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On the relation between communication and innovation activities: A comparison of hybrid electric and fuel cell vehicles

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ABSTRACT

The automotive industry has proposed and announced a number of technological innovations to reduce the environmental impact of transport. Whereas initially many of the proposed technologies were surrounded by very optimistic expectations, many technological innovations are not commercially available yet and expectations eventually turned into disappointment. The hypes concerning these alternative drivetrain technologies collapsed when optimistic announcements could not be met, within the proposed timeframe. This paper analyzes the relation between research and development activities (innovation activities) and communication activities in the automotive industry using patent statistics, press releases and interviews. The analysis reveals that the underlying characteristics of the specific technology have an influence on the relation between communication and innovation activities. When innovations depend on the build-up of a new infrastructure actors have a strong incentive to raise expectations. This suggests that the specific shape of the hype cycle is depending on the complexity of the technology.

1. Introduction

The transport sector is one of the most polluting sectors and several technologies have been proposed in the last decades to improve the energy efficiency and reduce the emissions generated by

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the sector (Geels, 2012; Sperling and Gordon, 2009). At different times during previous decades different technologies such as battery electric vehicles, fuel cells or bio-fuels, were considered the most promising candidate to reduce the environmental impact of the automotive-based transport system. However, many of these technologies could not fulfill their initial promises and positive expectations turned into disappointment. More specifically, we observed several hype disappointment cycles with regard to these green propulsion technologies (Bakker, 2010; Geels, 2012). The observed hypes eventually collapsed when the initially very positive expectations could not be met, and turned into disappointment (Linden and Fenn, 2003; van Lente, 1993; van Lente et al., 2013). These hype cycle dynamics are not just an artifact of the discourse around a technology, they also influence and are influenced by the actual innovation activities. Previous studies have shown, for example, that discourse activities are pivotal to expectation building processes and thus to policy and investment decisions (Borup et al., 2006; Konrad, 2006b). But whereas the uptake of the hype cycle can trigger innovation activities, the subsequent downturn may lead actors to eventually withdraw from their activities in the field (Bakker and Budde, 2012; Ruef and Markard, 2010b). In a worst case scenario the negative dynamics may even stop the further development of a technology. Thus the analysis of the patterns and causes of such expectation dynamics and insights in the role and nature of communication activities and their relation to innovation activities are important for actors involved in the development of a technology.

The main topic of this paper is therefore the extent to which the *announcements*, i.e., the communication activities of sustainability innovations by the automotive industry ("*talking*"), are matched by a corresponding level of activities for development and deployment ("*doing*"). The analysis of the relation between these two kinds of activities is in particular relevant since a gap between the promises made in the communication and the innovation activities may eventually lead to the emergence of a hype-disappointment cycle. In this paper we will therefore make an analytical distinction between activities focusing on the "*doing*", referring to them as innovation activities, and the "*talking*". The latter we refer to as communication activities. Following this analytical distinction we scrutinize the relation between the communication activities and the innovation activities in the automotive industry. We chose to analyze two clean vehicle technologies that differ with respect to market penetration: hybrid electric vehicles and fuel cell vehicles. While hybrid vehicles are widely diffused to the market, fuel cell vehicles are still not for sale to the general public. More specifically, this paper analyses the communication and innovation activities of the two leading car manufacturers of these technologies, Toyota (HEV) and Daimler (FCV).

Therefore we raise the following research questions:

> RQ: What is the relation between innovation and communication activities in the automotive industry and are there differences observable with regard to HEV and FCV and – if there are differences, how can these differences be explained?

The remainder of the paper is structured as follows: Section 2 discusses the conceptual framework, which is based on the literature on the sociology of expectations, (organizational) legitimacy and transition studies. In Section 3 we focus on the methods and the empirical data used for this paper, including descriptions and definitions of the two drivetrain technologies. Section 4 will present the empirical data, followed by conclusions in Section 5.

2. Theoretical background: expectations, discourses, legitimacy

This paper builds primarily on the literature on expectations which emphasizes the important role of communication activities for the motivation, guidance and coordination of innovation activities. First, we discuss the role of (collective) expectations shaped in discourses as described in literature on the sociology of expectations. Second, we will discuss the role of legitimacy and environmental pressures for the emergence and persistence of organizations and the role communication activities may play in these processes.

Innovation is a risky, long-term process in which many technologies eventually fail. This holds particularly true once a technological paradigm (Dosi, 1982) or dominant design has emerged (Tushman

and Anderson, 1986). Due to increasing returns to scale for the dominant technological configuration, it becomes increasingly better and more and more resources are spent in order to improve this dominant design. Once a dominant design has emerged 'rules of thumb' and routines are developed, which increase the capabilities of the dominant design, making it more difficult for alternative technologies to enter the market. While these difficulties arise in all radical innovation processes, low carbon technologies suffer from additional and specific obstacles. Unruh (2000) describes this situation as a 'carbon lock-in', caused by a number of forces that support the persistence of the current fossil fuel based energy and mobility systems. If an innovation requires an additional infrastructure, a further obstacle can be expected: Infrastructure providers are hesitating to invest in infrastructure when there are no users (e.g. cars) taking advantage of that infrastructure. However, potential users are not willing to invest in a new technology when there is no infrastructure available yet. This specific situation is often referred to as a "chicken and egg" dilemma which may results into waiting games (Bakker and Budde, 2012; Schumacher et al., 2009).

