



Will the momentum of the electric car last? Testing an hypothesis on disruptive innovation



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ABSTRACT

In this paper we study to what extent electric propulsion is disrupting 'the order' in the automotive industry with six extensions to Christensen's notion of disruptive innovation (1997). For decades the automotive sector has relied on the internal combustion engine (ICE) as the established propulsion technology, but due to environmental regulation and geo-political scarcity problems associated with fossil fuel use, electric propulsion is increasingly applied as sole or additional power source.

We elaborate the Christensen typology, rooted in industrial analysis, with a regime evolution framework based on changes in technology and the institutional context of production and use, with special attention to consumer perspectives and government regulation. We offer a hypothesis for structural conditions for market disruption and test this hypothesis against the development trajectory of full-electric vehicles (FEV). Drawing on evidence from a range of recent FEV studies, our analysis suggests that the disruptive niche of full-electric mobility is currently insufficient to displace the ICE regime.

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1. Introduction

In this paper we study to what extent electric propulsion is disrupting 'the order' in the automotive industry with six extensions to Christensen's (1997) notion of disruptive innovation. For decades the automotive sector has relied on the internal combustion engine (ICE) but with environmental regulation and geo-political scarcity problems associated with fossil fuel use, alternatives to the ICE vehicle have been proposed, including: The battery-electric or full-electric vehicle (FEV), the fuel-cell vehicle (FCV), the hybrid electric vehicle (HEV), and the plug-in hybrid electric vehicle (PHEV).

In this paper we elaborate the Christensen typology of disruptive and sustaining innovation, rooted in industrial analysis, with a regime evolution framework based on changes in technology and the institutional context of production and use, with special attention to consumer product frames of salient product characteristics and government regulation as important determinants of demand. In order to systematize our study, we offer a nested hypothesis for structural conditions for market disruption and compare this hypothesis against the FEV development trajectory. We test the hypothesis by drawing evidence from a range of recent FEV studies, and this analysis suggests that the disruptive niche of full-electric mobility is insufficient to displace the ICE

regime. While FEVs have been diffusing rapidly recently thanks to product improvements, supportive government policies and media attention, our analysis identifies that momentum is unlikely to be sustained because FEVs suffer from a web of constraints and weak "innovation motors".¹ An important constraining factor is the strong competition from more fuel-efficient ICE cars and from PHEVs. Compared to FEV, the PHEV fits better with consumer needs and the current regime of automobility based on individual ownership of cars. Although FEV has some symbiotic effects with PHEV, the negative competition effect dominates.

The method and structure of this paper are as follows. We adopt an explanatory case study approach to contribute to the development of theory of disruptive innovation. Section 2 reviews Christensen's notion of disruptive innovation and elaborates it for changes in the institutional context of production and use. It offers a hypothesis on when market disruption is likely to be successful. Section 3 tests this hypothesis for the emergence of full-electric vehicles between 1990 and 2015. For this we use secondary data on consumers, firms, policies and technology from a broad range of academic studies, business and policy reports and other documents on the automotive sector. We also use primary data of consumer product frames collected by one of the authors. Our knowledge of the car industry gathered in more than 20 years of research on

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¹ An early version of this paper was presented at a workshop entitled 'Electrification of the car: will the momentum last?' in 2012, and the title of our paper resounds the workshop title (see also Bakker and Farla [2014] introducing a Special Issue on the workshop).

innovation in car propulsion and company strategies by the authors helps to overcome limitations of secondary analysis such as lack of familiarity with data and complexity of the data (Bryman, 2001, p. 200). A wide range of methods is used within the case study approach, most notably questionnaire surveys, interviews, case studies and discourse analysis. Such a combination of methods can compensate for one-sidedness and prevent partial explanation of a complex phenomenon (Yin, 1994; Kemp and Pontoglio, 2011). Objective measures are used for the variables under investigation. The assignment of vehicles trajectories to the four segments of the market evolution scheme has an interpretive element but draws on objective information. Combining methods is usually challenging but found to be quite do-able in our case. We find that synthesizing findings of various methods is a useful and necessary approach to explain a complex phenomenon like the emergence of electric mobility. Section 4 interprets the results of the hypothesis testing (in the context of innovation ‘motors’ and ‘webs of constraints’), whereas Section 5 draws conclusions about the validity of our hypothesis in this sector for the current time period.

2. A hypothesis for market disruption

2.1. Disruptive innovation

Christensen (1997) distinguished between sustaining and disrupting technologies. In later publications (Christensen and Raynor, 2003; Johnson et al., 2008) he replaced the term disruptive technology with disruptive innovation, recognizing that few technologies are intrinsically disruptive or sustaining in character: it is the business model that the technology enables that creates the disruptive impact, not the technology as such. In Christensen’s typology, sustaining innovations foster improved product performance. He argues that most new technologies fall into this category and are mostly are of an incremental nature. What all sustaining innovations have in common is the capacity to improve the performance of established products that mainstream customers have historically valued. An automotive example is the innovation of electronic fuel injection, introduced in the 1980s, which improved the fuel efficiency of internal combustion engines but did not disrupt the market for cars.

