Corporate Social Responsibility and Knowledge Management Implications in Sustainable Vehicle Innovation and Development

Hamid Jafari Khaledabadi
School of Industrial Engineering and Management, Royal Institute of Technology (KTH), Stockholm, Sweden,
hjkh@kth.se
Thomas Magnusson
Department of Management and Economics, Linköping University, Linköping, Sweden,
thomas.magnusson@liu.se

Abstract

Recently, due to the ever-increasing concern regarding the environment, the automotive industry has experienced a significant technological competition in the power-train. Focusing on how Corporate Social Responsibility issues can affect product innovation in a mature industry, this paper studies different technology strategies in sustainable vehicle development. In this regard, after a comprehensive literature review, by carrying out a patent analysis in Europe, the study exemplifies how typical technological knowledge could be managed to enhance innovation strategies. The study reveals that hybrid and fuel-cell technologies have gained prominent attention in the past two decades and seem to be the least risky approaches of alternative technology vehicles in the foreseeable future. Also, the study shows that the Japanese carmakers, who have had a clear commitment to sustainable management, have been the pioneers in this field. Moreover, the paper has some strategic science-to-market transfer implications as well which could serve as the cornerstones of sustainable competitive advantage.

Keywords: Product innovation, Sustainable vehicle development, Innovation management, Corporate Social Responsibility, Knowledge management, Patent analysis

1. Introduction

Environmental changes, long-term increases of petrol prices and regulatory efforts to curb the threat of a global climate change are initiating a new kind of technology-based competition within the automotive industry. Since the late 1960s the automotive industry has faced strict regulations, most remarkably related to local emissions (NO_X, CO, VOC), fossil fuel use, and more recently, greenhouse gases (CO_2). According to de Haan *et al.* [1], CO_2 is the main contributor to transport greenhouse emissions (97%) and road transport is, in turn, the largest contributor to these CO_2 emissions (92% in 2000).

In the automotive sector – a once mature industry – new trajectories are transpiring and a dramatic competition is emerging. This competition, which is based on technological innovation in the very core of the product – the automotive power train –, comes in addition to the existing process-based competition, which has been in focus for several decades. Thus, the automotive industry seems to be entering an "era of ferment" ([2]) characterized by increased variation and experimentation. This period is marked by significant uncertainty, and strategic decisions will have strong implications for the future of the industry. Critical decisions, on component as well as on system level, involve which technologies to invest in and which to stop developing, which alliances to form, and which standards to commit to.

The purpose of this paper is to compare technology and product strategies of automotive manufacturers in response to the sharply-raised demands on fuel efficiency and reduced CO_2-emissions. By a comprehensive patent study of the major technologies, this paper strives to study the technological evolution patterns and to reveal the pioneers in sustainable vehicle development. Moreover, as most analyses of industrial evolution have primarily relied on retrospective studies (e.g., [2]; [3]), by adopting a real-time research approach, the paper adds to the literature. The advantage of such an approach is that it provides an opportunity to learn from an ongoing and highly uncertain process.

2. Background

In the recent years, there has been an increasing interest regarding the environmental impacts of technologies; including, acid rain, stratospheric ozone depletion and global climate change. In this regard, a variety of potential solutions to the current environmental problems associated with the harmful pollutant emissions have evolved. The current atmospheric concentration of greenhouse gases (GHG), 430 ppm CO_2- equivalents (CO_2-e), is already 50% higher than the pre-industrial level and annual emissions are rising fast [4].

Since the late 1960s, the automotive industry has carried out a remarkable process of engineering systems to control automobile emissions. Greening such industries is not a matter of providing more eco-benign products to the consumer, but of achieving a regime shift affecting multiple businesses and networks, and to change an integrated system of technologies and social

practices [5]. Improved engine design and changes in fuel source are important for reducing emissions. A measure of the industry's success is the fact that, by the 21st century, tailpipe emissions of HC, CO, and NO_X have been reduced by 99%, 96%, and 95% respectively to 1965 levels [6].