2.1. Expectations

Since innovations are by definition future oriented, actors have to operate under conditions of great uncertainty and, in the absence of more "robust" knowledge about the future; they have to rely on their expectations (Budde et al., 2012). Following Borup and colleagues we define expectations as "real time representations of future technological situations and capabilities" (Borup et al., 2006, p. 286). Expectations allow decision-making and reduce the uncertainty that characterizes innovation processes. In their expectation building actors regularly refer to expectation statements by other influential actors in the field. Eventually, some of these expectations become a central reference in the discourse and an increasing number of actors consider these expectations as relevant. These "*collective expectations*" emerge from discourses (Konrad, 2006b). The importance of (collective) expectations has been shown by several studies on the "sociology of expectations" which focuses on expectations and their role for emerging science and technology (Borup et al., 2006; van Lente, 1993; van Lente and Rip, 1998).

Several authors have investigated how expectations influence innovation processes. It has been shown that expectation statements in the discourse, for instance about the future capabilities of a technology, can legitimize the strategies and actions of organizations. Therefore expectations can help to mobilize resources and attract the attention of other actors (Bakker and Budde, 2012; Konrad et al., 2012; van Lente, 1993). van Lente and Rip (1998) emphasize the coordinating role of expectations and suggest interpreting expectations as "prospective structures"; expectations about future social structures may act as if they had materialized already, which may eventually result in self-fulfilling prophecies. Summarizing, expectations have a mediating role between actors and structure and play a key role in mobilizing, legitimating, guiding, and coordinating innovation activities (Konrad, 2006a, 2010; van Lente and Rip, 1998).

However, expectations are frequently subject to strong hype-disappointment cycles (Bakker, 2010; Ruef and Markard, 2010a; van Lente et al., 2013). van Lente (1993) explains these dynamics by the concept of promise-requirement cycles: Vague initial promises about a technology turn into requirements that have to be fulfilled. If these requirements cannot be met, disappointment sets in. The occurrence of hype cycle dynamics appears more likely if the statements and promises made in the discourse on a technology turn into an expectation race, rather than an innovation race (Bakker and Budde, 2012). Furthermore it has been shown that the specific features of technology hype cycles differ between technologies in specific fields (voice over ip, gene therapy, high temperature superconductivity), however little is said about the reasons for differences in the same sector (van Lente et al., 2013). Studies have shown that actors may try to inflate expectations about a technology they have an interest in, in order to increase their chances to mobilize resources (Bakker and Budde, 2012; Bakker et al., 2012; Brown and Michael, 2003). In related work Berkhout also emphasized the role of strategically deployed normative expectation statements (Berkhout, 2006).

In case of the automotive industry, central actors of the current automotive-based transportation system may have strong incentives to voice positive expectations about their innovation activities to show their responsiveness and willingness to address environmental challenges. The ability and willingness of central actors of the current mobility system is increasingly challenged, because of its

increasing CO_2 emissions and its dependence on fossil fuels (Geels et al., 2012). In response to this legitimacy challenge actors started to discuss and develop new options, such as alternative drivetrain technologies.

Thus the voicing of high expectations can be understood as strategies to create, maintain or restore the legitimacy of organizations in the automotive industry. Even though organizations may not be able to adapt their behavior or performance in a way audiences expect them to do, organizations can maintain their legitimacy if they demonstrate their responsiveness to the concerns of the audiences (Suchman, 1995). Frequently, this kind of responsiveness and acknowledgment of requirements is more important than immediate results as such (Meyer and Rowan, 1977). Following this argument by Meyer and Rowan (1977) and other proponents of the strategic tradition in the study of legitimacy (see Suchman, 1995 for an overview) we conclude that organizations are conducting certain kinds of activities to show the audiences of the organization (e.g., the public or policy makers) their responsiveness, for instance by announcements to work toward the desired outcome, even though that may take time. Against this background, announcements fuelling positive expectations about clean technologies could be interpreted as a means to improve the legitimacy of the automotive industry. However, these communication efforts are sometimes not backed up by changes in the actual activities of the companies, a strategy referred to as "greenwashing" (Wæraas and Ihlen, 2009).

Summarizing the literature above, we conclude that both are emphasizing the role of communication activities respectively discourses. Taking into account the argument of legitimacy studies that organizations try to maintain their legitimacy by showing signs of responsiveness to stakeholders and the importance of expectations shown by studies related to the sociology of expectations, we propose to analytically distinguish innovation and communication activities.

Innovation activities are activities that aim directly toward the diffusion of an innovation in a narrow sense (research, development, demonstration, etc.); in other words: the activities one would refer to as "doing" or working on (toward) the innovation itself. By *communication activities* we refer to all kinds of communications related to an innovation. Thus, communication activities represent the "talking or discussing" about the innovation.

To summarize, communication activities are stimulating and supporting innovation activities, but their relationship is complex and communication activities may not provide a comprehensive view or be the best indicator of innovation activities in a narrow sense. For a firm, there may be incentives to communicate intensively about green technologies to improve its legitimacy. Sometimes a gap between the discourse and innovation activities becomes apparent, when the claims and announcements made in the discourse cannot be realized. This paper aims to gain more insights in the role and nature of communication activities and in particular their relation to innovation activities in a narrow sense.

3. Definitions, data and methodology

This paper analyzes the relationship between innovation and discourse activities in the automotive industry, using the cases of hybrid electric vehicle (HEV) technology and fuel cell vehicle technology (FCV). In this section we will first define what we understand by HEV respectively FCV and what characterizes both technologies. Second, we elaborate on our research methodology, which encompasses a mix of qualitative and quantitative methods.

