

A market in transformation

- a study on the diffusion of E85 on the Swedish market -

ABSTRACT

The sales of E85 and flexi-fuel cars have rapidly increased over the last three years. This development has taken place despite the fact that voices have been raised questioning whether ethanol really is sustainable. This contradiction constituted the departure of this thesis. The purpose of this thesis is to explain why E85 has its current market position, and by that potentially develop the understanding of the mechanisms behind the diffusion of a technology. The thesis looks at market factors from an innovation and dominant design perspective. More specifically, the research questions answered in this thesis are: "Which market factors have affected the diffusion of E85 in Sweden?" and "How have market factors affected the diffusion of E85 in Sweden?".

This thesis takes an explanatory approach, and both qualitative and quantitative data is used. The analysis is conducted by examining 9 summarising analytical questions, which are then summed up to answer the research questions. The factors identified as positively affecting the diffusion of E85 are *technological superiority*, *reproducibility*, *complementary products*, *user preferences*, *economical forces*, and *government involvement*. The factors identified as negatively affecting the diffusion of E85 are *technological superiority* and *user preferences*. The factors identified as having no impact on the diffusion of E85 are *network effects*, *government involvement*, and *organizational interaction*.

Key words: Dominant design, Diffusion, E85, Fuel, Sweden.

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1. Introduction

This chapter starts by providing a background to the subject in focus of this thesis. Secondly, the purpose and research questions are presented. Thirdly, necessary clarifications and definitions are explained. Fourthly, the delimitations are formulated to offer the reader a better understanding of what will be encountered in the coming readings. Finally, a disposition of the thesis is presented.

1.1. Background

There is no doubt that the industrial revolution has contributed to an enormous improvement in production efficiency and social welfare. However, it has also affected the environment to a much larger extent than mankind ever expected. The knowledge of how the lifestyle that came along with the industrialization impinges on the climate has evolved as time has passed by. Today, there is a widespread understanding that it is not possible to continue development in the same trajectories. In the recent years, the emission of green house gases from cars has attracted much attention. Besides the issues with hazardous emissions, the threat of running out of oil poses a problem for future energy sourcing.

Responding to the problems of motoring, alternative fuels to gasoline have gained popularity. Today, there are several alternatives to fossil fuel where ethanol, biogas, biodiesel and hybrid electric vehicles are the most common. The present market for environmental friendly transportation is still very limited in size but constantly growing. In addition, the market is characterized by high uncertainty as it is too early to tell what fuel will become commercialized to a full extent in the future. Since the biofuel market is still in its early stages of development, there is a struggle between different alternatives.

There are both pros and cons with each fuel alternative.¹ Beginning with ethanol, it has low carbon dioxide emissions but the environmental friendliness of ethanol production has been seriously questioned. Biogas has existed on the market for some time. A positive aspect of biogas is that it makes use of waste products during its production. On the other hand, the gas is difficult to distribute and it would require great resources to realize a satisfactory network of biogas fuel station. The popularity of electric vehicles has grown as cars like Toyota Prius has gained attention in media. Today's electric vehicles are often hybrids which implies that they are run by a combination of electricity and gasoline. Electric hybrids have low emissions of

¹ See e.g. Svenska Bioenergiföreningen (2004); Gröna Bilister (2007).

hazardous substances but the cars can be very pricey. A fourth alternative is biodiesels such as rape seed oil-based RME and synthetic diesels e.g. Fischer-Tropsch. Practically no harmful emissions are discharged when using these fuels and they can be used with a regular diesel car.

Currently, the most common alternative to fossil fuels in Sweden is ethanol. At present, ethanol exists in the Swedish car fuel market in three shapes: as E5 in low-blending with gasoline, E85 and E92. E5 is the 5% ethanol content in regular gasoline while E85 and E92 are fuels which consists of 85% respectively 92% ethanol and the remaining part gasoline.² During the last years the news flow in the Swedish press reflects a sales increase in both E85 and flexi-fuel cars.

Dagens Industri reported of a doubled consumption of E85 between 2004 and 2005,³ and Statoil's sales figures of E85 reached an all time high in 2007.⁴ The ethanol cars seem to be the first choice amongst environmentally friendly cars for the Swedish consumer. Out of the newly registered cars classified as environmentally friendly cars in 2006, 65,7% were flexi-fuel cars, 22% were gasoline or diesel cars with low emissions, 7,7% were electric hybrid cars, and 4,5% were gaseous fuel cars.⁵ Furthermore, the premium for environmentally friendly cars that the Swedish government announced in March 2007 has spurred the sales of environmentally friendly cars.⁶ Parallel to this development, there are also an increasing number of sceptic voices regarding using ethanol in fuels for the future. It is not primarily the functionality that is questioned, but the production methods. Some claim that the production of ethanol demands such a great amount of energy that the fuel is not as environmentally friendly as first thought, and others discuss the problem with the limited possibility of a large-scale domestic ethanol production in Sweden.⁷

1.2. Purpose and research questions

The increased sales of E85 and cars using the fuel tell a different story than the current debate among experts. This contradiction initiates the questions of what has affected the development on the fuel market. Thus, the purpose of this thesis is to explain why E85 has its current market position, and by that potentially develop the understanding of the mechanisms behind the diffusion of a technology.

² Svenska Jordbruksverket (2006, p. 60).

³ Dagens Industri (2006).

⁴ Statoil (2007b).

⁵ BIL Sweden (2007, p. 25).

⁶ Sydsvenskan (2007).

⁷ See e.g. Dagens Nyheter Motor (2006); Dagens Industri (2007); Veckans Affärer (2006); Dagens Nyheter Ekonomi (2007).

In order to fulfil the purpose, it was decided to focus the study on market factors. These factors will be discussed from an innovation and dominant design perspective. More specifically, this thesis focuses on the diffusion process during the emergence of a dominant design. We aim to investigate *which* forces affect this process, and *how*. Hence, the research questions for this thesis are:

- Which market factors have affected the diffusion of E85 in Sweden?
- How have market factors affected the diffusion of E85 in Sweden?

1.3. Clarifications and definitions

First of all, a couple of frequently used terms need to be clarified in order to avoid misunderstandings. The clarifications also aims to give the reader a better understanding of what exactly this thesis intends to investigate.

- ***Ethanol*** refers to the liquid chemical compound with the chemical specification C_2H_5OH .
- ***E85*** refers to the car fuel that consists of 85% ethanol and 15% gasoline. This is the focal product of this thesis.

An exception from the above definitions is made in chapter 3, as previous research has not made any distinctions between various forms of ethanol fuels.

- ***Flexi-fuel car*** refers to the type of car that can use both E85 and gasoline as fuel. This is the only car run by E85 which is present on the market.

It could be difficult to grasp what exactly is meant by ***diffusion***. For the purpose of this thesis diffusion of E85 is defined as: an increase in the quantity of E85 sold, an increase in the number of flexi-fuel cars sold, and/or an increase in the number fuel stations offering E85.

The concepts of diffusion and adoption are closely related. For the purpose of this thesis adoption refers to embracement on an individual/organizational level. In other words, adoption is the actual action performed by individual actors, and diffusion is the result of that action.

1.4. Delimitations

The adjustment to new fuels for cars is taking place all over the world. However, this study takes on a national perspective and delimits the geographical scope to the country of Sweden. A larger geographical scope such as Europe or world-wide would result in a highly complex analysis. Moreover, the current large differences between national markets are would add further complexity to the matter. A study at this level of complexity would require larger amounts of resources than those available for this thesis. However, as the Swedish market is not an isolated island but rather a market intertwined with other national and international systems, the study will take major forces that affect the Swedish market into account. This will allow a dynamic analysis that views the problem from a holistic perspective.

The focal market of this study will be the Swedish car fuel market. The focal product for the study is E85. Since E5 is not a fuel in itself but only a component in another fuel, this thesis will mainly discuss E85. Moreover, E92 is only used for public transportation, which is outside the scope of this thesis. Hence, neither E5 nor E92 will be discussed in this thesis. However, in some situations the ethanol products can not be distinguished from one another. E.g. some statistical data on ethanol do not separate E5, E85 and E92 but treat them as a whole. In these cases, the other forms of ethanol will be included in the discussion. Moreover, we acknowledge that no development is taking place in vacuum. Thus, other fuels such as gasoline, diesel, fuel gas and the electric vehicle are taken into consideration when they affect the Swedish E85 market, but only then. It should also be mentioned that, in this thesis, the electric vehicles are treated as a fuel alternative although it technically is a car and not a fuel.

Fuels and vehicles are inseparable; one product is of no use without the other. Therefore, it is necessary to take the vehicle in which the fuel will be used into consideration when analyzing the future of a fuel. However, the vehicle in which the fuel is used will be considered a complementary product. As there are great differences between cars, trucks and public transportation regarding factors such as legislative framework and user behaviour, it is necessary to make a distinction between the different kinds of vehicles. Thus, the vehicles in this study are delimited to cars. The reason behind this choice is that these vehicles constitute the great majority of the transportation sector.⁸

⁸ BIL Sweden (2007, p. 13).

To establish a suitable timeframe for the period from which the empirical data was gathered, yearly statistics concerning the number of cars on the Swedish market and what fuel the cars used was consulted. The statistics revealed that the proportion of cars using other fuels than petrol and diesel increased significantly between year 2004 and 2005.⁹ We believe that a study that investigates market forces and new technologies need to depart from a point in time prior to the increase. To establish the starting point, we investigated when major efforts in the technology started. It was not until the second half of the 1990's serious commitments were initiated.¹⁰ Moreover, the use of E85 was not significant on the Swedish car fuel market at that time.¹¹ Thus, the time span taken into consideration is from the second half of the 1990's until the end of 2007. However, most empirical findings date from 2004 until the end of 2007, as it was not until 2004 that E85 became available to a significant extent in Sweden.

Furthermore, it should be clarified that only major issues within each market factor are analyzed. The scope of this thesis does not allow a highly detailed investigation of each factor. Instead, providing a comprehensive assessment of the Swedish fuel market has been prioritized above an exhaustive examination of a fewer number of factors. The latter would not offer a satisfactory overview of the development of E85 and hence it would not enhance our understanding for why E85 has its current market position.

1.5. Contribution

As mentioned in the discussion of the purpose, this thesis seeks to contribute by developing the understanding of the mechanisms behind the diffusion of a technology. The theoretical framework has not previously been applied to analyze the Swedish E85 market (please see chapter 3). Moreover, this thesis includes more variables than what has been traditionally done when studying fuels (please see chapter 3). These gaps provide possibilities for new discoveries and a potential to add to existing knowledge in the theoretical field.

In addition to a potential contribution to the theoretical field, a more managerial contribution is also aimed for. The theoretical framework of this thesis allows a broader study of the developments on the Swedish E85 market than previously conducted studies. By adding knowledge about how specific mechanisms affect the market, the thesis can increase the understanding of the fuel market. Thus, this thesis could be of strategic value through its new

⁹ BIL Sweden (2007, p. 13).

¹⁰ Näringsutskottet (2002, p. 18).

¹¹ See Figure 2, p. 35.

insights about what is important to consider when acting on this market. An increased understanding could help actors to better meet competition and exploit market possibilities. Moreover, an increased understanding could help actors to influence the market towards a desired direction. Hence, the results of this thesis could contribute positively to the decision-making of company managements and governmental institutions.

1.6. Thesis disposition

The structure of this thesis is as follows. Chapter 1 gives an introduction to the subject, the purpose and the research question of the thesis and the structure that will follow. Chapter 2 presents the research design, and the choices made throughout the research processes are discussed. Chapter 3 provides an overview of ethanol and other fuel technologies by reviewing earlier studies. Chapter 4 presents a theoretical framework, from which *9 summarizing analytical questions* are formulated. Chapter 5 aims at answering the *summarizing analytical questions* by presenting and analysing the empirical findings that have been acquired. Chapter 6 concludes the analysis, provides answers to the research questions and discusses the results of the study. Finally, managerial implications together with suggestions on further research are presented.