3. Corporate Social Responsibility

According to Dincer [7], environmental concerns are significantly linked to sustainable development. Activities which continually degrade the environment are not sustainable. Woodcock *et al.* [8] define *sustainability* as meeting the needs of the present generation without compromising the ability of future generations to meet their own needs. Greening of industry is a broad research field with global and general strategic views, and debates on how to reach them. Moving inside to the firm, more detailed research issues arise such as ethical aspects, organizational culture, company insurance issues, management compensation schemes, corporate non-monetary measures, production oriented aspects, product oriented aspects, and, in more general economic terms for the firm, whether it pays to be green or not [9]. According to [10], consumers will pay up to a 10% premium for a product that is more environmentally-friendly than current goods.

In this regard, Corporate Social Responsibility (CSR) has recently gained prominent attention as a critical factor affecting success and image of businesses. As Carrol [11] maintains, CSR has developed as a concept from basic philanthropy by business leaders to a facet of modern business and management itself.

One reason why social responsibility provides a sustainable competitive advantage is that it requires a culture that can successfully execute a combination of activities [12]. According to Zadek [13], the potential of competitiveness is grounded in several tiers or ways in which competition between nations and communities takes place, namely; direct and specific business benefits, corporate responsibility clusters, and innovation and flexibility.

In a comprehensive review of CSR definitions, Dahlsrud [14] highlights five main dimension; namely, environmental, social, economic, stakeholder, and voluntariness.

Lantos [15] maintains that in relation to social responsibilities, corporations should fulfill the following responsibilities:

- Ethical CSR (including economic, legal and ethical),
- Altruistic CSR (philanthropic, going beyond ethical, regardless of whether or not this will benefit the business itself), and
- Strategic CSR (i.e., fulfilling those philanthropic responsibilities which benefit the firm through positive publicity and goodwill).

4. Innovation Management

Innovation has a connotation of "newness", "success", and "change" [16] and can be defined respectively as "the generation, development, and adaptation of an idea or behavior, new to the adopting organization" [17]. Several authors (e.g., [18]; [19]) have regarded innovation as a key factor for a company to survive and grow on the long run.

Innovation, according to [16] covers the continuum from incremental or sustainable innovation (remodeling functionality) to radical or disruptive innovation (breakthrough, paradigm shift). Thus, innovation can take place at an individual level (improvement), at functional level (process improvement or adaptation), at company level as an entire value chain (radical product and service innovation, new business models), and at industry level (technology breakthroughs) as systems of innovation.

4.1 Phases of Innovation

Abernathy and Utterback [3] describe how a technology undergoes certain phases of its maturity. This phenomenon, often termed as *technological discontinuity*, offers sharp price performance over existing technologies. They maintain that technological discontinuity might be in the forms of competence-enhancing or competence destroying. Christensen [20] terms these specific forms as sustaining and disruptive, respectively. According to Anderson and Tushman [2], the competence-enhancing discontinuity is very likely initiated by established firms, whilst competence-destroying discontinuity is introduced by new entrants.

Moreover, Abernathy and Utterback [3] contend that when a new technology is introduced, there are considerable uncertainties related to both the technology itself and its market. During this *fluid* phase, an introduced product might be characterized by ill-developed, unreliable, and expensive gauged against characteristics owned by an established product for a major market. According to [19], this phase involves extensive experimentations which come with several failures. However, the transitional phase product performances are improved and therefore, the uncertainties are reduced drastically. Thereafter, a *dominant design* emerges which, according to Utterback [21], is the product "that wins the allegiance of the marketplace, the one that competitors and innovators must adhere to if they hope to command significant market following" in a product class. Moreover, this so-called *transitional* phase is typified by delivering product reliably, cheaply, with higher quality, and extended functionality [19]. Following the

transitional phase, further incremental innovation and differentiation of the dominant design is directed to meet the needs of specific users. In this *specific* phase, process innovation is applied to reduce costs, add features, and improve productivity.

4.2 Innovation Strategies

According to [22], there is a wide range of alternative innovation strategies which firms may follow depending on their resources, heritage, capabilities, and aspirations. In this regard, four main innovation strategies have been widely studied (e.g., [19]; [22]; [23]). A more common classification of such strategies and their main characteristics of the aforementioned strategies are highlighted in Table 1.

5. Knowledge-based Innovation

In several firms, Knowledge Management (KM) has become a main investment priority. It is recognized that the performance of KM is highly associated with the intellectual capital of the firm, which in turn affects its innovation and financial achievement [24]. According to [25], effective KM facilitates innovation, reduces project duration, and can improve both quality and customer satisfaction. Organizations that are aware of their knowledge resources possess a valuable, unique resource that is difficult to imitate and can be exploited to achieve a sustainable competitive advantage ([26]; [27]).