3.1. Definition of technology: HEV & FCV

Hybrid electric vehicles (HEV) are vehicles combining a conventional international combustion engine with an electric drivetrain. Therefore, HEV can be used like conventional gasoline/diesel vehicles and the battery is charged by the use of regenerative breaking. In other words: HEV are able to store the energy that is otherwise lost (transformed into heat at the brakes), into their battery (Staunton et al., 2006). The vast majority of current HEV models on the market by Toyota and others do not require (or offer the possibility) to charge the battery of the HEV from the electricity grid. Thus,

the operation of HEV does not require any additional infrastructure, like charging stations or battery swapping stations.[1]

Fuel cell vehicles (FCV) are powered by a fuel cell which produces the energy necessary for propulsion, and do not require an internal combustion engine. The fuel cells itself have to be fueled by an energy carrier, for instance hydrogen or methanol, thus the operation of fuel cells need the build-up of a new infrastructure. The on-board fuel cells produce electricity, which can be stored in an intermediate battery. The battery is used to assist the fuel cell during acceleration and to improve the durability of the fuel cell. Therefore FCV can be and are regarded (or marketed) as fuel cell hybrid vehicles (FCHV) by some OEMs, which was taken into account in our search strategies (see below). However, for reasons of clarity we will stick to the abbreviation FCV for vehicles propelled by a fuel cell in the remainder of the paper. FCV are not commercially available yet, but a relatively small numbers of vehicles are deployed within demonstration projects or on special lease contracts to selected customers only (US DoE, 2011a).

3.2. Quantitative methods: media data, patents

We use media attention and patent statistics as quantitative indicators to measure the level of communication respectively innovation activities

3.2.1. Media data: press releases

In order to measure the level of discourse activities we choose to use the number of press releases in two major channels for the publication of press releases: Business Wire and PR Newswire. Both companies describe themselves as market leaders in commercial press release distribution on a global scale (Business Wire, 2012; PR Newswire, 2012). Although media attention in newspapers has been used as an indicator in a number of studies (e.g. Weingart et al., 2002), we choose to use the number of press releases since they are a closer indicator for the communication activities of a company, than media coverage in newspapers. The articles were retrieved through the media database Factiva (Factiva, 2013). The first step of the identification of the technology specific articles was done by using the search terms “hybrid” respectively “fuel cell*” and its respective truncations. The search was not limited to titles or abstracts, but the whole corpus of the articles was included. In order to relate articles to a certain organization (Daimler, Toyota) we used the Intelligent Indexing function provided by the Factiva media database. Intelligent Indexing is a proprietary taxonomy structure provided for all articles in the Factiva media database. It assigns every article (or press release in our case) to a company, taking into account not only the company name itself but as well quoted subsidiaries and key unquoted subsidiaries (see Factiva, 2012; Sykes, 2003).[2] Therefore a search using for instance “Daimler AG” as the chosen actor will also yield articles related to subsidiaries of the Daimler Corporation. In addition we measured the coverage of the respective technology in three major newspapers (New York Times, Washington Post, Wallstreet Journal) to compare the communication activities of Toyota and Daimler to the uptake of these communication activities in the general press.

3.2.2. Patent statistics

We used patent statistics as an indicator of innovation activities. Despite of its limitations, patent statistics remain an important and widespread used information source to obtain information about innovation activities, in particular in sectors where innovation activities are highly confidential as in the automotive industry (Frenken et al., 2004; Hekkert and van den Hoed, 2004; Järvenpää et al., 2011; Oltra and Saint Jean, 2009; van den Hoed, 2005). Nevertheless patents may not capture all innovation activities; Among the limitations of patent analysis is that patent applications are potentially part of a deliberate patent strategy, and not all inventions are patented (OECD, 2009), for example in order to

[1] More recently the concept of Plug-In Hybrid Electric Vehicles (PHEV) has been proposed, which is basically a HEV with an increased battery capacity and the opportunity to charge the battery from the grid (Sovacool and Hirsh, 2009).

[2] A detailed list of codes and criteria for coding is available at http://factiva.com/content/indexing/indexing2.asp.

keep them secret from competitors (Kleinknecht et al., 2002; Zuniga et al., 2009). Moreover, we are aware that some technologies provide more opportunities to patent than others and patent classes are not directly comparable since some have a broader coverage than others, thus the total numbers of patents cannot be compared between HEV and FCV (Archibugi and Planta, 1996). Moreover the patent intensity may differ between countries, with some countries like Japan having traditionally a higher patent intensity than the US (Cohen et al., 2002). However this paper focuses on the dynamics of patent activities in relation to communication activities rather than on counting patents and comparing the innovation activities between the two technologies. The patterns can be compared for Toyota and Daimler, as earlier studies indicate that the patenting strategies of these companies are similar although their technological focus differed in the past. (van den Hoed, 2004, 2005) We used the Espacenet database provided by the European Patent Office (EPO), which encompasses more than 70 million patents from 90 countries worldwide (EPO, 2011). We followed the patent search strategies for environmental-related technologies proposed by the OECD which specifies relevant patent classes for specific technologies (OECD, 2011). To identify fuel cell related patents we used the proposed patent classes "Fuel Cells" (Y02E60/3*) and "Hydrogen Technologies" (Y02E60/5*) and the patent class "Technologies specific to hybrid propulsion" (B60K6 and B60W20) for HEV technology. Furthermore "Daimler*" respectively "Toyota" were used to filter the relevant patents. The time lag between research activities and patenting was minimized by the use of the priority date to assign a certain patent to a specific year.