2. Methodology

This chapter will give an understanding of the design of the study. Choices concerning the approach and research design are described to give the reader an understanding of why the study got its final appearance. Finally, the reliability and validity of this thesis is discussed in order to determine the research's quality.

2.1. The approach of thesis

This study takes an explanatory approach since the purpose is to explain *why* E85 has its current market position. This is done by analyzing relationships of different market factors. Research questions in terms of *which* and *how* were formulated to specify more exactly what was to be examined. By examining whether or not the identified factors have had an effect on the market, and what effect they had, the aggregated answers to *which* and *how* explains *why*.

2.2. Research design

With the explanatory approach in mind, both experimental and non-experimental research methods could have been applied. However, the problem studied in this thesis covers a considerably wide range of issues. This creates difficulties with manipulating and isolating necessary variables during an experiment. Thus, a non-experimental method was found to be more suitable and the experimental method was rejected.

An abductive approach has been recommended when the aim is theory development, rather than theory generation or theory confirmation.¹² As theory development is exactly in line with the expected contribution of this thesis, an abductive method has been applied. Thus, the theoretical framework has been shaped parallel to the identification and collection of empirical data.

2.3. Shaping the theoretical framework

This thesis derives from an innovation and dominant design perspective. Furthermore, it takes a market-level approach rather than investigating individual actors. When reviewing the previous literature within the field, the factors which refer to firm level issues have thus been excluded from the discussion in the theoretical section. Moreover, we are aware of that sampling factors from numerous articles creates a risk for combining concepts that build on different schools of thought. However, this risk has been handled by reviewing the references in the studied articles and we have been able to conclude that they derive from similar academic backgrounds.

¹² Dubois and Gadde (2002, p. 559).

2.4. Collecting the empirical data

The rather large area included in this study has created a demand for empirical data that includes a wide spectrum of information. Characteristics of the both the car market and the fuel market have been combined to obtain a realistic picture of the forces affecting the diffusion of E85 in Sweden. The variables used have spread from the features of the cars and the fuel itself, to the legal framework and public opinions.

We considered it necessary to obtain both qualitative and quantitative data in order to answer the research questions. This is mainly due to the wide variety of variables with different characteristics investigated in this thesis. Neither qualitative nor quantitative data alone would have provided an enough detailed basis for analysis.

When discussing from what sources the required data should be obtained, we defined a number of important criteria. These criteria guided the data collection:

1. The suppliers of data should have a high level of expertise in the subject to maximize accuracy;
2. the suppliers of data should represent a wide-spread opinion, rather than an individual to avoid narrow information; and
3. the supplier of data should not have a significant reason to provide an incorrect picture of reality, to avoid biased information.

Most of the required data was available in writing. Thus, the majority of empirical data has been collected from written sources. However, data collection has also been carried out in form of six interviews with knowledgeable actors on the market. This initiated the data collection process and the main objective of these interviews was to obtain a holistic view of the market as both authors had little prior knowledge of the subject in focus. However, some of this data has been used as empirical data in the thesis. In those cases, the reason was to complement other data sources or to fill gaps where other reliable sources have not been available. At all occasions when the interviews have served as empirics, the credibility of the interviewee with regard to each specific issue has been assessed as high.

The interviews were conducted with each actor separately. To avoid steering the interviewees, an open-ended questions format was used. During the interviews a tape recorder was used to make sure no information was missed out on. Each interview was then transcribed and sent back to the interviewee to ensure no misinterpretations had occurred. The interviewees were:

- the CEO of BIL Sweden, Bertil Moldén;
- the Head of Lantmännen Energi, Bengt Håkansson;
- the CEO of the Svenska Petroleum Institutet, Ulf Svahn;
- the CEO of Svensk Bensinhandel, Ingvar Persson;
- the Head of Transportation Issues at Svenska Naturskyddsföreningen, Magnus Nilsson;
- and a senior technician at Motormännen, Rolf Lööw.

BIL Sweden represent the manufacturers and importers of cars, Lantmännen Energi represents the Swedish producers of ethanol, Motormännen has a good overview of what the consumers are concerned about when purchasing cars, Svenska Petroleum Institutet is the industry association for oil companies in Sweden, Svensk Bensinhandel represents the 1400 independent Swedish fuel stations, and Svenska Naturskyddsföreningen is one of Sweden's largest NGO's specialized in environmental protection.

The written data were of both quantitative and qualitative character. The data include a wide variety of sources such as industry reports, sales statistics, and news paper articles. Industry reports and sales statistics were acquired from major industry actors and governmental bodies. News paper articles served as empirical data mainly to reflect public or other widespread opinions.

2.5. The analysis and the design of the final paper

The method which we analyze data in this thesis can further be described to be of qualitative rather than quantitative nature. Thus, the conclusions in this thesis are of qualitative character. This means that the *which* and *how* research questions are answered through reasoning rather than mathematical calculations.

Inspiration on how to structure the analysis was attained from a study on the electric vehicle by Cowan and Hultén¹³. They used several “summarizing analytical questions” that were answered throughout the analysis. The answers to these questions were then joined together to answer the main research question. This approach requires a thorough discussion of the theoretical factors to understand which “summarizing analytical questions” are important. This study has applied this “summarizing analytical questions” approach.

¹³ Cowan and Hultén (1996).

The “summarizing analytical questions” will be presented in the end of the theoretical framework (chapter 4), and those will then be answered in chapter 5. The empirical data and the analysis are presented parallel to each other in the same chapter. This way, unnecessary repetition of information can be avoided. At the same time, this arrangement provides a smooth connection between data and analysis which could facilitate understanding. The risk with this method is that empirical data could be presented selectively in line with the initial knowledge that E85 has been diffused. However, this risk has been balanced by the authors’ sincere efforts in seeking evidence for both supporting and opposing mechanisms. In relation to the above risk of bias, it should also be stressed that this study does not aim to prove that E85 is good or bad. Such a valuation would impede on the understanding for the mechanisms that determine the market’s appearance.

2.6. Research quality

The importance of reliability has been kept in mind throughout the research process. With regards to the conducted interviews, the format of these poses a threat to the reliability. This is a result of the fact that an answer to an open-ended question might be influenced by the interviewee’s mood or the atmosphere between the interviewers and the interviewee. However, to reduce that risk and thus strengthen the reliability the interviews were recorded and the interviewees were allowed to comment on the transcripts. Thus, we consider the reliability of the interviews to be high.

The majority of written sources have been collected directly from the origin. Thus, the risk for errors by intermediaries was minimized. Moreover, the static nature of the written secondary sources also avoids the risk of attaining different data from one independent measure to another. On the other hand, the news paper articles risk reducing the level of reliability. We do however consider the measures undertaken to verify the information to be sufficient to claim that the overall reliability of this thesis is satisfactory.

To obtain highest possible internal validity, data have been cautiously evaluated. One safety measure for achieving high internal validity is to acquire secondary data from sources which comply with the “sourcing criteria” presented above. The chosen sources are regarded as representative for their field due to their knowledge, experience and legitimacy. Data originating from those sources, e.g. governmental bodies and established industry organizations should be considered as internally valid. Relying on these sources rather than consulting individual companies for data, reduces the risk for obtaining inaccurate or biased data.

Another safety measure has been to carefully consider the data from our primary sources. The information provided by individuals often speaks for that individual's belief and should not be taken for the public opinion. However, if the individual makes a statement as an agent for an organization and/or industry, the statement can be considered to represent that organization and/or industry. To further prevent internal validity from becoming compromised, information from interviews has been used in the least extent possible as a data source. In the cases where interview information has been referred to, the internal validity of that particular data has been critically evaluated and judged as high. Here it could be mentioned that although Lantmännen is not an industry organization but an individual company, they represent the vast majority of the Swedish ethanol production with an 80% market share. Thus, the statements by Lantmännen can be considered to represent the Swedish ethanol producers.

In general, the internal validity of news paper articles could be questioned. We have been aware of this fact and used such sources with great precaution. Same as for data from interviews: where news paper articles have been referred to, the internal validity of that particular data was critically evaluated and judged as high. There are mainly two objectives for using news papers as a source. The first is to draw on important sources that are made available through certain articles. I.e. an important market actor has been interviewed and revealed interesting information, which cannot be obtained elsewhere. In those cases the information provided through the article has been regarded as sufficiently internally valid as data. The second objective is to reflect a public, or in some other way widespread, opinion. Conclusively, the result from this thesis can thus be considered as giving a good reflection of reality.

The fact that this thesis only concerns one geographical market and one focal fuel impedes on the possibility to generalize the conclusions drawn in this study. Even though we previously in this section have established that the results reflect the reality, this only concerns the specific issue in focus. However, we see that the main feature in this thesis that can be applied on a more general level are the 9 summarizing analytical questions concluded in section 4.4.

3. Overview of alternative fuels

This chapter provides an introduction to the different fuel technologies discussed in the recent academic debate. By doing so, it places this thesis in relation to the current research in the field.

3.1. Previous research on alternative fuels in general

Within fuel research, many studies take a technological viewpoint where features like fuel efficiency and environmental impact are investigated. An example of such a technological study is Alhvik and Brandberg, who have compared six different car fuels by conducting so called well-to-wheel analyses.¹⁴ A well-to-wheel analysis is a study of a fuel's energy efficiency taking its entire life cycle into account, from production to consumption. The authors find that the relative environmental impact of different fuel alternatives depends on the specific production method. Balat also takes a technological approach and compare the environmental impact of different fuels. He concludes that alcohols, hydrogen, biodiesel, boron, natural gas, liquefied petroleum gas, p-series, electricity, and solar fuels can be classified as environmentally friendly engine fuels. However, Balat does not take market conditions into consideration but looks only at the fuels performance and its potential to decrease emissions.¹⁵

A more market-oriented perspective can be found in some works. Eikeland has studied how the increased focus on biofuels within the EU has affected the oil companies and their business models. The study concludes, after having studied the regulations on both EU and national level and the companies practise, that recent political changes has affected the possibility of diffusion of biofuels positively. This, in turn, is likely to motivate oil companies to invest in biofuels for the European market.¹⁶ Piel focuses on what role existing fuel technologies play in the decision of what fuel-vehicle combination will be used in the future. He examines the US market and addresses issues such as oil production, price comparisons, the existing vehicle fleet, and fuel transportation costs. He concludes that gasoline and diesel will be dominating also in the foreseeable future, but with improved versions.¹⁷

More in-depth research about individual fuels has also been made. Previous research on the electric vehicle (EV) and hybrid electric vehicles (HEV) consists largely of technological studies

¹⁴ Alhvik and Brandberg (2001).

¹⁵ Balat (2005).

¹⁶ Eikeland (2005).

