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Modularised eco-innovation in the auto industry

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ABSTRACT

The article explores the integration of alternative drivetrain solutions in the automotive industry. The article includes an analysis of the structure of the conventional automotive value chain and presents four examples of alternative vehicle designs. The article concludes that the component sharing across drivetrain solutions such as the battery electric, the hybrid and the fuel cell system opens a window of opportunity for modular design strategies that may make integration into the otherwise locked conventional production system possible.

1. Introduction

The automotive industry is facing a huge challenge to reduce the environmental impact from cars. The pressure on the automotive industry to innovate and improve the performance of technology fitted in cars is created by a combination of consumer demand for fuel efficient cars, European Union legislation on CO_2 emissions of newly registered cars (European Commission, 2009) and by national and local authorities who set up incentives for car-users to purchase cleaner and more fuel efficient cars.

The conventional mass-market vehicles offered to consumers are typically based on steel bodies and fitted with ICEs. These vehicles are designed and manufactured in a production system characterised by modular design and manufacturing strategies for the core technologies fitted in the cars (Pandremenos et al., 2009; Persson, 2006a; Sturgeon and Lester, 2003). The modular design and manufacturing system enables the vehicle manufacturers to increase scale and cut costs, but it also results in huge sunk costs in production equipment at the vehicle assembly plants. These huge production equipment costs eventually create high entry barriers to technologies that are not easily adapted to the mass-production paradigm of the conventional automotive industry (Andrews et al., 2006). The high entry barriers have, for decades, hindered the integration of alternatives to the conventional fossil fuel powered combustion engine (Orsato and Wells, 2007). This article explores how alternative drivetrain solutions can be implemented in the conventional mass-production system.

2. Revolution or evolution

Vehicle manufacturers have presented a variety of different prototype vehicles with alternative drivetrains at auto-shows, but only a small number of vehicles equipped with alternative core technologies have gone one to be offered to consumers on any significant scale. Huge sums of money have been invested in the development of, for example, fuel cell powered vehicles (van den Hoed, 2007; Oltra and Saint Jean, 2009), but market penetration has so far been insignificant.

Researchers (Wells, 2004; Lovins and Cramer, 2004; van den Hoed, 2004) and NGO's (Kågeson, 2005) therefore argue that the automotive industry has failed to renew the technological base on which new cars are developed and produced, especially within the areas of environmental performance of the cars. Lovins and Cramer (2004) argue that

> "[A]utomaking is exhibiting all the signs of a classic over-mature industry: hypercompetition over shrinking niches for

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convergent products in saturated core markets, global over-capacity and consolidation, cutthroat commodity pricing, modest to negative margins, stagnant basic innovation (until the mid-1990s), and limited attractiveness for recruiting top talent or strategic investment. In short, automaking, like airlines, is a great but challenged industry, ripe for fundamental change." (Lovins and Cramer, 2004)

The question is therefore whether the automotive industry will be able to meet the challenges they are facing and renew the technological base, so that consumers are offered cleaner and more energy efficient cars? Three potential future scenarios describe possible outcomes: 1) The industry could modify the existing production system in order to facilitate the integration of alternative technology or 2) a breakthrough technology could revolutionize industry structure and pave the way for more environmentally sustainable business models or 3) the existing companies could fail to renew the technological base and in time find themselves outcompeted by intruding companies with business models based on cleaner and more energy efficient technologies.

A vast amount of literature addresses the question about how industries create or react to technological changes. Nelson and Winter (1982) explored the process in which 'routines' in established companies function as barriers or roads to identify and adopt new technologies. Based on the work by Schumpeter, Nelson and Winter furthermore introduced the concept of trajectories in order to emphasize that industries usually develop incrementally along a defined path, constituted by patterns of routines, and often find it difficult to break away from that development path. Freeman (1991) introduced the distinction between 'incremental' technological changes (small scale changes to existing design), 'radical' changes (discontinuous events that result in changes to the way industries are organised) and 'technological system'-changes (changes that revolutionize the technical and economic foundations of the industries) in order to understand the differences in magnitude and impact between various types of technological changes.