The innovative efforts include the search for, discovery, experimentation, and development of new technologies, new products and/or services, new production processes, and new organizational structures [28]. Scholars of innovation have argued that novel innovations often result from combination of existing pieces of knowledge ([19]; [21]). A knowledge-based view of the firm emphasizes that a firm's accumulated knowledge is key to its continued ability to innovate, and ultimately to its ability to compete. Therefore, having a diverse knowledge base within the firm can facilitate innovation through novel combinations of readily accessible pieces of knowledge [29].

Trott [23] contends that technical knowledge – in the form of "patents" – or commercial knowledge – in the form of "unique channels of distribution" – are available to other firms as well.

In this regard, Amidon [30] defines Knowledge Innovation (KI) as "The creation, evolution, exchange and application of new ideas into marketable goods and services, leading to the success of an enterprise, the vitality of a nation's economy and the advancement of society."

5. Methodology

Patent analysis has become increasingly popular in studying R&D behavior of firms, industries and counties. It illustrates how technological preferences have shifted over time [31] and is a valuable source of information that can be used to plot the evolution of technologies over time [32].

As Ma and Lee [33] highlight, patent statistics is used as measure of inventive activities' output, innovative activity, technological change, technological strength, accumulated capabilities, and specialization in many industries, and thus is widely accepted. Therefore, researchers have applied patent statistics as measures of innovation and inventive activities. Scholars have also tried to infer the impact of patenting on innovation by examining the relationship between either patenting activity or patent strength, and measures of innovation or innovative activity – usually R&D or sometimes patenting itself [34].

In this paper, therefore, patent analysis was chosen to study the innovative activities in the automotive industry. Thereafter, the paper tries to capture the potential links between the innovativeness of automotive companies, the frequency of their registered patents, and their sustainability policies. Hence, it will show how companies can manage patent knowledge to help their innovation strategies. Also, in order to prevent the concerns linked to the non-linearity of innovation activities, a time span of 17 years – from 1990 to 2007 – was chosen for the patent analysis. The patent search was done in the European Patent Office database.

Table 1: Major Innovation Strategies and Their Respective Characteristics

Strategy	**Characteristics**	
	Porter [23]	**Trott [22]**
Leader/Offensive	Strong corporate commitment to creativity and risk-taking	High R&D; Substantial marketing resources
Fast-follower/Defensive	Commitment to competitor analysis and intelligence, cost-cutting, and learning	Agility in manufacturing, design and development, and marketing
Cost-minimization/Imitative	Competitor analysis; Reverse-engineering, Low-cost production;	Economies-of-scale; Skills in production and process engineering
Market Segmentation Specialist/Traditional	Specific market segment focus	Niche-marketing; Few product changes; Small-scale manufacture

6. Empirical Patent Study

Studies have shown that hybrid electric technology (HET), fuel-cell technology (FCT), and battery electric technology (BET) have been the most attractive technologies in alternative fuel vehicle (AFV) development (e.g., [34]; [35]). In a study of the United States Patent and Trade Office (USPTO), van den Hoed (2007) analyzed automotive activities in these technologies. The study shows that by the year 2000 close to 35% of all AFV patents were FCT-related, 50% HET-related, and 15% BET-related. The results further reveals that since 1996 the amount of patents in BET in the US has undergone a decline whilst the other two technologies have been brought into focus. This signifies a lack of interest among automakers to pursue R&D and allocate innovation budgets in BET.

In this paper, a comprehensive study of the issued patents of the mentioned technologies will be carried out in Europe in the 1990 to 2007 period. The patent information is extracted from The European Patent Office database.

Table 2: Summary of the Patent Study

Technology	Query Keywords	Retrieved patents	Patent Classes	
			A	B
HET	"hybrid" AND "vehicle"	456	441	15
FCT	"fuel cell" AND "vehicle"	58	57	1
BET	"battery electric" AND "vehicle"	-	-	-

Thereafter, a relevance study of the patents was performed. For this purpose, all patent abstracts were studied thoroughly; and the issued patents were classified into:

A: "most likely relevant for AFV's"; and

B: "most likely not relevant for AFV's".

A summary of the patent survey is provided in Table 2.