Disruptive innovations bring to the market a very different value proposition than had been available previously, and in this have the power ultimately to precipitate the failure of incumbent firms. Initially their performance is usually below that of mainstream products but lower price or unique features compensate it. An example is the photography market after 2000. Early digital cameras suffered from low picture quality and resolution and long shutter lag, but the convenience of small memory cards and portable hard drives that hold thousands of pictures made them attractive for some consumers. Economies of scale and dedicated R&D resulted in cheaper and better products, which helped them to reach a wide consumer base. As a result, non-digital cameras were transformed into a niche product.

Later, Christensen made a distinction between new-market innovations and low-end market innovations. Low-end market innovations are those that do not result in better product performance; they serve users who are attracted by low prices. An example of a low-end innovation is cheap retailing by megastores like Wal-Mart. On the other hand, new market innovations are those serving new users. The personal computer is an example, since new customers had not owned or used the previous generation of products (Johnson et al., 2008).

Christensen does refer to market evolution in various ways, but the analysis and the consequent recommendations are kept at the firm level, since his interest is on how companies (should) behave when confronted with disruptive innovation. Although his analysis addresses the interplay of product performance and firm strategies, he does not assess how the evolution of the market share of the disruptive innovation may or may not lead to a new market regime through a process of niche development and co-evolution.

Disruptive innovation can provide significant competitive advantage to firms. Advantages may stem from being a quick mover or a quick follower. The ‘first-moving’ firm potentially occupies a whole new market segment. Its position may stem from technological leadership or from the fact that the first entrant can gain control of resources that followers may not be able to match (Lieberman and Montgomery, 1988). First-movers are potentially rewarded with generous profit margins and a monopoly-like status. Being the first also comes with disadvantages: the costs of developing the market and product falls upon one company, which may be too much to bear. The first mover may not be able to capitalize on its advantage, leaving the opportunity to other firms to compete effectively and efficiently versus their earlier entrants. There are “second-mover advantages”, in the form of free-rider effects through imitation (and according R&D savings) and lessons from the initial users (successes and failures). Nevertheless, Lieberman and Montgomery suggest that no simple managerial prescriptions apply with regard to first-mover advantages and to the optimal timing of entry.

Studies of radical innovation have proposed that not incumbents but entrepreneurial new entrants are usually the first-movers regarding disruptive innovation. Incumbents struggle with disruptive technologies for several reasons, as summarized by Bohnsack (2013):

First, they often fail to recognise demand outside the circle of their well-known key customers. Second, incumbents tend to find disruptive technologies unattractive because of small initial profit margins (Christensen and Bower, 1996). Furthermore, they are restricted by resource allocation processes that are not aligned to the new situation, and a ‘familiarity trap’ (Ahuja and Lampert, 2001) that favours past routines, prior knowledge and prevailing technologies. Hence, incumbents are often neither motivated nor able to develop disruptive technologies: they lack economic incentives and/or face organisational barriers (Henderson, 1993).

At the same time, however, Chandy and Tellis (2000), who labeled this complex of factors the “incumbent’s curse”, suggest that this conventional wisdom may not always apply, referring to many cases of (radical) innovative incumbents.

2.2. Regime evolution

Christensen’s analysis is less concerned with changing consumers’ perspectives and government regulation. For our case of electric mobility, however, we think the latter two are especially important, and therefore suggest an elaboration of Christensen’s typology into a regime evolution framework based on changes in both technology and the institutional context of production and use, especially consumer perspectives and government regulation.

Whereas economists and business researchers talk about markets, others have coined the notion of regime (Kemp, 1994; Rip and Kemp, 1998; Geels, 2002): the socio-technical system that has grown between the hardware and user perspectives and practices (reflecting their preferences and endorsed social connotations), producer capabilities, business models and production technologies, regulations, and supporting institutions. Product regimes are socio-technical ensembles that have been aligned and, over time, reproduce the conditions for their own continuation. The prevailing ICE-focused automotive regime is thus an example of a socio-technical system in which dynamic stability is obtained through economies of scale and scope, sunk costs, and social learning. Although alternative regimes can be contemplated, they are not easily realized because they would have to go through a process of emergent realignment during which they must compete against well-developed alternatives.

Dijk et al. (2015) have suggested a regime-based typology of market evolution with four possible quadrants: regime reproduction and regime reorganization (both regime sustaining), and regime-amidst-

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