3.3. Qualitative methods: interviews, discourse analysis

To understand the nature of the relation between communication and innovation activities we draw on the qualitative analysis of semi-structured interviews with decision makers in the automotive industry and qualitative analyses of media articles. In the period from 2007–2009 we conducted *31 semi-structured interviews* with key actors in the field of alternative drivetrain technologies: The interviewees include employees of car manufacturers (8); other industry actors (supply companies, pioneer users – such as fleet operators: 7), scientists (universities, research centers: 8), policy makers (public agencies/ministries: 5), and others (venture capitalists, consultancy companies: 3). The interviewees were identified during the discourse analysis and through the snow ball method (Atkinson and Flint, 2001). In order to allow the interviewees to speak relatively open, they were guaranteed confidentiality and the reference section of the paper only states the general position of the interviewee, and the date and place of the interview. Although interview data can be biased due to impression management or retrospective sense making by the interviewees, interviews are a highly efficient way to gather relevant data (Eisenhardt and Graebner, 2007). In order to limit this potential bias we interviewed experts from different hierarchy levels whereas most of the data in particular in the case of Toyota were in senior/top management positions at the time when the fist HEV vehicles at Toyota were developed. This data was gathered during a series of workshops (Japan, Sweden, USA, and Germany in 2008/09) organized within the context of an International Energy Agency (IEA) task force scrutinizing the development of electric and HEV in the 1990s.[3]

A *qualitative discourse analysis* of the press releases (see Section 3.3) provided insights into the content and dynamics of statements made by the actors. The analysis was supplemented by public media sources, such as newspaper articles, policy debates and engineering journals. The qualitative analysis enables and supports the interpretation of the results. Furthermore additional information is required to understand the rationales of the actor strategies. Some of the most relevant interview data was gathered through interviews with retired employees who could speak in a rather free manner. However, the names of the interviewees remain confidential by mutual agreement.

[3] IEA implementing agreement on hybrid and electric vehicles: Task 14, market deployment of electric vehicles: lessons learned.

4. Empirical findings

The empirical analysis consists of an analysis of the communication and innovation activities of Toyota regarding HEV technology and Daimler concerning FCV technology. The innovation trajectories of those two technologies have evolved completely different; while HEV are available for purchase on the market and sold in meaningful numbers (cumulated sales 1999–2010: 1,9 million vehicles, (US DoE, 2011b)), fuel cell vehicles are currently only deployed in research or demonstration projects and not yet available for regular customers.

4.1. HEV & Toyota: innovation and discourse patterns

In 1997 the *Toyota Prius* was the first HEV introduced on the market in Japan. Three years later, in 2000, the Prius became available in the US and some other countries. Honda followed with the development and introduction of its hybrid model *Insight* in 1999 (the first to offer a HEV in the US), and Ford with several models including the sports-utility-vehicle *Ford Escape hybrid* in 2004. In subsequent years, most major car producers developed and marketed HEV with different configurations. In 2011 there were HEV from Toyota, Honda, Ford, GM, Nissan, BMW, Hyundai and Volkswagen for sale in the US, and cumulative sales in the US from 1999 to 2010 were 1.9 million vehicles (US DoE, 2011b). Toyota was and still is the industry leader in HEV technology and sales (Nonaka and Peltokorpi, 2006; Pohl and Elmquist, 2010). Despite the fierce competition from other car manufacturers Toyota maintained a market share of 69% of all HEV sold in the US in 2011, followed by Ford and Honda with approximately 12% each (US DoE, 2011b). The remainder of this section focuses on the history of HEV technology at Toyota, the technology and market leader in HEV technology.

Within the Toyota company discussions concerning sustainability and the future need to reduce the environmental burden of cars started in early 1992. In response to the 1992 "Earth Summit"[4] conference in Rio, Toyota's top management introduced guiding principles emphasizing the role of forest management, conservation, and sustainable development. Based on these guiding principles the Toyota Earth Charter was drafted, which states the policy and guidelines of the company on how to achieve a more sustainable business, emphasizing the importance of more efficient vehicles (Expert 1; Hino, 2006; Toyota, 2012).

Furthermore, the Low Emission Vehicle (LEV) program that was introduced in California in 1990 (see Collantes and Sperling, 2008; Kemp, 2005), which would have eventually required automotive companies to achieve an increasing share of LEV and Zero Emission Vehicles (ZEV) of their overall sales in California, caught the attention of Toyota's management. The implementation of the LEV program and further discussions concerning future regulations added momentum to the debates on more environmentally friendly technologies within the company. One option that was considered was to avoid the high costs of developing new technologies and to eventually pay fines in case future regulations would require more environmentally friendly technologies. However, this option was abandoned since it was not in line with the overall strategy defined by the Toyota Earth Charter (Expert 1; Expert 2). Furthermore, management aimed to give Toyota the image of a "green brand", and this required compliance with environmental regulations and. As a result, Toyota management decided to develop more environmentally friendly technologies (Expert 2).

At that point it was not clear if battery electric vehicles (BEV), fuel cell vehicles (FCV) or HEV were the most promising technology. Technology assessment exercises for the different technological options were conducted in the early 1990s, and in 1994/95 the outcomes were presented to the top management. Toyota decided that HEV technology was most promising and that HEV development activities should be intensified (Expert 2). More specifically, in late 1995, Toyota decided to develop the Prius model and initially planned to start serial production in 1999 (Expert 1). Later on, top management shortened the research and development time and ordered that the Prius should already be presented in 1997, when the Kyoto conference[5] on climate change took place in Toyota's home country, Japan.

[4] United Nations Conference on Environment and Development (UNCED), Rio de Janeiro, Brazil, also known as "Earth Summit" or "Rio conference".