¹⁷ Piel (2001).

concerning the vehicle's power management, a crucial part of the EV.¹⁸ Chau and Wong have studied the latest power management technologies for HEVs. These researchers conclude that current solutions can not compete with conventional internal combustion engine vehicles (ICEV), i.e. most cars run by liquid fuel like e.g. gasoline, diesel, ethanol. However, different technologies are under development and they predict that different kinds of EVs will coexist in the future.¹⁹ Moseley and Cooper find that much improvement has been made in EV power management technologies and they argue that this development point toward a bright future for EVs.²⁰ Apart from the studies of mainly technological focus, the relationship between EVs and ICEVs has been explored by many researchers. Harding points out the differences in the pace of technological development for ICEVs and EVs, where the latter has been seriously neglected. In the article, Harding investigates whether the technological development of EVs in the nearest future will take a different course of action than historically. The findings indicate a more positive development possibly thanks to legislative forces.²¹ Cowan and Hultén have taken a deeper look into the interdependencies between technologies. They use the concept of technological lock-in and show how the car industry is dominated by the gasoline car, making it severely inhibited to shift to the EV technology. Moreover, the authors throw light upon the influential power of regulations, which can help to direct the market away from the lock-in. They also acknowledge the power of user preferences for technological development.²² On a similar note, Hekkert and Van den Hoed have studied the interaction between EVs and fuel cell vehicles (FCV). They argue that EV could become the dominant technology (if fossil fuel is to be replaced by more environmentally alternatives) at the expense of FCVs, despite the car industry's support for FCVs.²³ Pilkington and Dyerson has studied EVs with respect to regulations, focusing their study on California, USA.²⁴ They conclude that the regulation on zero-emission vehicles has affected the car producers which have formed alliances to cooperate to be able to develop the necessary skills for producing zero-emission cars.

With regards to fuel cell vehicles, there are several fuels that can be used in the fuel cell. The most commonly discussed are hydrogen, gasoline or methanol.²⁵ Acres has reviewed the recent development in fuel cell technology and its possible applications in all fields. He concludes that

¹⁸ Chau and Wong (2002); Moseley and Cooper (1999); Lyshevski (2000).

¹⁹ Chau and Wong (2002).

²⁰ Moseley and Cooper (1999).

²¹ Harding (2002).

²² Cowan and Hultén (1996).

²³ Hekkert and Van den Hoed (2006).

²⁴ Pilkington and Dyerson (2004).

²⁵ See e.g. Thomas et al. (2000); Ogden et al. (1998).

the “the most significant has been the rapid development of the SPFC [Solid Polymer Fuel Cell, *authors’ comment*] system for transport applications, together with the realisation that success in this field would provide the basis of a low temperature stationary unit for combined heat and power applications”²⁶. He further states that the choice of fuel and the fuel infrastructure has now gained additional attention.²⁷ On that note, Thomas et al. state that most analysts prefer hydrogen in terms of vehicle complexity, but what fuel would be preferred in terms of infrastructure costs has been debated. They have thus performed a study on infrastructure costs and show that “the total fuel infrastructure cost to society including onboard fuel processors may be less for hydrogen than for either gasoline or methanol”²⁸.

Researchers have studied biogas fuel for cars mainly from a technological point of view with focus on environmental properties and production methods.²⁹ Nilsson et al. have undertaken a life-cycle analysis for biogas, where the fuel’s total impact on the environment from production to combustion is calculated. To increase the accuracy of their calculations, two scenarios are constructed to represent two possible market situations. The results for the scenarios are then compared and also evaluated against other car fuel alternatives. The researchers find that biogas is environmentally superior in some aspect but not all compared to e.g. ethanol. They further express the difficulty to prioritize among environmental issues. However, their results show that fossil fuels have the highest negative impact on environment.³⁰

Biodiesel have mostly been studied from a technological perspective. Many researchers have discussed various production methods, and what raw material that is appropriate.³¹ For example, Ma et al. reviews several production methods of biodiesel, and concludes the main production process is transesterification³² of vegetable oils and animal fats. They further state that the problems that needs to be overcome are related to costs for raw materials and production, and provide suggestions for lowering these costs.³³ They finally conclude that “biodiesel can be used most effectively as a supplement to other energy forms, not as a primary source”³⁴. Van Gerpen also recognizes biodiesels difficulties to replace petroleum-based diesel, but regard the development of biodiesel justified as it 1) creates a market for excess production of vegetable oils

²⁶ Acres (2001, p. 65).

²⁷ Acres (2001).

²⁸ Thomas et al. (2000).

²⁹ See e.g. Börjesson and Berglund (2006); Batzias et al. (2005); Bouallagui et al. (2003).

³⁰ Nilsson et al. (2001)

³¹ See e.g. Haas (2005); Ma et al. (1999); Bournay et al. (2005).

³² Transesterification is the reaction of a fat or oil with an alcohol to form esters and glycerol.

³³ Ma et al. (1999).

³⁴ Ma et al. (1999, p. 15).

and animal fats, 2) decreases the US dependence on imported petroleum, 3) does not contribute to global warming, 4) decrease the emissions of carbon monoxide, unburned hydrocarbons, and particulate emissions compared to regular diesel fuels, and 5) transforms regular diesel fuel with poor lubricating properties into an acceptable fuel when adding it to in an amount equal to 1–2%.³⁵

3.2. Previous research on ethanol for fuel in particular

None of the studies above focuses in particular on ethanol fuel though. Lugar and Woolsey, on the other hand, have studied ethanol in a US foreign affairs perspective. They discuss ethanol's potential to become a driving force to reduce the dependency on the a few countries with large oil reserves, the environmental role the fuel could play, and the relatively high production costs compared to gasoline. Lugar and Woolsey consider ethanol having the characteristics of being able to balance influence on the world's energy supply and decrease emissions. Furthermore, they suggest that the US government should invest in R&D to create knowledge that could decrease the relatively high production costs.³⁶

Mahy et al. also focuses on the US market, but has studied ethanol's potential from a market perspective. They discuss the availability of ethanol, the impact of governmental policies, and incentives for companies to engage in the industry. They conclude that the ethanol as a fuel will be viable in the future if the cellulose technology is significantly improved within the next 10 years.³⁷

Lee examines the ethanol fuel's potential, both as an individual fuel and as a compound in low-blending. In his article he investigates the demand and supply for ethanol on the US car fuel market. More specifically, he examines the production capacity in the US, the demand from traditional oil companies for low-blending in gasoline, and the relative price to MTBE^{38, 39}.

Walter et al. evaluate the ethanol automotive fuel market up till 2030, and the good's potential as an international traded good. The study takes on a global perspective, and uses forecasts of gasoline consumption and the targets of ethanol fuel. The study estimates that ethanol fuel

³⁵ Van Gerpen (2005).

³⁶ Lugar and Woolsey (1999).

³⁷ Mahy et al. (2003).

³⁸ MTBE is a compound used in low-blending with gasoline.

³⁹ Lee (1993).

consumption in 2030 will displace between 10-16% of the forecasted gasoline consumption depending on the outcome of the policies that the US government is going to implement in the coming years. It also concludes that international trade of ethanol fuel has many obstacles to overcome. However, increased trade is viewed as an essential issue in the process of being able to displace 10% of the gasoline.⁴⁰

Few studies have focused on the Swedish market. One that has though is Borup, who has studied the new Swedish excise duty on cars that focuses on the environmental impact.⁴¹ He concludes that “the environmental vehicle excise duty in Sweden has resulted in a drastic increase in the number of new green cars”⁴². This study, though, does not take the type of fuel into consideration when discussing an increase in environmentally friendly cars.

In July 2007, he presented a report on behalf of VINNOVA. It regards how Sweden will be affected by the EU directive proposed earlier the same year. Kågeson discusses likely reactions from the fuel distributors, as well as what he regards as probable tax changes. He also discusses necessary regulatory changes needed to reach the EU goal for cars to emit maximum 130g/km of CO₂ by year 2012.⁴³ In his other study, Kågeson investigates the future of the car from a Swedish perspective. Kågeson considers different biofuel alternatives, among others ethanol. He writes about the evolution of car utilization and some consequences of car utilization focusing on environmental issues. The book takes a future perspective as Kågeson explores what car utilization could look like in 2050. Moreover, he communicates his opinion regarding how things should be. In short, Kågeson is speculating about the future rather than looking into the mechanisms which have given the market its current appearance.⁴⁴

3.3. This thesis' position in relation to previous research

Much research has been conducted on all existing fuel alternatives. Reviewing previous research reveals that researchers have often taken a technological viewpoint on matters concerning fuels. The high density of technological studies is not surprising, since fuels is a product of highly technological character. However, the scope of this thesis lies within the field of marketing; thus, the technological aspect will only be one component among others.

⁴⁰ Walter et al. (2007).

⁴¹ Borup (2007).

⁴² Borup (2007, p. 6).

⁴³ Kågeson (2007a).

⁴⁴ Kågeson (2007b).

Earlier studies have also been conducted from a market perspective. These studies include economical factors, regulations and user preferences in their analysis of different fuel alternatives. Furthermore, one market topic was of particular interest; the concept of dominant design. Some of the market studies apply this concept to examine how fuel technologies compete for attention from consumers and relevant industries. Inspiration for this thesis was provided by the findings in the previous studies departing from the market perspective and especially from the dominant design concept.

The geographical markets encountered in the studies with a market perspective mostly concern the US or the EU. Studies which deal with the Swedish market have mostly been profiled to give a recommendation for future market developments, rather than to provide explanations for the evolution that has already occurred.

Thus, in relation to previous research, this thesis will further elaborate on market aspects but include a broader spectrum of such aspects. It will also study the Swedish market but with the objective to explain a historical development.

4. Theoretical framework

This chapter firstly provides an overview of earlier research in the academic field which this study departs from. Secondly, factors that drive diffusion are discussed. Finally, 9 summarizing analytical questions are formulated drawn from the theoretical framework.

4.1. Previous research on technology and innovation

Today's innovation theories essentially derive from the works of Joseph Schumpeter. Before Schumpeter, there has been a long history within economics of considering innovation as an exogenous factor shaped outside the economic system.⁴⁵ However, Schumpeter claimed the opposite: that innovation is generated within an economic system. By showing how new products were developed, he derived innovation to the struggle among entrepreneurs for strategic advantage. He referred the process as creative destruction; a constant search where innovation establishes new rules, thus destroying the old ones.⁴⁶ The concept of creative destruction had major implications for the view on innovation. Innovation was no longer a stochastic, autonomous factor. Instead it became a factor that can be understood and to some extent manipulated by individuals or firms. The concept of creative destruction has gained much attention by researchers within the field of innovation. It has been extensively studied and developed in various directions.⁴⁷ However, despite the great impact creative destruction has on innovation theories, it does not explain why certain technologies achieve dominance and others do not.

Another tradition of innovation research deals with the origin of innovation. Many researchers address the issue of what factors give rise to innovation. Some claim that market forces dictate a certain demand, thus triggering innovation which satisfies this demand, while others argue that innovation is a result of technological processes.⁴⁸

There are two kinds of innovation described in previous research: innovation that results from incremental change or radical innovation.⁴⁹ The researchers that support the idea of incremental change show on the constant improvements and continuous strive for perfection carried out in existing technologies.⁵⁰ These step-by-step enhancements on technology sometimes reach a critical level where it differs importantly from the earlier technology, and it can be said that an

⁴⁵ Abernathy and Clark (1985, p. 3).

⁴⁶ Schumpeter (1942).

⁴⁷ See e.g. Perelman (1995); Abernathy and Clark (1985); Boisot (1995).

⁴⁸ Abernathy and Clark (1985, p. 3); Dosi (1982, p. 157).

⁴⁹ See e.g. Abernathy and Utterback (1978); Abernathy and Clark (1985); Dosi (1982, p. 158).

⁵⁰ Abernathy and Clark (1985).

innovation has occurred. Applying either of these perspectives on innovation will not explain why a certain technology diffuses. These perspectives merely tell us what innovation emerges from.

In order to understand the process where technologies diffuse, a different approach to innovation has to be considered. Instead of focusing on the source and nature of innovation the efforts should be directed towards the evolution of innovation and technologies. It is necessary to learn how products and technologies develop on the market after they are invented in order to answer our research questions.

The concept of product life cycle is an acknowledged approach within product and technology development. This research shows that products and technologies tend to follow a certain trajectory on the market after the innovation is made. First, there will be an introduction stage where the market, both consumers and suppliers, learn how to utilize the product or technology. As this stage carries on, the demand for the specific product/technology will grow and the product/technology passes on to a stage of growth. As the growth comes to its peak the maturity stage is reached and from here the product/technology will enter a stage of decline as it becomes obsolete while new innovations enter the market.⁵¹ This tradition of innovation theory has important strategic implications for businesses on how they should manage their products on the market. However, it does not reveal why products or technologies diffuses, which could be seen as entering the growth stage in the product life cycle.

Deviating from the market-perspective on innovation is the tradition pursued by Utterback and Abernathy. These well-know innovation researchers have created the concept of dominant design.⁵² There definition of dominant design differs somewhat from scholar to scholar; however, they all seem to include the fact that a dominant design is widely adopted, and that the emergence of dominant design apparently changes the nature of competition.⁵³ By understanding how dominant design emerges, it becomes possible to answer the research questions of this thesis.

4.2. The diffusion of a technology

The concept of dominant design can be incorporated into a wider sense of technological evolution. While Abernathy and Utterback suggested that dominant design emerges once in a

⁵¹ Best (2005, p. 79).

⁵² Abernathy and Utterback (1978); Utterback and Abernathy (1975).

⁵³ Murmann and Frenken (2006, p. 932).

product category,⁵⁴ the sociological market perspective views technological change as a cyclical model with processes of variation, selection and retention.⁵⁵

Tushman and Rosenkopf present a model describing the trajectory of change that technologies undertake as they evolve. Technological change is here divided into four stages: 1) Technological discontinuity, 2) Era of ferment, 3) Dominant design, and 4) Era of incremental change. These four components are connected into a cycle that illustrates their causality. In this model, dominant design is a major, technological breakthrough between two eras of technological change.⁵⁶ As a result, a design remains dominant until the next technological discontinuity occurs, which causes the old design to become obsolete.

One of these evolutionary stages is of particular interest for this thesis: the era of ferment. This is the interface between innovation and the success of the technology. During the era of ferment, technological diffusion takes place and eventually a specific technology becomes the dominant design. In other literature, the era of ferment has also been referred to as “the black box”.

Rosenberg describes the diffusion preceding a dominant design as a complex interaction between technological and non-technological factors.⁵⁷ Numerous factors of various characters affect the diffusion during this stage of technological evolution. In the section below (4.3), these factors are presented.

Many studies on innovation focus on one specific technology and analyze the development of that technology in isolation from other technologies. However, as Wade points out, it is important to look at the technology in a competitive context to not miss out on important external influences.⁵⁸ Acknowledging the work of Wade, this thesis will focus on E85, but will do so by putting it into such a competitive context.

4.3. Previously identified factors which affect diffusion

Researchers have identified a number of factors involved in the diffusion of a technology during the era of ferment. Apart from purely technological factors, there are economical, social, political and organizational factors. Even though it is possible for a technology to dominate all categories

⁵⁴ Abernathy and Utterback (1978, p. 27).

⁵⁵ See e.g. Anderson and Tushman (1990); Tushman and Rosenkopf (1992); Henderson and Clark (1990).

⁵⁶ Tushman and Rosenkopf (1992, p. 317).

⁵⁷ Rosenberg (1982).

⁵⁸ Wade (1995, p. 112).

of technical merit, in the majority of cases, it is the sum of all factors that determines what technology that finally achieves dominance.⁵⁹

Perhaps the most obvious element that affects diffusion is **technological superiority**. A technology is “focused on doing a task in a given context”⁶⁰. Technological superiority refers to how well a particular technology performs its task compared to competing alternatives. On the whole, the technology needs to be better or at least as good as other technologies in terms of completing its task.⁶¹ The better the technology performs compared to its competitors, the higher the probability of it becoming the dominant design.⁶² Furthermore, a technology’s compatibility with or technological closeness to earlier technology, can improve its chances to become dominant.⁶³ If the technology is not superior to other technologies, there will be little incentive for customers to use it.⁶⁴ However, many researchers have showed that designs which become dominant are not necessarily the technological superior one. Other factors may have a more prominent effect on the outcome.⁶⁵ Despite this fact, technological superiority remains an important factor to shed light on when studying the design selection process.

Reproducibility also impacts a technology’s probability of diffusion. It is essential to the success of a technology that it is possible to reproduce it in sufficient quantities in order to allow a commercialization.⁶⁶

The rate of technological change determines the probability of something to become obsolete. If the rate is high, the **probability of obsolescence** is high and thus users will have little incentive to commit to a specific technology.⁶⁷

Many technologies can not work in isolation but need to be compatible with other products, systems and the rest of the technological environment in order to become successful.⁶⁸ This issue highlights the importance of **complementary products**. Technologies and their complementary products are often developed parallel to each other and affect the outcome. Cowan and Hultén

⁵⁹ Tushman and Rosenkopf (1992, p. 316).

⁶⁰ Tushman and Rosenkopf (1992, p. 313).

⁶¹ Suarez (2004, p. 276); Lee et al (1995, p. 6).

⁶² Suarez (2004, p. 276).

⁶³ Suarez (2004, p. 278); Srinivasan et al. (2006, p. 5-6).

⁶⁴ Lee et al (1995, p. 6).

⁶⁵ Arthur (1989, p. 128); Cowan and Gunby (1995, p. 540); Cusumano et al. (1992).

⁶⁶ Lee et al. (1995, p. 6).

⁶⁷ Lee et al. (1995, p. 8).

⁶⁸ Teece (1986, p. 288); Lee et al. (1995, p. 9-10); Cusumano et al (1992, p. 64).

refers to this interaction as path-interdependence.⁶⁹ They recognize that “the development of a technology is linked to developments elsewhere in the economy and that ruptures that appear to be independent of the technology may affect its development”. Rosenberg demonstrates the role of complementarities by describing the development of American railroads in the late 19th and early 20th century.⁷⁰ He explains that the greater loads and the greater speeds could not have been achieved without other inventions such as the telegraph, block signals or the substitution to iron rails from steel rails. Several inventions had to be generated simultaneously to support the focal technology. A similar reasoning is conducted by Dahmén, although he uses the term development blocks.⁷¹ A development block is a number of complementarities that create a network through its interconnected firms from different industries.

Other researchers have stressed the influential role of *network effects* during the era of ferment. Network effects exist when an individual user’s utility for a technology increases or decreased by changes in the total number of users. Strong network has a positive effect on a technology’s probability of becoming dominant.⁷² In addition to direct network effects, indirect network effects are also relevant for the adoption of a technology. When there is a large installed base, i.e. the total number of users that has adopted the technology, indirect network effects can encourage more users and suppliers to adopt the technology thanks to lower unit prices, increasing variety of complementary products and lower prices for complementary products.⁷³

User preferences can play a great role in the diffusion of a technology.⁷⁴ More specifically, Cowan and Hultén conclude that even if users are interested in one specific characteristic of a product (e.g. environmental friendliness), consumers will still compare the product as a whole. Thus, for the new technology to be adopted by users, it needs to provide the same, or very similar, benefits to the gasoline car in addition to the new required attribute.

In the era of ferment, *economical forces* can tilt the scale toward a certain technology. Market actors are value maximizers who seek options that minimize the cost and risk of their investments. An implication of this is that customers will choose the alternative that demands the least economic investment both initially and in the long run in relation to other available

⁶⁹ Cowan and Hultén (1996, p. 63-64).

⁷⁰ Rosenberg (1972, p. 21-23).

⁷¹ Dahmén (1989, p. 109).

⁷² Suarez (2004, p. 278-279); Srinivasan et al (2006, p.4); Wade (1995, p. 112).

⁷³ Cusumano et al. (1992, p. 64); Katz and Shapiro (1985, p. 424); Wade (1995, p. 119); Suarez (2004, p. 278); Gupta et al. (1999, p. 397); Lee et al. (1995, p. 8); Chou and Shy (1990, p. 270).

⁷⁴ Lee et al. (1995, p. 9); Cowan and Hultén (1996, p. 6, 21).

technologies. This includes minimizing search costs, purchasing price, maintenance costs and possible switching costs.⁷⁵

Another factor affecting the diffusion of a technology is ***government involvement***.⁷⁶ Governments can act through market policies and regulations.⁷⁷ These actions could greatly impact on key resources as well as dictate the rules for doing business. This in turn affects innovation, technological development and the possibility to commercialize different technologies.⁷⁸ Thus, government actions could to a large extent determine the direction of technological diffusion.

Organizational interaction implies that market actors do not act alone in situations when new technologies are to be adopted. Rather market actors collaborate with and/or learn from others.⁷⁹ Cowan's study on nuclear power reactors constitutes an illustrative example. In this example, central European authorities worked closely with the US government to achieve conformity in the nuclear power industry. This wish for a uniform system later resulted in the implementation of the light water technology, but the process took about 10 years.⁸⁰

Appropriability is another factor that can affect the diffusion of a technology. This concept refers to the extent in which an innovation can be exploited by separate actors on the market. Important for this factor is the fact that access to a certain technology can be limited by the use of patent or copyright. However, the chemical composition of E85 is not and can not be patented and thus this factor is not applicable in the analysis of this thesis.⁸¹

There are a number of firm-level factors that have been previously identified by e.g. Suarez⁸² and Lee et al.⁸³. However, since this thesis takes a market-level approach these factors will not be discussed.

⁷⁵ Lee et al. (1995, p. 9).

⁷⁶ See e.g. Suarez (2004, p. 278); Lee et al (1995, p. 9).

⁷⁷ Lee et al. (1995, p. 9); Suarez (2004, p. 278); Van de Kaa et al. (2007).

⁷⁸ Lee et al. (1995, p. 9)

⁷⁹ Lee et al. (1995, p. 9); Cowan (1990).

⁸⁰ Cowan (1990).

⁸¹ Patent-och Registreringsverket (2007).

⁸² Suarez (2004).

⁸³ Lee et al. (1995).

4.4. Summarizing analytical questions

To be able to answer the research questions, each factor discussed in the section 4.3 will be studied to find out in what direction it has affected the Swedish E85 market. To do so, 9 questions have been formulated by summarizing each factor's impact on diffusion. The analysis in chapter 5 aims at investigating these summarizing analytical questions. The summarizing analytical questions are:

- Has E85 been technologically superior to the competing alternatives?
- Have a sufficient amount of E85 been available to support diffusion?
- Has the probability of obsolescence affected the commitment to E85?
- Have there been complementary products that have affected the diffusion of E85?
- Have there been network effects that have affected the diffusion of E85?
- Have there been user preferences that have affected the diffusion of E85?
- Have there been economical forces that have affected the diffusion of E85?
- Has there been government involvement, of influential or compelling character, that has affected the diffusion of E85?
- Has there been organisational interaction that has affected the diffusion of E85?

5. Description and analysis of the Swedish E85 market

This chapter reviews each summarizing analytical question in separate sections in the same order as presented in end of the theoretical framework. By supplying answers to each of these questions, conclusions to the research questions can be drawn in chapter 6.

5.1. Has E85 been technologically superior to the competing alternatives?

First of all, it is necessary to identify which fuel technologies are to be compared to E85 with respect to technological superiority. Examining what fuels currently exist on the Swedish market, there are mainly three alternatives to E85: fossil fuel (gasoline and diesel), biogas and electric vehicles.⁸⁴

Secondly, since technological superiority refers to superiority in completing a specified task, the task in question needs to be identified. When speaking of biofuels, the goal for consumers to adopt such a car fuel is not merely to fuel/run their cars but to do so in an environmentally friendly way. Thus, this is the task of interest. Defining the consumer's goal as only making it possible for their car to run, the aspect of environmental friendliness would be unfairly diminished in the discussion.

Finally, it is necessary to identify a number of variables by which technological superiority can be evaluated. Some fuel qualities are more important than others for the decision to adopt a certain fuel technology. In an extensive report, the Swedish Road Administration has compared the following technological features for different fuels: *environmental friendliness*, *driving range* and *distribution features*.⁸⁵ This report has attracted international interest.⁸⁶ Thus, these features will be the basis for analysis in this thesis.

The most important parameters for environmental friendliness include emission levels of environmental hazardous substances and sustainability of production.⁸⁷ The level of CO₂-emission is 60-80% lower for E85 compared to gasoline and 40-60% lower compared to fossil diesel. Furthermore E85 has approximately 60%⁸⁸ lower emissions than a hybrid electric vehicle.⁸⁹

⁸⁴ BIL Sweden (2007, p.25).

⁸⁵ Ahlvik and Brandberg (2002a, p. 3).

⁸⁶ Ahlvik and Brandberg (2001, p. i).

⁸⁷ These parameters are included in e.g. Ahlvik and Brandberg (2001, p. 7); Ahlvik and Brandberg (2002a, p. 3); Svenska Petroleum Institutet (2006, p. 15).

⁸⁸ $[1-(50/125) = 0,6]$ Miljöförvaltningen (2007).

However, biogas is calculated to have approximately 80% lower emissions than E85 when comparing cars of similar size.⁹⁰

The other critical factor determining a fuel's level of environmental friendliness is the production method.⁹¹ Ethanol can be produced from many kinds of input and in several ways, with great variation in energy efficiency. The Brazilian production of ethanol based on sugar cane has proven to be relatively energy efficient as well as the Swedish production from grain, although the latter is somewhat worse.⁹² However, for some production methods, the positive impact on the environment from using ethanol-based fuels instead of fossil fuels is nearly, entirely or more than entirely outweighed the great amount of resources being put into the production. One heavily criticized method is using corn as the input resource; a method that is common in USA where large amount of corn is produced by the agriculture industry.⁹³ Bad examples like this have given rise to critical voices in e.g. media. The production of fossil fuels is much less energy demanding comparing to the production of most biofuels. This is because the process of converting biomass to fuel is far more complex than that of converting oil to gasoline and diesel.⁹⁴ Since hybrid electric vehicles are fuelled with gasoline, the fuel production attributes are the same as for gasoline. Waste products from sewage treatments facilities, the food industry and households are used for the production of biogas. This production method is environmentally friendly and helps to reduce CO₂-emissions.⁹⁵ However, although the following argument is not related to technological superiority, it should be mentioned that the availability of such production input is highly limited and consequently experts regard biogas only as a niche fuel.⁹⁶

The driving range of similar cars varies depending on what fuel technology it applies. The driving range provided by a specific fuel is an important feature.⁹⁷ When coming to driving range per full tank, biogas has a shortcoming as it has a poor driving range of an average of 200-350km.⁹⁸ A survey comparing the most sold flexi-fuel cars with their gasoline counterparts shows that the gasoline models have a driving range of ca 1000km while the E85 models only managed ca

⁸⁹ Here it should be noticed that Toyota Prius is a slightly heavier car with a curb weight of ca 1400kg while corresponding figure for Ford Focus FFV is ca 1350kg. Since additional weight adds emission to the car, a weight-adjusted percentage would be slightly lower than 60%. Figures from Konsumentverket (2007, p. 15, 17).

⁹⁰ Miljöfordon (2007c); Miljöförvaltningen (2007); Gröna Bilister (2007c).

⁹¹ Svenska Petroleum Institutet (2006a, p. 16).

⁹² Energimyndigheten (2007b).

⁹³ Energimyndigheten (2007b).

⁹⁴ Ahlvik and Brandberg (2001, p. 7).

⁹⁵ Miljöfordon (2007b).

⁹⁶ Svenska Petroleum Institutet (2003, p. 22-23).

⁹⁷ Ahlvik and Brandberg (2002a, p. 3).

⁹⁸ Miljöförvaltningen (2005).

700km.⁹⁹ This is explained by the fact that E85 has a 30% lower energy content compared to gasoline.¹⁰⁰ However, a driving range of 700km is satisfactory as the recommended minimum driving range is 500km.¹⁰¹ At present there are no purely electric vehicles for sale in Sweden,¹⁰² however, a few hybrid models have been introduced. Hybrid electric vehicles are run by both electricity and gasoline, where the electric drive helps to reduce the car's fuel consumption.¹⁰³ Since the tank volume of a hybrid electric car does not differ from that of a regular gasoline car, the driving range of the hybrid car is even longer than that of the gasoline car.

Regarding distribution features, E85 and other liquid biofuels are clearly superior compared to gaseous alternatives. The physical characteristics of gases make the product difficult to transport and special pipelines are needed in a great extent. The difficulties in transport cause great distribution inefficiencies which result in high distribution costs. Also for this reason is biogas considered as a niche fuel.¹⁰⁴ Furthermore, liquid biofuels have a user advantage over gaseous fuels because the handling is the same as for gasoline which has been the market standard throughout motoring history. This way, users do not have to learn how to use the new fuel, i.e. how to refuel their vehicles with the new type of fuel. Neither for the distributor does a liquid biofuel cause any changes in handling.¹⁰⁵

Compared to gasoline, it can be concluded that E85 is superior from an environmental aspect, given the correct production method. It is further negligibly inferior in terms of driving range and level with regards to distribution features. Biogas is more environmentally friendly than E85 but the driving range is poor and the distribution is troublesome. More importantly, biogas can not compete with E85 since it can not be produced in significant amounts. Electric vehicles are less environmentally friendly compared to E85. However, the driving range for electric vehicles is longer but on the other hand, the driving range of E85 is more than enough in relation to the recommended distance. Furthermore, these alternatives are level concerning distribution aspects. The technological superiority of E85 has positively affected its chances of being adopted.

⁹⁹ Dagens Nyheter Motor (2007b).

¹⁰⁰ Svenska Petroleum Institutet (2007c).

¹⁰¹ Ahlvik and Brandberg (2002a, p. 3).

¹⁰² Gröna Bilister (2007b).

¹⁰³ Average fuel consumption per 100km for a hybrid Toyota Prius is 4,3 l, which can be compared to a gasoline Toyota Auris requiring 5,0 l. Figures from Konsumentverket (2007, p. 17, 55).

¹⁰⁴ Ahlvik and Brandberg (2002a, p. i, 10-11, 29); Svenska Petroleum Institutet (2003, p. 22-23).

¹⁰⁵ Ahlvik and Brandberg (2001, p. xi); Gröna Bilister (2006).

5.2. Have a sufficient amount of E85 been available to support diffusion?

As previously explained, E85 consists of 85% ethanol and 15% gasoline. The availability of E85 is thus crucially dependent on the availability of ethanol. To find out whether a sufficient amount of E85 has been available, the availability of ethanol is examined.

In year 2006, the yearly Swedish ethanol consumption amounted to 300 000 m³ and was growing.¹⁰⁶ Currently there is mainly one production facility for car fuel ethanol in Sweden: the Norrköping factory of Lantmännen Agroethanol which is producing 55 000 m³ ethanol yearly. Apart from this facility there is also a smaller one in Örnsköldsvik producing 18 000 m³ annually.¹⁰⁷ This means that the total yearly domestic ethanol production is ca 73 000 m³. The most important source of ethanol for E85 has been import. As much as 70-80% of the yearly ethanol consumption is imported, predominantly from Brazil.¹⁰⁸

These figures show that up till today there has been no shortage of ethanol for the production of E85, although much is thanks to an extensive import. In other words, reproducibility has enabled a diffusion of E85 and thus it can be said that reproducibility has been a positive force in the diffusion process.

However, investments in car fuel technologies are costly and thus they are intended to last for a long time. The Swedish National Road Administration state in their report that “[t]he resource base [of the fuel alternative in focus] must be large and durable so that a substantial market can be maintained in the long term”¹⁰⁹. This implies that the reproducibility of a fuel alternative is not only evaluated on a today basis but also on a long-term basis. Thus, the potential availability of ethanol will be examined below.

In Sweden, an expansion of the Norrköping factory is under construction and will be finalized in 2008. After the expansion the total domestic production will rise to ca 220 000 m³,¹¹⁰ but this will not be enough.¹¹¹ Thus, the question is whether there is a potential for significantly increasing ethanol production or in some other way satisfy demand.

¹⁰⁶ Riksdagen (2007); Svenska Petroleum Institutet (2007e); Svenska Jordbruksverket (2006b).

¹⁰⁷ Agroethanol (2007); Svenska Jordbruksverket (2006a, p. 63).

¹⁰⁸ Svenska Petroleum Institutet (2007d); Swedish Trade Council (2006).

¹⁰⁹ Ahlvik and Brandberg (2002a, p. 3).

¹¹⁰ 73 000 + 150 000 = 223 000 m³. Lantmännen Energi (2008).

¹¹¹ Svenska Jordbruksverket (2004).

The reproducibility of ethanol is determined by the availability of biomass, which is the feedstock for ethanol production. Biomass can be obtained from many agricultural products, e.g. sugar cane, sugar beets, corn and grain. It can also be obtained from the forestry industry in form of forestry residues.¹¹² Following, an analysis of the Swedish biomass availability will be presented.

Swedish ethanol is mainly produced from grain.¹¹³ Sweden is rich of agricultural land compared to other countries¹¹⁴ and the prospects of increased energy resources from agriculture are assessed as very good by many expert organizations.¹¹⁵ Today, only 1 TWh of bioenergy is produced by the agricultural industry but the potential for ethanol production only is by some estimated to be 5-9 TWh.¹¹⁶ Therefore, there are good possibilities for increasing the production of agricultural ethanol. However, different industries compete about the agricultural resources. With today's production technologies, the agricultural resources are not sufficient for providing consumers with both food and fuel and a significant increase in food prices threatens.¹¹⁷ This fact has resulted in a great debate regarding the usage of agricultural products. Many ethanol critics believe that food production resulting in low food prices and also a reduction of world famine should be prioritized before car fuel.¹¹⁸

Currently, no significant amounts of E85 are produced from forestry products.¹¹⁹ However, great hope is put on forestry resources for the future provision of input to the Swedish ethanol production, and investments are made in this field.¹²⁰ The availability of forest is very good¹²¹ and there is potential to further develop this biomass source.¹²² but there can be a tough competition about these resources. Sweden's great paper and pulp industry is less than happy about this new usage of forestry products.¹²³

¹¹² Svenska Petroleum Institutet (2006a, p. 9); Svenska Jordbruksverket (2006a, p. 9-10).

¹¹³ Lantmännen Agroetanol (2007).

¹¹⁴ Ahlvik and Brandberg (2002a, p. 7).

¹¹⁵ Energimyndigheten (2007c, p. 64-65); Svenska Petroleum Institutet (2003, p. 12-13, 47); Ahlvik and Brandberg (2002a, p. 9).

¹¹⁶ Energimyndigheten (2007c, p. 61-65).

¹¹⁷ United Nations Energy (2007, p. 31-32); Gröna Bilister (2006).

¹¹⁸ See e.g. Dagens Nyheter Motor (2007a); Aftonbladet (2007).

¹¹⁹ Jordbruksverket (2006a, p. 10); Swedish Trade Council (2006).

¹²⁰ Energimyndigheten (2007a).

¹²¹ Skogsstyrelsen (2007); Svenska Petroleum Institutet (2003, p. 47).

¹²² Ahlvik and Brandberg (2002a, p. 7-8); Ahlvik and Brandberg (2002b, p. 9).

¹²³ Dagens Nyheter Ekonomi (2007b); E24 Näringsliv (2007).

The import, mainly from Brazil, is predicted to continue being a major source of ethanol,¹²⁴ but harsh competition about the Brazilian resources meets the Swedish market as South American countries and the US threatens to claim a greater share of that production.¹²⁵

It is uncertain whether it will be possible to attain sufficient amounts of ethanol in the future. There are possibilities to expand domestic production but this has been much criticized and sufficient import volumes can not be guaranteed. It is possible that the risk of insufficient future reproducibility has impeded the diffusion on E85. However, this effect can not be confirmed or rejected. Obtaining information that would allow conclusions to be drawn on this matter requires a study or survey covering a large number of car owners and fuel station owners. Since market conditions vary in different parts of Sweden, such a study would need to have a national reach rather than regional in order to grant sufficient reliability. We have not found any previous studies or surveys which more closely investigate the reasons behind previous rejections of E85. Neither do we have the resources to conduct such a study within the scope of this thesis, thus no conclusions will be drawn on this matter.

5.3. Has the probability of obsolescence affected the commitment to E85?

At present, there are mainly three biofuel alternatives on the Swedish market: E85, biogas and the electric vehicle.¹²⁶ Apart from these, there are also a couple of alternatives in the development stage e.g. biodiesel and the fuel cell vehicle.¹²⁷ These alternatives, existing and those to come, compete about the market. If another alternative surpasses E85, E85 could turn obsolete.

There seems to be a possibility that E85 will become obsolete in a foreseeable future. This is expressed by major market actors' difficulty in assessing what alternative or alternatives will be dominating the future car fuel market. BIL Sweden's CEO Bertil Moldén stresses that no one knows which technology will survive the battle for dominance.¹²⁸ Bengt Håkansson, head of Lantmännen Energi, states that it is uncertain which technology will be the future solution and when it will appear.¹²⁹ Håkansson's statement should also be considered in the light of the fact that he represents a company that operates in the ethanol business. Håkansson identifies

¹²⁴ Svenska Jordbruksverket (2004); NyTeknik (2005).

¹²⁵ Automotive Sweden (2007).

¹²⁶ BIL Sweden (2007, p. 25)

¹²⁷ Research and testing is in progress by e.g. Programrådet för fordonsforskning (2007); Motormännen (2007).

¹²⁸ Moldén (2007).

¹²⁹ Håkansson (2007).

production inefficiency as a major obstacle for the success of E85.¹³⁰ Hence, both these industry experts leave the door wide open for the possibility of E85 being outperformed by other alternatives.

This uncertainty could have inhibited the adoption of E85. However, the figures for flexi-fuel car sales and E85 fuel pump implementation contradict such an effect. Flexi-fuel cars have been adopted in a much greater extent than any other environmentally friendly alternative.¹³¹ The same goes for E85 fuel stations relative to other biofuels.¹³² The conclusion that can be drawn from this is that either the uncertainty is low, and therefore not inhibiting E85 diffusion, or the uncertainty do not affect the diffusion of E85. It has at least not prevented a diffusion of E85. However, the diffusion of E85 could have been greater if there were no probability of E85 becoming obsolete.

Confirming the exact effects that probability of obsolescence has had on the diffusion of E85 requires detailed information about the reasons behind adopting and not adopting E85 when deciding on what car to buy or what fuel pump to install. Since such a study is missing and conducting such a study is beyond the scope of this thesis (compare section 5.3 regarding future reproducibility) it can not be confirmed whether or not there has been a relationship between the probability of obsolescence and the diffusion of E85.

5.4. Have there been complementary products that have affected the diffusion of E85?

With regards to complementary products to E85, we consider the vehicle in which it should be used as the most important. Thus, this section focuses on whether the existence of flexi-fuel cars has had an impact on the diffusion of E85.

The number of cars running on various fuels on the Swedish market depends partly on what the producers of cars offer. To investigate this further, we identified the most common brands sold on the Swedish market (see Table 1 below), and whether those brands offered flexi-fuel cars.

¹³⁰ Håkansson (2007). See section 5.2 for more details on ethanol production.

¹³¹ BIL Sweden (2007, p. 25).

¹³² Svenska Petroleum Institutet (2007f).

2004		2005		2006	
Volvo	53200	Volvo	54173	Volvo	55832
Saab	25085	Volkswagen	23251	Saab	25624
Volkswagen	21051	Saab	21273	Volkswagen	25061
Toyota	19248	Toyota	20564	Toyota	22393

Table 1: Newly registered cars, sorted by brand.

Source: BIL Sweden (2007, p. 25).

Volvo shut down its gas car production in early 2006. The reason behind the termination of the gas production project is explained by the slow development of infrastructure and the difficulty to reach profitability.¹³³ Volvo, however, introduced its first flexi-fuel car on the Swedish market in fall 2005,¹³⁴ and offers its flexi-fuel concept in five different models by the end of 2007.¹³⁵ Saab also introduced its first flexi-fuel car in 2005 under the biopower concept,¹³⁶ and has not introduced any other alternative car technologies on the market. Since 2007, Saab offers flexi-fuel engines in all its cars models.¹³⁷ Volkswagen, on the other hand, markets a wider variety of alternative engines for alternative fuels. They offer flexi-fuel and gas engines to their different car models.¹³⁸ Toyota, the fourth most common brand among Swedish buyers, has focused on the hybrid technology, offering a combination of gasoline and electricity. The first model was Prius, which was introduced on the Swedish market in 2000.¹³⁹ With regards to the most popular brands, it can be said that the flexi-fuel engines is the most common alternative engine among the most popular car manufacturers in Sweden. This implies that there is a significant supply of complementary products to E85. The supply of complementary products has allowed sales of flexi-fuel cars. According to respondents in a Synovate/Temo survey, each flexi-fuel car is refuelled with 75% E85.¹⁴⁰ This means that for each flexi-fuel car that is sold, the consumption of E85 increases. Thus, the diffusion of E85 has been enabled through the existence of complementary products.

¹³³ Söderberg (2007).

¹³⁴ Söderberg (2007).

¹³⁵ Volvo Cars (2007d).

¹³⁶ NyTeknik (2004).

¹³⁷ Saab Automobile (2007a).

¹³⁸ Volkswagen (2007).

¹³⁹ NyTeknik (2008).

¹⁴⁰ Svenska Petroleum Institutet (2007b).

5.5. Have there been network effects that have affected the diffusion of E85?

As stated in the theoretical framework, network effects exist when an individual user's utility of a technology increases or decreased by changes in the total number of users. When analysing the market for E85, no such direct effect has been identified, as the total number of user's of E85 does not affect an individual user's utility when using that very same type of fuel. In other words, there are no indications showing that an additional user of E85 would have a positive or negative effect on the utility of E85 for the previously existing users.

Concerning indirect network effects, we have investigated whether the number of users (measured by the number of flexi-fuel cars) has a positive effect on prices for both cars and the actual E85 price. The number of flexi-fuel cars on the market and the E85 prices is depicted the Figure 1 and 2 below.

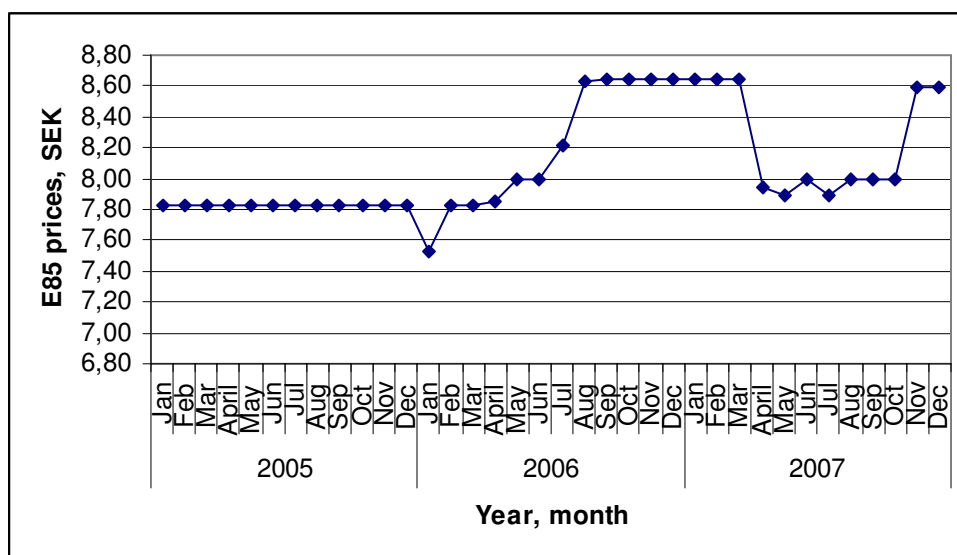


Figure 1: E85 prices 2005-2007

Source: Statoil (2007c).

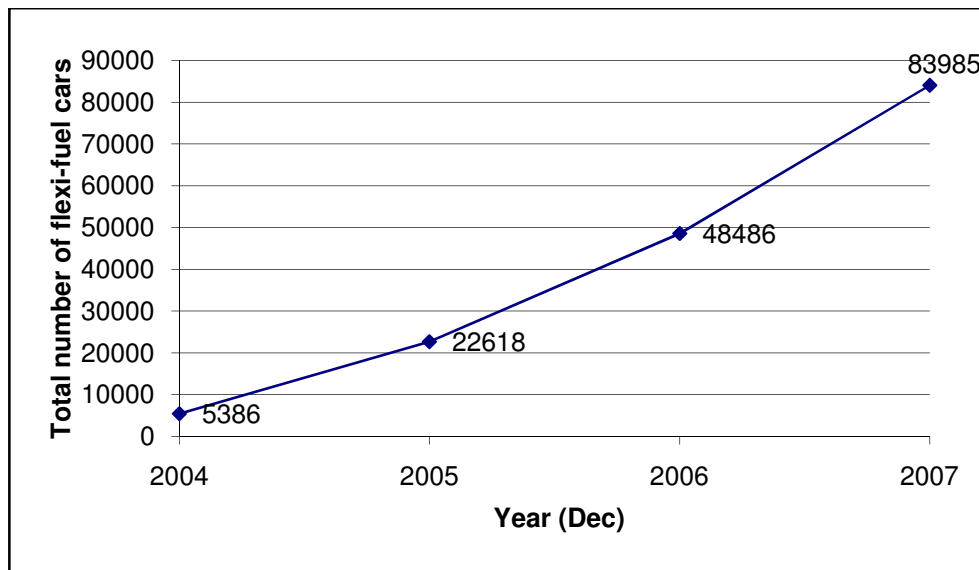


Figure 2: Total number of flexi-fuel cars in Sweden

Source: Bioalcohol Fuel Foundation (2007a)

Statoil points out that the price on E85 is higher during winters as the proportion of gasoline is higher in the fuel to achieve a better winter performance.¹⁴¹ The winter quality was introduced during the winter 2006/2007.¹⁴² Statoil also decided to lower the price March and April 2007 as the quality was readjusted to summer quality.¹⁴³ Moreover, Sekab explains ethanol shortage and increased handling costs resulted in an increase in price during the second half of 2006.¹⁴⁴ Based on these statements, it can be concluded that the increase in price during the end of 2007 can be explained by the increased amount of gasoline in E85, and the decrease in price between March and April 2007 can be explained by a decrease of the gasoline proportion. The fact that the price is not changing during winter 2005/2006 is has a logical reason as the winter quality had not yet been introduced. The increase in price in the second half of 2006 can be explained by ethanol shortage and increased handling costs. If the number of flexi-fuel cars was affecting the E85 price, a steep decrease in the E85 price should have been noticed as the number of flexi-fuel cars has increased rapidly. However, that is not the case as can be seen in the graph above. Thus, it appears that the installed base has not created indirect network effects in this regard.

Based on the same reasoning, a noticeable decrease in prices on the actual car should be possible to observe if indirect network effect are present. To do so, we investigate the most popular flexi-fuel cars that have been present on the market since 2005. The most commonly sold flexi-fuel

¹⁴¹Statoil (2007a).

¹⁴² BioAlcohol Fuel Foundation (2007a).

¹⁴³ Dagens Nyheter Ekonomi (2007a).

¹⁴⁴ Dagens Nyheter Ekonomi (2006).

cars during that period are Saab 9-5 Biopower, Ford Focus Flexi-fuel, Volvo V50 Flexi-fuel.¹⁴⁵

The prices on those cars have developed as in Table 2 below. It can thus be concluded that the installed base does not appear to have created indirect network effects in this regard either.

	2005	2006	2007
Saab 9-5 Biopower	262 000 SEK	263 900 SEK	265 900 SEK
Ford Focus Flexi-fuel	169 900 SEK	167 900 SEK	167 900 SEK
Volvo V50 Flexi-fuel	215 900 SEK	217 900 SEK	217 900 SEK

Table 2: Prices on flexifuel cars 2005-2007

2005: *Konsumentverket* (2006, p. 14).

2006: *Konsumentverket* (2007, p. 15-17).

2007: *Saab Automobile* (2007b); *Ford* (2007); *Volvo Cars* (2007a).

5.6. Have there been user preferences that have affected the diffusion of E85?

In general, Sweden there seems to be a trend among Swedish car buyers to purchase large cars to a larger extent today than earlier. In 2001, cars weighing more than 1500 kg stood for 45,0% of the newly registered cars; a number that reached 53,4% in 2006.¹⁴⁶ To put the weight in perspective, a Volvo V70 weighs between 1570-1625 kg,¹⁴⁷ and Volvo's SUV, XC 90, weighs between 2070 and 2183 kg.¹⁴⁸ Heavier cars mean larger fuel consumption and more emissions; something that per se is harmful to the environment. The trend to buy larger cars reflects an attitude among buyers that shows that care for the environment is not such an important factor when purchasing a car. This attitude has negative implications for the diffusion of E85, as those using E85 does so mainly because of environmental concern¹⁴⁹.

However, if the consumers' preferences to drive large cars can be satisfied by offering larger cars with E85 compatible engines, the negative effect can be countered. To understand if this is reality today, it was analysed if the five most popular cars that weighs at least 1500kg also are offered with E85 compatible engines. As shown in Table 3 below, only two of the five models were offered with E85 compatible engines. Moreover, these two models were manufactured by the same producer, Saab. Thus, it can be concluded that the user preference to purchase large cars has not supported the diffusion of E85.

¹⁴⁵ BIL Sweden (2007, p. 25).

¹⁴⁶ BIL Sweden (2007, p. 23).

¹⁴⁷ Volvo Cars (2007b).

¹⁴⁸ Volvo Cars (2007c).

¹⁴⁹ Svenska Petroleum Institutet (2007b).

Model	Numbers sold 2006	Numbers sold 2005	Possible to get with E85 compatible engine
Volvo V/C70	29 539	27 796	No
Saab 9-5	14 494	11 894	Yes
Saab 9-3	11 130	9 379	Yes
Volkswagen Golf	9 016	9 603	No
Volkswagen Passat	8 857	7 906	No

Table 3: Large cars and whether they are offered as flexi-fuel cars

Source: BIL Sweden (2007, p. 24); Volvo Cars (2007); Saab Automobile (2007); Volkswagen (2007).

Statistics over car sales in Sweden give an indication of Swedish consumers' fuel preferences when buying a car. In 2006, cars using other fuels than gasoline and diesel amounted to 11,4% of the total number of newly registered cars.¹⁵⁰ Cars for alternative fuels still represent a relatively small share of the newly registered cars. However, they have gained market share since 2004 (see table 4 below). Out of the newly registered cars using alternative fuels, 80% were flexi-fuel cars (see Figure 3 below),¹⁵¹ which corresponds to 9,2 % of the total number of newly registered cars. With regards to relative market share, it should also be noted that cars using E85 has increased its market share during since 2004, whereas both gas cars and hybrid technology has lost market share. On a similar note, the four most commonly sold car alternative fuel car models are all E85 cars.¹⁵² The statistics implies that users still buy gasoline or diesel cars, but flexi-fuel cars seem to be the only alternative to that has been able to compete with the already established technologies.

Year	Newly registered cars, total	Newly registered cars that (can) use alternative fuels	% of total number newly registered cars that (can) use alternative fuels	% of total number newly registered cars that (can) use E85
2004	264246	7136	2,7%	2,0%
2005	274301	14094	5,1%	3,8%
2006	282766	32163	11,4%	9,2%

Table 4: Newly registered cars and fuel technology

Source: BIL Sweden (2007, p. 22, 25).

¹⁵⁰ Total number of newly registered cars 2006: 282 766. Number of newly registered cars using other fuels 2006: 32 162. BIL Sweden (2007, p. 22, 25).

¹⁵¹ Number of newly registered cars using other fuels 2006: 32 162. Number of newly registered cars using ethanol fuel 2006: 25 876. BIL Sweden (2007, p. 25).

¹⁵² The most common car models are Saab 9-5 Biopower, Ford Focus Flexi-fuel, Volvo V50 Flexi-fuel, and Saab 9-3 Biopower. BIL Sweden (2007, p. 25).

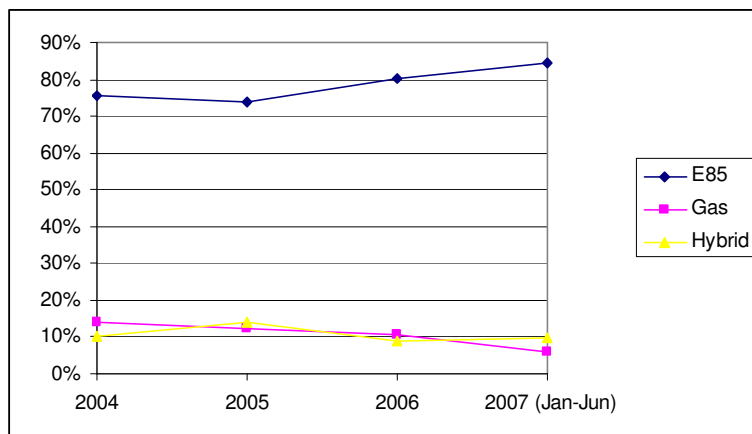


Figure 3: Percentage of the biofuel car market, sorted by technology
Source: BIL Sweden (2007, p. 25)

Furthermore, flexi-fuel car owners state that the availability of fuel stations is important for the choice of what fuel to run the car by.¹⁵³ Thus, the availability of fuel stations needs be investigated. By the end of 2007, there were 3701 fuel stations.¹⁵⁴ Out of those, 1001 offer E85. Those E85 fuel stations are mostly located in the south and middle of Sweden, and along the coast in northern Sweden.¹⁵⁵ The number of E85 fuel stations and the number of flexi-fuel cars has increased dramatically during the last years (see Figure 4 and Figure 5 below), where the big break for flexi-fuel cars and stations came during 2005. Thus, it appears as the development concerning distribution channels for E85 has developed in a direction where users get their user preferences met. Thus, the development of fuel stations has made users of flexi-fuel cars more willing to adopt E85.

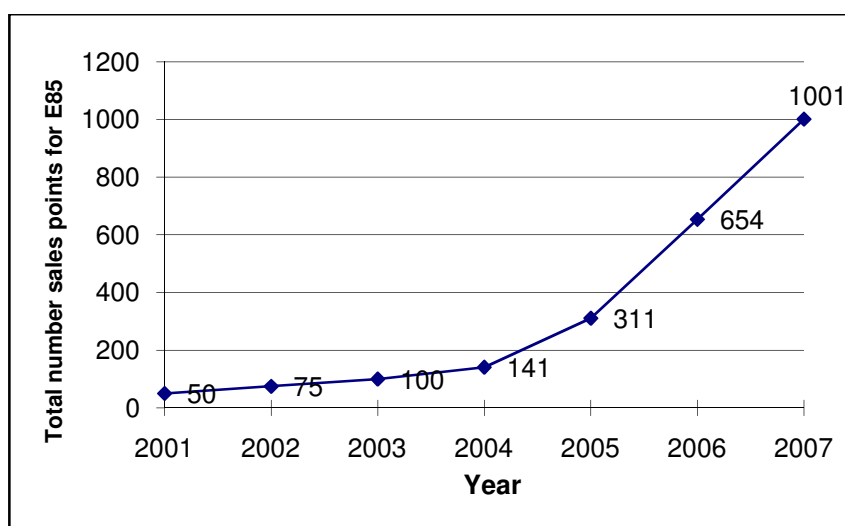


Figure 4: Total number of sales points for E85 in Sweden
Source: BioAlcohol Fuel Foundation (2007b).

¹⁵³ Svenska Petroleum Institutet (2007b).

¹⁵⁴ Svenska Petroleum Institutet (2007a).

¹⁵⁵ Numbers are until November 2007. BioAlcohol Fuel Foundation (2007b).

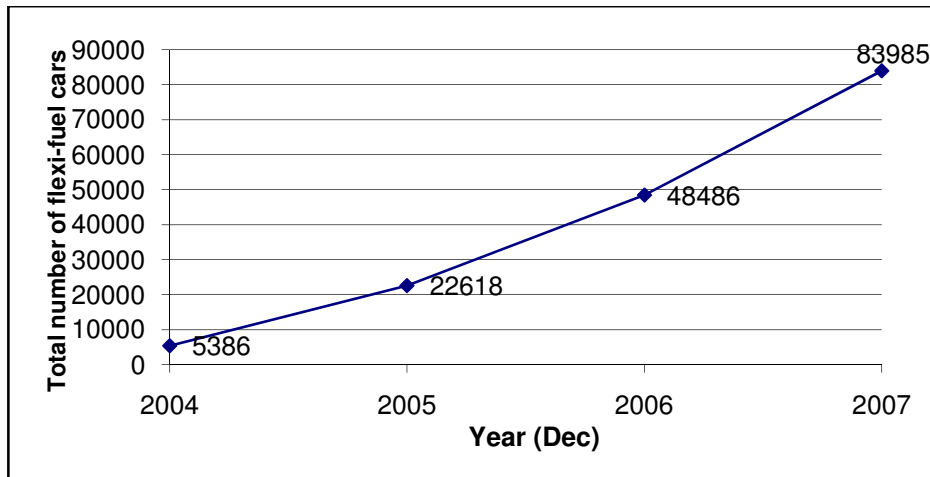


Figure 5: Total number of flexi-fuel cars in Sweden

Source: Bioalcohol Fuel Foundation (2007a)

The availability is not only important for flexi-fuel car owners, but for any potential buyer of a new car. The report from the Swedish National Road Administration states that the availability of fuel stations is an important factor to achieve customer acceptance.¹⁵⁶ Thus, if the availability of fuel stations for fuel gas was larger than that for E85, it would have affected the diffusion of E85 negatively.

When studying the development of fuel gas stations, (see Figure 6 below) it shows that the number of stations offering fuel gas has increased from 31 to 87 in number. The availability of fuel gas has apparently increased, but the availability has never been in the same range as that for E85 (see Figure 4 above). Hence, the low availability of fuel stations for fuel gas does not appear to have impeded the sales of flexi-fuel cars to any significant extent.

¹⁵⁶ Ahlvik and Brandberg (2002, p.3).

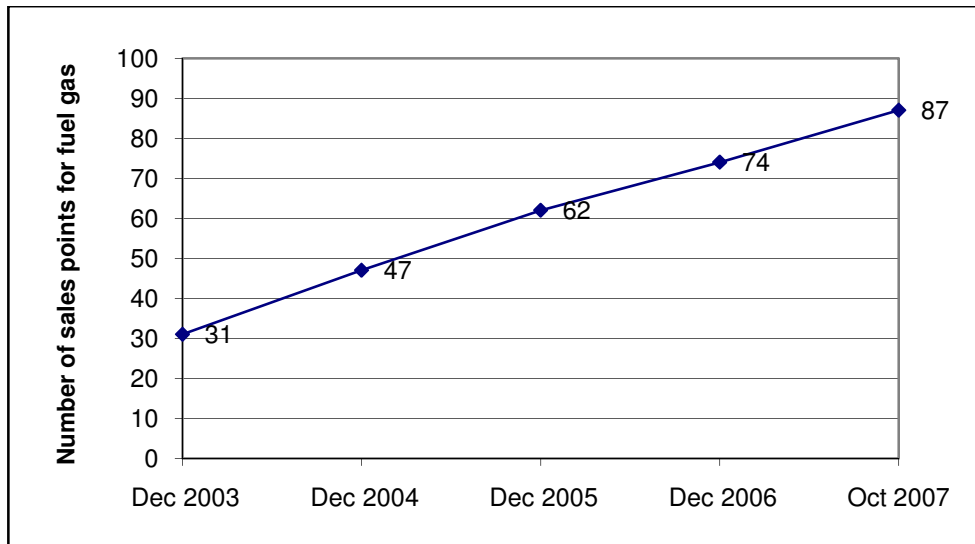


Figure 6: Total number of sales points for fuel gas in Sweden

Source: Svenska Petroleum Institutet (2007f)

5.7. Have there been economical forces that have affected the diffusion of E85?

Theory suggests that pricing can be of importance for a technology's diffusion. To understand whether that is the case, one needs to consider the prices on both E85 and the car in which the fuel will be used. To understand whether there is a difference in prices between gasoline and flexi-fuel cars, the prices on those car models that are offered with both types of engines were compared. The comparison is based on the most commonly sold E85 models on the Swedish market. As the prices of flexi-fuel cars have not varied significantly since 2005 (see section 5.5), we consider it sufficient to only investigate the pricelists for 2007.

Car model	Jan-Dec 2005	Jan-Dec 2006	Jan-June 2007
Saab 9-5	3 745	10 941	4 993
Ford Focus	5 483	7 239	4 024
Volvo V50	597	5 172	2 239
Saab 9-3	Not offered	Not offered	1 829
Volvo C30	Not offered	Not offered	791

Table 5: Most popular flexi-fuel cars (number sold)

Source: BIL Sweden (2007, p. 25).

The prices on the versions with gasoline engines and those with E85 compatible engines seem to be similarly priced. For example, “Saab 9-5 Sedan Linear 2.0t (150 hk)” with a gasoline engine has a recommended price of 256 900 SEK, whereas the “Saab 9-5 Sedan Linear 2.0t Biopower (180

hk)”) has a recommended price of 265 900 SEK.¹⁵⁷ Moreover, the “Ford Focus Trend 1.6 115 hk Ti-VCT 5D” with a gasoline engine has a recommended price of 166 900 SEK, and the Ford Focus Trend 1.8 125 hk Flexi-fuel 5D” has a recommended price of 167 900 SEK.¹⁵⁸ Similarly, the “Volvo V50 1.6 (100 hk)” with a gasoline engine has a recommended price of 203 900 SEK, the “Volvo V50 2.0 (145 hk)” with a gasoline engine has a recommended price of 223 900, and the “Volvo V50 1.8 Flexi-fuel (125 hk)” has a recommended price of 217 900 SEK.¹⁵⁹ Thus, it does not seem like the major car producers have applied low prices to encourage sales.

On a similar note, the prices for hybrid vehicles and fuel gas vehicles should also be discussed. The only hybrid that has been sold to a significant extent is Toyota Prius, the only fuel gas car sold to any significant extent is the Volvo V70 Bi-Fuel.¹⁶⁰ The price for a Toyota Prius is 252 900 SEK. As a comparison, the price for Volvo V70 Bi-Fuel was 274 900 SEK.¹⁶¹ The Toyota Prius lies in the same or even at a higher price range as the flexi-fuel cars discussed above. The price for the Volvo V70 Bi-Fuel is higher than any of the flexi-fuel cars. Thus, it does not appear as there have been economical forces in this perspective that have impeded the sales of flexi-fuel cars. Rather, it is possible that economical forces have spurred the sales of flexi-fuel cars.

With regards to the E85 fuel itself, SPI states in its report “Förnybara drivmedel” that the use of E85 depends on the price on E85 in comparison with gasoline.¹⁶² Whether it is profitable to refuel a flexi-fuel car with E85 is determined by the ratio between the price of gasoline and that of E85.¹⁶³ Thus, the diffusion of E85 is highly dependent on that the price for gasoline is higher than the price for E85. This relationship has also been shown in a recent survey conducted by Synovate/Temo concerning the attitudes among flexi-fuel cars. Those that use both gasoline and E85 state that the fuel price is an important reason for the choice of fuel. 42% of those owning the car privately state the price is important, whereas 28% of those having a company car regard the price as an important factor. Thus, as long as the E85 price is lower than the gasoline price, it is more likely that the users will prefer to drive their car on E85.

The actual prices on E85 have been lower than the prices on gasoline since January 2005.

¹⁵⁷ Saab Automobile (2007b).

¹⁵⁸ Ford (2007).

¹⁵⁹ Volvo Cars (2007a).

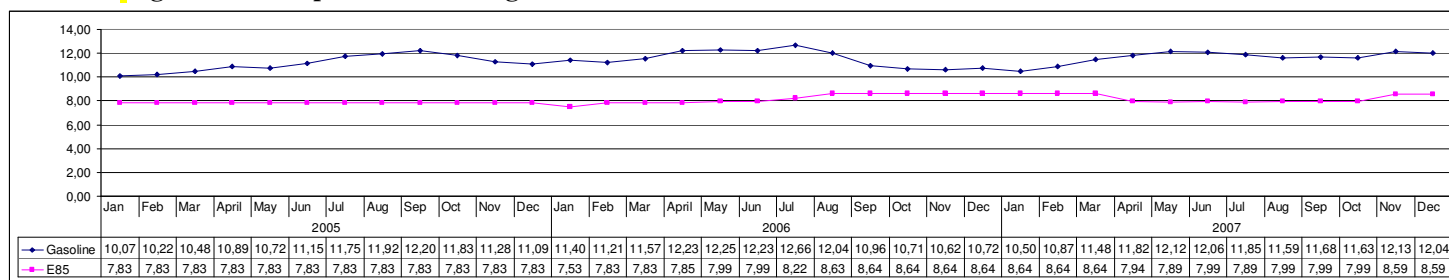
¹⁶⁰ BIL Sweden (2007, p. 25).

¹⁶¹ Konsumentverket (2007, p. 17).

¹⁶² Svenska Petroleum Institutet (2003, p. 18).

¹⁶³ Svenska Petroleum Institutet (2003, p. 19).

Figure 7: Actual price of E85 and gasoline



Source: Statoil (2007c).

However, as stated in section 5.1, 35-40% more fuel volume is required for E85 compared to gasoline.¹⁶⁴ Thus, the E85 prices need to be adjusted to be able to make a fair comparison. The gasoline price should instead be compared with about 1.35 times the E85 price. In that case, the price comparison looks as in Figure 8 below.

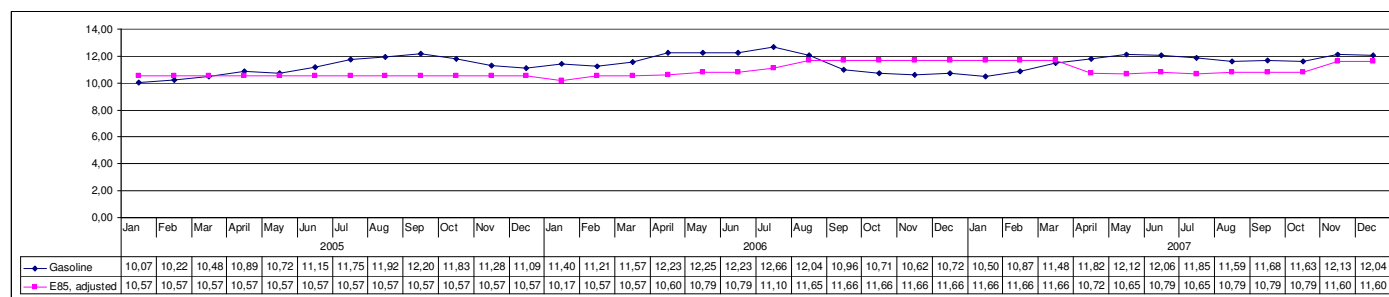


Figure 8: Adjusted E85 prices and regular gasoline prices

Source: Statoil (2007c).

The importance of prices can be illustrated by the decreasing sales of E85 during fall 2006. Even though the number of fuel sales points and flexi-fuel cars on the market were increasing, the sales of E85 were decreasing (see Figure 9 below). As seen in the Figure 8 above, the adjusted prices during the months August to November 2006 the prices on E85 was higher than the price for gasoline. Ulf Svahn, CEO at the Swedish Petroleum Institute, explained in a press release in early November 2006 that the decreasing sales between August and October was indeed an effect of that the price on E85 was higher than the price for gasoline.¹⁶⁵ The drop in E85-sales and the relatively high price on E85 are thus not coincidences. Based on the effect the fuel prices have on the diffusion of E85, the fact that the adjusted E85 prices mostly have been lower than the prices for gasoline should thus be regarded as positively affecting the diffusion of E85.

¹⁶⁴ Miljöfordon (2007a).

¹⁶⁵ Svenska Petroleum Institutet (2006b).

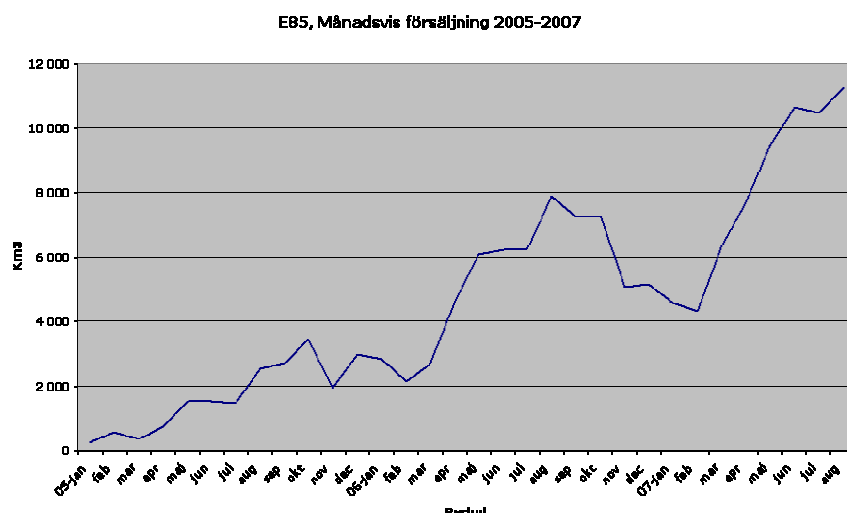


Figure 9: Sold volume of E85

Source: Svenska Petroleum Institutet (2007g).

5.8. Has there been government involvement, of influential or compelling character, that has affected the diffusion of E85?

There are mainly two governmental actions of compelling character affecting the Swedish market. First of all is the Swedish law SFS 2005:1248 which obligates fuel stations' to offer renewable fuels. This law states that all gas stations of a certain size (i.e. with sales volumes exceeding a certain limit) must supply at least one renewable fuel alternative.¹⁶⁶ Gas station owners, which constitutes of private franchisers and big oil companies, have to bear the cost of the new equipment necessary for the new fuel alternative they offer. Since they seek to minimize costs, fuel alternative with the lowest implementation cost are preferred. