific example involves the interpretation of state aid regulations in the European Community in the late 1980s and early 1990s. In this situation, while state aid was permissible to support innovation, it was not permissible for supporting mere modernisation; member states could be challenged if they were found to be in violation of this proviso. An attempt was made by the research team at the Motor Industry Research Unit [2] on behalf of the European Commission's Directorate General IV (Competition policy) to define innovation within the specific state aid regulatory context of the European Community, in particular how this applied to the automotive sector. The European car industry, at that stage, was thought to be suffering from a competitive disadvantage vis-à-vis the Japanese car industry. A catching up exercise was in progress whereby European car makers gradually adopted 'lean' car manufacturing technologies and methods as exemplified by the Toyota Production System (cf. [4,26]). The definition used in this context was:

> The operation, on an industrial basis, of a new system or process which, in whole or in part, represents a significant step forward for a particular industry in terms of product quality, cost savings, or the safety of the workforce. [2] (p. 2).

This definition, which was broadly accepted by all stakeholders, allowed the EC automotive industry to be identified as "a particular industry", allowing it to be treated as a special case. This then also allowed the adoption of innovations from outside the EC (e.g. Japan) to be interpreted as innovative within the context of the EC automotive industry, but only in so far as they constituted a first application within the EC. However, it was also recognised that two competing EC firms may be working on introducing the same innovation at the same time. It was considered unfair if only the firm who managed to introduce it even a day before the other was able to benefit from being classed as innovative under the state aid rules. For this reason, the report proposed a period of twelve months within which such innovations could be considered as being concurrent, while beyond this period the next introduction would be classed as modernisation rather than innovation [2] (p. 4). This approach represents a more practical notion of innovation since it moves beyond the pure academic and theoretical into the regulatory and policy-making areas. Such notions are important when it comes to explaining the behaviour of the automotive industry in the face of more sustainable alternatives, as we explore in subsequent paragraphs.

In order to assess the extent to which regulations may actually have played a role in the introduction of new automotive technologies, we have tracked a number of key technologies in more or less widespread use on modern cars. Most of these originate in the motorsport arena, so we located them at an historical motorsport event or specific vehicle in their pioneering form and track the process whereby they are adopted by production cars in Table 1.

Technologies have made the transfer from motorsport to road cars for a variety of reasons. Most commonly these involve improved performance or safety – which itself can often help to enable cars to be driven faster (e.g. four wheel brakes). However, there is a persistent strand – particularly since the 1960s – of technologies that made the transfer as a result of governmental regulations. This applies, in particular, to tightening emissions legislation. Multivalve cylinder heads and the related technology of double overhead camshafts can be traced directly to the need to improve control over the combustion process in order to improve the toxic emissions performance of cars. Other related technologies include variable valve timing, while more obvious examples of new technology introductions in this area include the catalytic converter and the particulate trap, although these cannot be traced back to motorsports technologies. Turbocharging also started life as a motorsport technology, although it was pioneered in the aeronautics sector and made the transfer as a result of the need to extract more performance from an engine without having to enlarge the engine. It is now being proposed as one of a number of possible solutions to the regulatory need (in the EU) to reduce engine sizes in order to reduce their CO_2 emissions without loss of performance. The more widespread adoption of this technology over the next ten to twenty years could therefore, become another example of such regulation-induced technology transfer.

An interesting case is that of disc brakes, a technology pioneered for aircraft in the aftermath of World War II and first used on a road car by Chrysler in 1949. It was withdrawn in 1950 after the firm noticed that none of its competitors followed this innovative move. It required the motorsport demonstration by Jaguar to make it credible enough for other firms to adopt it for road cars.