[5] Conferences of the Parties (COP) 3 in Kyoto, generally known as the "Kyoto conference".

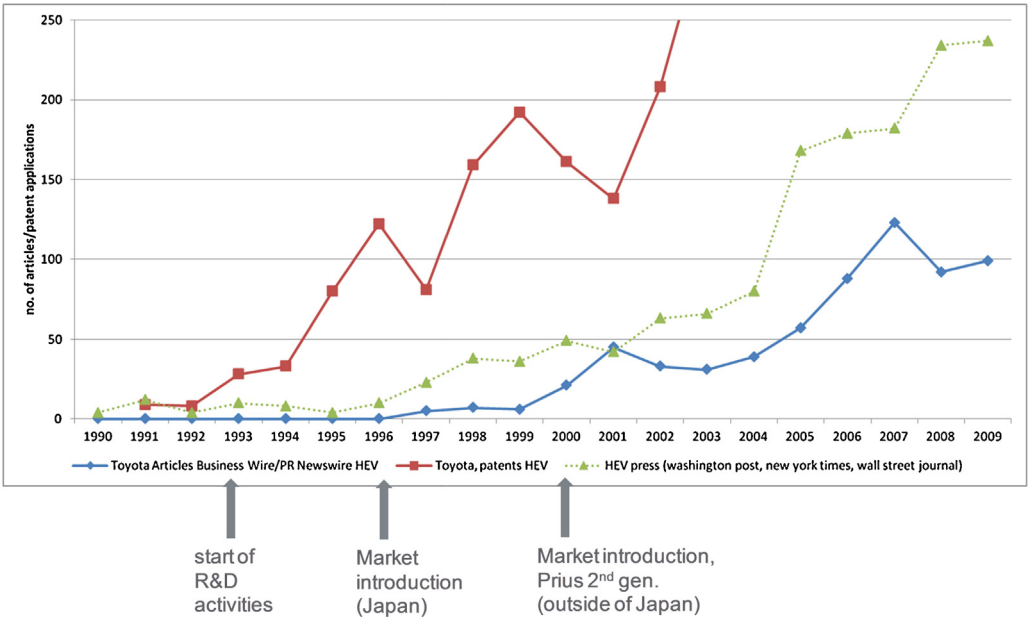

Fig. 1. Number of HEV patents and PR articles per year.

Although Toyota was known for its relatively short development cycles in the industry, this decision was highly risky and experts were skeptical if it would be possible to develop the Prius within this timeframe (Expert 1; Expert 2). Concerns especially focused on the feasibility of the development of the control system and the battery within such a short time frame (Expert 2). Despite these concerns Toyota and its suppliers managed to present the Prius in 1997 and it turned out to be a huge success, compared to the initial expectations within the Toyota R&D team (Expert 1). The Prius model played a decisive role in pioneering HEV technology at Toyota and beyond.

Fig. 1 shows the quantitative indicators describing the innovation and communication activities of Toyota. More specifically, it shows the total number of PR articles (as an indicator of communication activities) and the total number of patents applied for by Toyota with regard to HEV technology (as an indicator of innovation activities). Patenting activities started already in 1991 at a small scale, and subsequently increased in 1993 and 1994 to 28 respectively 33 patents. At the same time press coverage was limited with only a few articles from 1990 to 1995. After the decision to develop the Prius in 1995, the number of patent application increased sharply to 122 patents in 1996. Concerning the communication activities it is remarkable that no press release concerning the development of a HEV could be identified prior to 1997, when the first releases occurred, which were mostly related to the market introduction of the Prius in Japan. However, communication activities remained modest with less than 10 press releases per year until 1999. A similar pattern can be observed with regard to the press coverage of HEV technology in general. Moreover, as Toyota was modest concerning the content during that time. Most press releases mentioned the market introduction of the Prius in Japan. Market introduction in the USA was announced “after observing consumer reaction and performing further evaluation in Japan” and “as early as possible, and before the end of this century” (PR Newswire, 1997), which was slightly delayed but confirmed in the following year by Toyota President Okuda (PR Newswire, 1998a). In addition a number of press releases announced ride and drive events for the motor press and selected customers prior to the official market introduction in the US (e.g. PR Newswire, 1998b). Although Toyota was praising the advantages of HEV technology, there was hardly any revolutionary rhetoric and many press releases regarding HEV technology were mentioning the potential of full electric vehicles (PR Newswire, 1997).

The communication activities by Toyota itself increased sharply from the year 2000 onwards; the time of the market introduction of the Prius in the US. That can be explained by the use of our databases focussing on the US. However, a similar pattern concerning the communication activities can be found in Japan, where HEV technology was hardly mentioned in the press prior to the market introduction of the Prius in 1997.[6] After the global rollout, innovation and communication activities generally increased until 2007, with some decrease in 2008 and 2009.[7] Patent applications were still rising in recent years indicating the further development of HEV technology.

To conclude, Toyota started its innovation activities prior to its communication activities. The database contains no press releases by Toyota before the market introduction of the Prius. A similar picture holds true for Japanese media, where hardly any newspaper articles related to HEV technology were published before the market introduction of the Prius. Communication activities substantially increased in conjunction with the market introduction of the Prius in the US.