As shown in Figure 1, in the 1991 to 1995 period, totally 8 patents were registered with an average of 1.6 patents per year. However, in the following 5 years, totally 89 patents were registered, where the average of issued patents per year (17.8) is approximately 11 times more in comparison with that of the antecedent period. This is not so surprising however, since this period corresponds to the "HET-boom" with the introduction and mass-production of Toyota Prius. In the following 7 years, totally 294 patents are issued which is almost 3 times more than the total issued patents in the previous decade. The trend shows that there is an-ever rising interest among manufacturers in this area.

The data shows that the Japanese companies are the pioneers in registered patents in HET, where approximately 57% of the issued patents are assigned to "Toyota", "Honda", and "Nissan". However, except for Ford – which holds about 4% of the issued patents – other American manufacturers or European automotive giants rarely have any issued patents or are laggards. There is a great concern why others seem to be quite passive.

The study of the FCT-related patents shows that from 1999 only one patent was issued annually; however, after 2002, there is an obvious increasing trend. This could be linked to the introduction of Honda FCX to the market. The graph reaches its climax in 2005 where more than the whole patents registered since 1999 were issued. The trend obviously shows that there is a rising interest among manufacturers in FCT. The declination in 2007 might be due to the fact that some of the issued patents might have been pending for publication in the database at the time of the study.

Again, the FCT study shows that the Japanese companies are the pioneers in registered patents in FCT, where almost 58% of the issued patents are assigned to "Honda", "Nissan", and "Toyota". Also, Renault's rank, as the only European manufacturer among the leaders, might be due to their close alliance with Nissan. Again, there is a concern why other automotive manufacturers have attained a defensive strategy. Also, several cases of early shake-out were observed (e.g., DaimlerChrysler).

However, the study of BET patents – with various combinations of the keywords – retrieved no results from the database. This in turn shows the lack of interest among the manufacturers to invest in BET-related R&D programs and obviously reveals that BET has not been taken into account as a dominant technology in the near future. This is rather surprising since the Norwegian "Think Public" has introduced the "Th!nk" models in Europe. However, searches within the database with "Think" in the "Applicant" or "Inventor" fields retrieved no relevant results either.

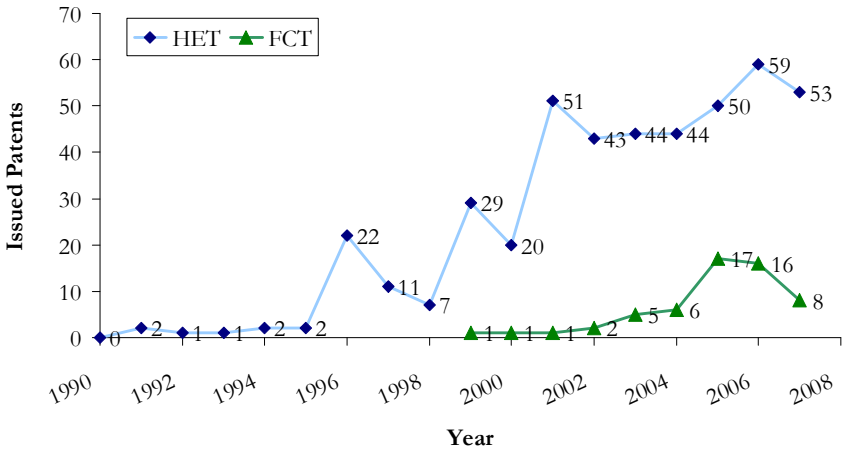

Fig 1. European Patents in AFV's Applied For by Automotive Firms

Finally, a thorough classification study of the issued patents was done. The study shows that most of the relevant patents within HET and FCT were within "Physical or Chemical Processes or Apparatus In General", and "Basic Electric Elements classes.

The patent study revealed that the Japanese carmakers are head and shoulders above others in AFV; where both in HET and FCT, Toyota, Honda, and Nissan hold the first ranks. The only European automotive manufacturer that has an appealing number of patents in FCT is Renault which in turn has close partnership with Nissan. Other giant manufacturers, including the American carmakers, seem to be quite passive. Only Ford holds 16 patents in HET since 2002 when its first patent was assigned. The reason why Ford has adopted a "follower" approach might be linked to the high level of uncertainty or lack of technological knowledge.