A key point in this body of literature is the concept of 'lock-in', which describes a situation where a technology system is locked to self-reinforcing development path (trajectory). A lock-in can arise from elements such as search routines, technology, existing competences and knowhow, investments, economies of scale, fixed buyer–supplier relationships etc., which makes it difficult for the embedded companies to adopt new technologies that require fundamental changes to the way the system-elements are organised (Unruh, 2002; Cowen and Hultén, 1996). The concept of lock-in has been used in the analysis of different sectors and technologies including the automotive industry (to give a few examples see Orsato and Wells, 2007; Unruh, 2002; Cowen and Hultén, 1996; Dijk and Yarime, 2010; Johan Schot et al., 1994). These studies all identified a 'lock-in' situation in the automotive industry constituted by system-elements that support a continued production of vehicles fitted with ICEs. Furthermore, theoretical work on the lock-in phenomena suggests that the lock-in situation can be eliminated by a combination of regulation, technological breakthroughs, change in consumer behaviour or emergence of niche markets, but also recognises that such system changes are rare and are difficult to organise.

Rather that discussing the preconditions for a complete re-invention of the automotive industry, as suggested by Lovins and Cramer (2004), this article explores if and how the current lock-in in the automotive industry can be bypassed by utilising existing production principles (namely modular production and design) to integrate new technologies (alternative drivetrain solutions). The article thereby critically investigates the first of the three future scenarios that was presented above; that the automotive industry modify the existing production system in order to accommodate design and production of vehicles with alternative drivetrains.

The article is divided into two parts: first, an analysis of the automotive industry structure and; secondly a presentation and discussion of four cases in which the principle of modular design and production has been utilised in order facilitate integration of alternative drivetrain technologies. Large-scale adaptation and diffusion of alternative drivetrain technologies is yet to be seen in the automotive industry. The four examples discussed here are therefore meant primarily as illustrations of ways in which the modular principle could potentially be deployed in the future to assist the integration of alternative drivetrain options.

3. The structure of the automotive industry

The design, deployment and diffusion of environmental technologies in the automotive industry are largely dependent on current configuration of the production system. The large-scale production in the automotive industry, with economic break-even points approaching 250,000 units per car model (Orsato and Wells, 2007), has enabled car manufacturers to incrementally reduce production costs and supply consumers with relatively cheap cars (compared to, for example, handmade custom cars) (Womack et al., 1990). However, the mass-production system of the automotive industry also favours the continued production of cars based on existing technology (a steel body and a conventional combustion engine), as large-scale investments in production equipment makes it difficult to integrate new technologies that require changes to the established production processes. Andrews et al. (2006) estimate that the price of a modern vehicle assembly plant including a press shop, a welding plant, a painting shop and an assembly shop is somewhere between 390 and 665 million £. The combustion engine is usually manufactured at a separate factory also associated with very high unit numbers in order to reach economic break-even points. The average production capacity at British engine plants was just below 500,000 engines per year in 2005 (Rhys et al., 2005). This production system has created a lock-in situation, in which it is economically unattractive and technically unattainable for the vehicle manufacturers to experiment with alternative drivetrain options (Wells and Nieuwenhuis, 2003).

The high volume production furthermore makes the industry vulnerable to changes in consumer demand for cars. IHS Global Insight estimates (IHS Global Insight, 2009), in a report prepared for the European Commission, that the economic crisis in the autumn 2008 and the resulting fall in car sales in Europe (EU 27) will cause a decrease in capacity utilisation at European vehicle assembly plants from just above 80% down to 65% during 2009 – the typical profitability zone is above 80% (IHS Global Insight, 2009)! These figures illustrate that the profitability of the mass-production system in the automotive industry is highly sensitive to capacity utilisation at the assembly plants. This is a feature of the system that also adds to the lack of radical innovation and experimentation in the area of environmental technology.

In addition, the organisation of design, purchasing and process operation also favours large-scale mass-production, as the benefits of the high volume production system not only apply to the assembly plants but to the entire automotive value chain. The end result is a highly complex mass-production system. Two commonly used interlinked production principles are especially important for the mass-production system in the automotive industry value chain. *Modular production*, which makes it possible for the vehicle manufacturers to reuse outsourced technologies across models and brands, and the *platform production*, which makes it possible