4.2. FCV & Daimler: innovation and discourse patterns

In contrast to HEV technology, FCV technology is not yet commercially available. However demonstration projects exist in Europe, USA, Japan, Korea and China involving most of the large car manufacturers (Bünger et al., 2010). Fuel cell technology has already been through several hype disappointment cycles: Whereas expectations initially were highly optimistic and a market introduction was already announced for the early 2000s these positive expectations subsequently turned into disappointment (Bakker, 2010; Bakker and Budde, 2012). The remainder of our description focuses on Daimler, generally described as the fuel cell pioneer in the automotive industry (Aigle et al., 2007; Bakker, 2010; van den Hoed, 2005; Weider et al., 2004). In the 1990s, Daimler focused its research on alternative propulsion technologies mostly on fuel cells (Expert 3; van den Hoed, 2004) and it was the first major car manufacturer presenting prototypes of fuel cell vehicles, after the initial fuel cell experiments by General Motors (GM) in the 1960s in the USA.

In 1994 Daimler presented its first prototype *NECAR I* (New Electric Car, but also referring to the Neckar river near Daimlers headquarter in Germany) triggering large interest in the technology. With the presentation of these prototypes, in particular the following NECAR II which demonstrated a large progress compared to former prototypes, Daimler generated optimism and high expectations about fuel cell technology (Expert 3; Expert 5). During the 1990s Daimler made several announcements of the market introduction of relatively large number of vehicles (up to 100.000) within a short time frame. It was announced that the first commercial vehicles would hit the market until 2004 (see for instance Jürgen Schrempp, Chairman of the Board, Daimler Chrysler, The Economist 22.03.1999). However, no fuel cell cars by Daimler or any other manufacturer have been introduced on the market as of the beginning of 2013. Nevertheless, a number of car producers including Daimler and Honda are deploying smaller series of fuel cell vehicles (up to several hundred) to selected customers in order to test them and gain data about FCV in real world conditions (Bünger et al., 2010).

Fig. 2 shows the selected quantitative indicators for the case of Daimler. It shows that Daimler's first patent application regarding FCV technology was in 1991. Subsequently, the patenting activities increased from 7 to 13 applications annually between 1993 and 1996. This pattern matches with qualitative information concerning the start of R&D activities and the presentation of the first prototypes in this time period. The level of communication activities remained very low with only one press release annually until 1997. From 1999 to 2001 we observed a modest increase in patent activity with around 20–30 patent applications every year, while the communication activities were intensified. Starting from only four press releases in 1998 this number increased to 10–20 press releases annually in the period 1999–2001. In 2002, both innovation and discourse activities rose to 65 patent applications and

[6] A media analysis presented by Akiteru Maruta during an IEA meeting (26.05.2008) revealed that hybrid vehicles were only mentioned 11–23 times per year from 1991 to 1996, and 356 times alone in 1997 in five major nationwide newspaper in Japan (Nihon Keizai Shimbun, Yomiuri, Asahi, Mainichi, Sankei).

[7] To maintain clarity and visibility the *y*-axis is limited to 250 patent applications per year. Otherwise it would be hardly possible to recognize the pattern in earlier years due to the large increase in patent applications from 2001 onwards. The number of patent applications for the years not visible in Fig. 1 are 607 (2005), 841 (2006), 1209 (2007), 1148 (2008).

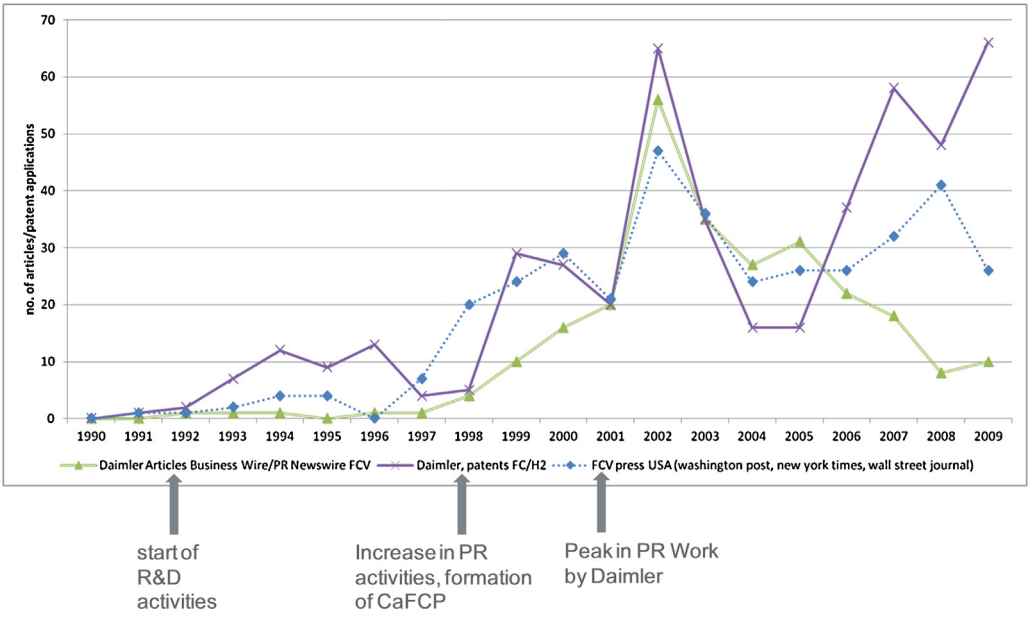

Fig. 2. Number of FCV patents and PR articles per year.

56 press releases. After this peak in 2002, both innovation and communication activities decreased. Whereas the level of communication activities decreased even further during the subsequent years, the number of patent applications rose again to the peak level of 2002. FCV coverage in the three major newspapers developed similar to the pattern of Daimler's communication activities with high levels of coverage from 1998 onwards and a peak in 2002.