Some other companies that are absent in the ranking, have acquired the knowledge through partnerships or licensing. A conspicuous instance in HET could be Bosch which is not an automotive manufacturer but is a major supplier to several carmakers including VW and BMW. This is a critical concern in shaping the power structure in the value chain. The rest of the manufacturers seem to have applied a "hands-off" approach and tend to focus on their own market niches. The study also highlights the significance of governmental regulations and support of sustainable products.

Another notable, and yet logical, issue with regards to patents is that in the chronological study of the issued patents, by the introduction of a market-shaking product, the number of patents reaches a peak or increases drastically. Instances could be the roll-out of Toyota Prius and Honda Insight in 1997 and Honda FCX in 2002.

Obviously, Toyota is in the driving seat in HET. It introduced Prius to the Japanese market in 1997 and then to an initial niche market in the US in 2000 thanks to its sustainable commitment reputation. Recently, Toyota offers HET in several vehicles to cover various market segments. The same story applies to Honda as the leader in FCT by its FCX, and yet more recently, Clarity. It was the first carmaker to release a hybrid (Insight) to the US market and is offering HET in several products now. The other pioneer in this respect is Nissan which also has a portfolio of sustainable vehicles. Currently, it produces Tino and Altima hybrids and it introduced the battery-electric PIVO in 2005. The review of the mission, vision, value statements, and production systems of these companies reveals that they all have had a unanimous commitment to CSR and sustainability.

7. Conclusions

This paper dealt with the concept of innovation in the automotive industry. In order to pinpoint the main drivers of sustainable vehicle development, sustainable management and CSR, Innovation Management, and KM literature were reviewed in the theoretical framework. The patent study of HET and FCT revealed that these technologies are gaining increasing attention by manufacturers and seem to be prevalent in the forthcoming future. However, the products in this field are experiencing a diverse range of trial and errors and are yet to seek for a dominant design. Surprisingly, European carmakers were missing among the active companies in sustainable products and the Japanese were the pioneers in holding patents, and respectively. Moreover, since these companies started commercializing their "green" products to a strategic niche market in the beginning and then expanded their target markets, it could be concluded that strategic niches may foster innovations (either radical or incremental). Also, the studies showed that these companies have a clear CSR strategy and mission and are highly investing in R&D projects. Also incumbent carmakers seem to be seeking a balance between incremental and radical innovations when it comes to the engine. Besides

improved conventional internal combustion engines, HET seem to dominate the market in the near future since it is gaining increasing adoption and acceptance and is passing its infancy. However, in the long-term, BEV's and some other next-generation AFV's might be on R&D agenda. Finally, the study showed that governmental regulations can foster innovations in sustainable vehicles and also sustainable vehicle development can foster environmental regulations as well. An interesting area for future research could be studying the transactions and partnerships in the automotive industry and how these alliances affect innovation policies.

References

[1] De Haan, P., Mueller, M.G., and Peters, A., "Does the hybrid Toyota Prius lead to rebound effects? Analysis of size and number of cars previously owned by Swiss Prius buyers", *Ecological Economics*, (58), 2006, pp. 592-605.

[2] Anderson, P., and Tushman, M.L., "Technological discontinuities and dominant designs: a cyclical model of technological change", *Administrative Science Quarterly*, (35), 1990, pp. 604-633.

[3] Abernathy, W.J., and Utterback, J.M., "Patterns of industrial innovation", *Technology Review*, (June-July), 1978, pp. 41-47.

[4] Stern, N., (2007): *Stern Review on the Economics of Climate Change*, The Stationery Office Books, London, UK.

[5] Kemp, R., Schot, J., and Hoogma, R., "Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management", *Technology Analysis & Strategic Management*, (10:2), 1998, pp. 175-198.

[6] Mondt, J.R., *Cleaner Cars: The history and technology of emission control since the 1960s, Society of Automotive Engineers Inc.*, Warrendale, PA, (2000).

[7] Dincer, I., "Environmental and sustainability aspects of hydrogen and fuel cell systems", *International Journal of Energy Research*, (31), 2006, pp. 29-55.

[8] Woodcock, J., Banister, D., Edwards, P., Prentice, A.M., and Roberts, I., "Energy and transport", *Lancet*, (370), 2007, pp. 1078-1088.

[9] Williander, M., "Fading eco-benign networks: The causes found at Volvo Car Corporation and Ford Motor Company", *European Journal of Innovation Management*, (9:1), 2006, pp. 92-107.

[10] Ottman, J.A., *Green Marketing: Opportunity for Innovation*, 2nd ed. NTC Business Books, Chicago, IL, 1998,.

[11] Carrol, A., "Corporate social responsibility – evolution of a definitional construct", *Business and Society*, (38:3), 1999, pp. 268-295.

[12] Smith, A.D., "Making the case for the competitive advantage of corporate social responsibility", *Business Strategy Series*, (8:3), 2007, pp. 186-195.

[13] Zadek, S., "Corporate responsibility and competitiveness at the macro level. Responsible competitiveness: reshaping global markets through responsible business practices", *Corporate Governance*, (6:4), 2006, pp. 334-348.

[14] Dahlsrud, A., "How corporate social responsibility is defined: an analysis of 37 definitions", *Corporate Social Responsibility and Environmental Management*, (15:1), 2006, pp. 1-13.

[15] Lantos, G.P., "The boundaries of strategic corporate social responsibility", *Journal of Consumer Marketing*, (18:7), 2001, pp. 595-630.

[16] Assink, M., "Inhibitors of disruptive innovation capability: a conceptual model", *European Journal of Innovation Management*, (9:2), 2006, pp. 215-233.

[17] Damanpour, F., "Organizational complexity and innovation: developing and testing multiple contingency models", *Management Science*, (42:5), 1996, pp. 693-716.

[18] Tushman, M.L., and P. Anderson, Technological discontinuities and organizational environments, *Administrative Science Quarterly*, (31), 1986, pp. 439-465.

[19] Tidd, J., Bessant, J., and Pavitt, K., *Managing Innovation: Integrating Technological, Market and Organisational Change*, 3rd ed., Wiley, Chichester, 2005.

[20] Christensen, C.M., *The Innovator's Dilemma. When New Technologies Cause Great Firms to Fail*, Harvard Business School Press, Boston, MA, 1997.

[21] Utterback, J.M., *Mastering the Dynamics of Innovation*, Harvard Business School Press, Boston, 1994.

[22] Trott, P., "The role of market research in the development of discontinuous new products", *European Journal of Innovation Management*, (4:3), 2001, pp. 117-125.

[23] Porter, M., *Competitive Strategy*, The Free Press, NY, 1980.

[24] Wong, K. Y., "Critical success factors for implementing knowledge management in small and medium enterprises", *Industrial Management & Data Systems*, 2005, (105:3), pp. 261-79.

[25] Love, P. D., Edum-Fotwe, F., and Irani, Z., "Management of knowledge in project environments", *International Journal of Project Management*, (21:3), 2003, pp. 155-6.

[26] Lundvall, B-Å., and Nielsen, P., "Knowledge management and innovation performance", *International Journal of Manpower*, (28:3/4), 2007, pp. 207-223.

[27] Darroch, J., "Knowledge management, innovation and firm performance", *Journal of Knowledge Management*, (9:3), 2003, pp. 101-115.

[28] Carneiro, A., "How does knowledge management influence innovation and

competitiveness?", *Journal of Knowledge Management*, (4:2), 2000, pp. 87-98.
[29] Singh, J., "Distributed R&D cross-regional knowledge integration and quality of innovative output", *Research Policy*, (37), 2008, pp. 77-96.
[30] Amidon, D. M., *Innovation Strategy for the Knowledge Economy: The Ken Awakening*, Butterworth-Heinemann, Boston, MA, 1997.
[31] Van den Hoed, R., "Sources of radical technological innovation: the emergence of fuel cell technology in the automotive industry", *Journal of Cleaner Production*, (15), 2007, pp. 1014-1021.
[32] Pilkington, A., and Dyerson, R., "Innovation in disruptive regulatory environments: A patent study of electric vehicle technology development", *European Journal of Innovation Management*, (9:1), 2006, pp. 79-91.
[33] Ma, Z., and Lee, Y., "Patent application and technological collaboration in inventive activities: 1980–2005", *Technovation*, 2007, In press.
[34] Kanwar, S., and Evenson, R., "Does intellectual property protection spur technological change?", *Oxford Economic Papers*, (55), 2003, pp. 235–264.
[35] Magnusson, T., and Berggren, C., "Innovation in sustainable vehicles - managing the new technology based competition within the auto industry", R&D Management Conference, Bremen, Germany, 4-6 July 2007.