Although the total number of patent applications cannot be compared directly between the case studies, due to the different underlying technologies and potential differences in the general patentability (see Section 2), the analysis of the temporal dynamics and relation of both indicators reveals some important differences between FCV and HEV. In the case of FCV we observed that innovation and communication activities exhibited similar patterns during the period 1990–2005. Daimler started its FCV communication activities already in the late 1990s and intensified them from 2000 until the peak in 2002. Daimler was already undertaking communication activities during the R&D period, while Toyota only started its HEV communication activities at the time of the market introduction of the technology.

In summary, Daimler's FCV communication activities co-evolved with FCV innovation activities. Thus we observe a different relation between innovation and communication activities in the two cases. In the following we will analyze and compare the rationales behind these patterns.

4.3. Comparative analysis of the two cases

This section compares both cases and scrutinizes the reasons for the differences identified in the previous section. The analysis of Toyota's HEV strategy showed an intensification of innovation activities, and no communication activities before the market introduction. Communication activities started just shortly before the market introduction of HEV technology in Japan. A major increase of communication activities took place in conjunction with the market introduction in the US. Most press releases were related to the market introduction of the Prius and emphasized the advantages of the new technology in general and of the Prius in particular and Toyota was not creating attention for its HEV technology before the market introduction. In the case of FCV and Daimler we observed that the communication activities co-evolved with the innovation activities. Daimler already engaged

in communication activities several years before a potential market introduction. Daimler thus pursued a different strategy for its FCV communication activities than Toyota did in the case of HEV. We will argue that this discrepancy is related to the different technological characteristics of the two technologies: While HEV are note dependent on new infrastructure to operate them, FCV rely on a completely new infrastructure. We argue that Toyota had no incentive to create attention and positive expectations already years before the actual market introduction was planned. The successful introduction of HEV did not require widespread optimism about the potential of the technology in order to mobilize other actors (outside of the supply chain), to develop components or services in order to be able to operate HEV. On the contrary, in a highly competitive industry like the automotive industry, it contributes to competitive advantage if R&D activities are kept secret as long as possible. Although positive expectations about the technology help to generate demand for the technology, it appears sufficient when these expectations are raised around the time of the market introduction.

From the interviews it becomes apparent that the incentives were different for Daimler. Daimler was developing different types of FCV which could be fueled by hydrogen or methanol, however the latter was given up later due to technical problems and a lack of commitment by the oil industry and other car producers (Expert 4; Expert 8). The build-up of a hydrogen infrastructure requires large investments and a coordinated effort by various stakeholders (BMW Group et al., 2006; HFP Europe, 2007; HyWays, 2008; US DoE, 2001). Due to the technological and organizational complexity of FCV and the required infrastructure, Daimler's management regarded it as essential to mobilize several stakeholders to join the efforts.

"The development of such a technology [fuel cells] cannot be managed by a single car manufacturer [. . .] [Thus] we had to find partners in order to have a large enough momentum to get states, energy companies and other automotive companies on board. It is necessary that many others join to achieve a technology change. However Daimler has to stay in the leading position." (Expert 3, translated from German)

Thus Daimler as a pioneering company was dependent on the support of other stakeholders and needed them to join the race. Therefore Daimler was confronted with a situation in which incentives were given to raise positive expectations about fuel cells. In this period Daimler managers gave very optimistic statements concerning the future deployment of FCV. Asked for the background of these optimistic statements one of our interview partners stated:

"I thought it [the fuel cell commercialization] would go faster [. . .]. Second, you had to fly your flag in order to get some people together. [. . .] Thus, we said, in order to get some attention, that we can imagine to produce 25 000 cars by 2004. However we really had the hope [to achieve that], since we were really satisfied with the performance of the technology. It was time to reduce costs and to extend reliability. We had a really nice plan for that, therefore we announced that number [25.000 vehicles by 2004]. It had an effect, it was positive. Daimler showed the way and everything was very optimistic." (Expert 3, translated from German)

These statements indicate that Daimler was following the incentives to spur optimistic expectations about fuel fell technology to raise awareness and mobilize other actors. Eventually this strategy was relatively successful in motivating other car producers and policy actors to engage in the field of fuel cell technology. Other car producers intensified their activities in the field, at least partly, motivated by the momentum which was caused by Daimler's activities (Expert 5; Expert 6; Expert 7).

"And there was a strong sense of competition [in the industry]. When one automotive manufacturer says that it will change the whole automotive world in five years, the others are listening carefully. And I think this impulse was necessary to convince almost the whole automotive industry that this technology [fuel cells] is the right one in the long term." (Expert 9)

Furthermore Daimler was able to mobilize some policy support:

"The [subsequent] policy programs did not evolve independently from the automotive industry. It is always the case, that they are emerging from discussions with those, who are supposed to be supported. And of course it [the communication activities by Daimler] were important to raise the willingness of politics to join. And on the long term it [fuel cell development] doesn't work without policy support, industry alone is not enough." (Expert 5, translated from German)

However, as other interviewees point at, it was only possible to motivate other actors, since expectations about fuel cell technology were rather optimistic within the Daimler company (and its subsidies

developing fuel cell components) and the fuel cell community as such. An engineer involved in the development of FCV at another large car manufacturer summarized it as following:

"[. . .] Nobody [of the engineers working on FCV] really believed it [market introduction of FCV] would happen in 2004, however hardly anybody working within the topic, was believing that it would happen so late." (Expert 5, translated from German)

To conclude, the positive expectations about fuel cell technology, and its market introduction within a relatively short period of time, were largely triggered by the optimistic statements made by Daimler representatives during a period of rather optimistic expectations about FCV in the fuel cell community and the automotive industry in general. Daimler managers raised expectations about FCV in order to mobilize other actors to join the innovation race, since they realized that a complex technology such as FCV could not be developed and deployed by a single car manufacturer.

We argue that the differences we found in the analysis of communication and innovation activities cannot be explained by cultural differences between Toyota/Daimler respectively Germany/Japan. Although a number of car manufacturers (e.g. GM, Ford, Chrysler, Volkswagen) developed HEV in the early 1990s, none of them conducted intensive communication activities concerning HEV during that time, as can be seen from the total number of HEV articles in the press. Furthermore we checked the number of press releases from the automotive industry, which exhibit a similar pattern to Toyota's communication activities. Relatively few articles during the 1990s and a steep increase from the year 1999 onwards Although a number of press releases were launched during the early 1990s concerning HEV these statements were rather modest and mostly discussing HEV as a side issue to EV development. HEV technology was framed by the car manufacturers, which presented and produced a small number of HEV (GM, Volkswagen, Ford) already in the early 1990s, as one option among several others (PR Newswire, 1991a,b,c). Thus even though other car manufacturers from Europe and the US developed HEV, none of them conducted intensive communication activities concerning the technology.

5. Conclusions

This paper discusses the relationship between innovation and communication activities in the automotive industry. The analysis shows the strategic character of communication activities, but also points out the need for a technology-specific interpretation.

The comparison between HEV and FCV technology reveals that the underlying characteristics of the specific technology have an influence on the relation between communication and innovation activities. Whereas it has been shown that actors with a stake in a certain technology have an incentive to voice optimistic expectations about the technology since that will facilitate the mobilization of resources fur further innovation activities, this paper shows that these incentives can differ considerably between different technologies in the same sector.

The most remarkable difference between HEV and FCV is the complexity in technology and infrastructure development. While HEV are not dependent on the build-up of a new infrastructure, the operation of FCV would require the development of a dedicated infrastructure. Furthermore the development of FCV also requires new modes of cooperation between actors from different fields. A variety of actors are necessary to finance the development and build-up of a completely new system encompassing the vehicle and the infrastructure. Therefore Daimler, as a pioneering company and in particular the fuel cell division of Daimler, had a strong incentive to raise expectations in order to motivate other actors (other automotive companies, energy industry, policy) to join their innovation activities in the field of fuel cell technology.

Promises and positive expectations about a technology are probably necessary to mobilize actors and resources with regard to almost all innovation activities. However, in case of HEV and Toyota these processes probably took place within the company and its suppliers. In the case of Daimler, the positive expectations about FCV technology also had to be expressed outside of the company in order to motivate and coordinate external actors due to the complexity of fuel cell technology. Cultural differences may play a certain role to explain these differences; however we argue that the technological characteristics are more influential, since none of the other car manufacturers developing HEV in the early 1990s engaged intensively in communication activities stimulating optimistic

expectations about HEV, although they developed market ready HEVs (Wyczalek, 1999). Moreover, whereas we have not seen hype in the media concerning HEV before its market introduction, FCV were going through a strong hype-disappointment cycle. Around the turn of the millennium, almost all car manufacturers, including Toyota, raised very optimistic statements about FCV contributing to the hype (Bakker, 2010), while Toyota did not in case of HEV.

To conclude, the need to motivate and coordinate actors from different fields to develop and introduce a complex and infrastructure dependent technology such as fuel cells provides an incentive to raise or even inflate expectations. This finding indicates why complex and infrastructure dependent innovations seem to be particularly prone to strong hype disappointment cycles. As expectations have an even more important role in coordinating innovation actors. This motivating and coordinating role of expectations has been identified in the literature on the sociology of expectations before (Borup et al., 2006). However no differentiation with regard to the characteristics of the underlying technology was made, whereas we argue that more complex technologies require more (positive) expectations to coordinate innovation activities.

These insights contribute to discussions about the role of (incumbent) actors in transitions (see Farla et al., 2012). Whereas the automotive industry probably engaged, and probably continues to engage in activities which we refer to as “window dressing” or “green washing”, this paper shows that there can be motivations to spur expectations about emerging technologies which co-exist with strategies to motivate other actors to engage in innovation activities.

However, this paper does not aim to judge if the automotive companies in focus are working toward a transition or not. Whereas probably some of the communication activities by the automotive industry were (are) aimed to delay a transition toward sustainability or not, however the main argument of this paper is that there are technology specific reasons which contribute to expectation dynamics. Therefore these technology specific incentives to inflate expectations probably supplement other motivations (maintaining legitimacy, delaying regulation, “green image”) which eventually culminate into hype.

Even though the rationale to showcase new environmentally friendly cars may be beneficial to the legitimacy of an automotive manufacturer and play a role in the decision to engage in communication activities, our empirical case studies indicate that the technological characteristics appeared to be more influential on the nature and timing of communication activities. Furthermore, the Toyota case shows that the company was not raising expectations prior to the market introduction of the Prius, although the company was confronted with the upcoming Low Emission Vehicle (LEV) regulation and the upcoming Zero Emission Vehicle (ZEV) mandate. Finally, from a policy perspective, our results indicate that the analysis and interpretation of hype disappointment cycles should take into account the specific technological characteristics of the underlying technologies.

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Expert 5, Senior Manager, General Motors, Interview with Senior Manager, Vienna.
Expert 6, Researcher, Interview with Researcher, Ottobrunn.
Expert 7, Scientist, Interview with Scientist, Switzerland.
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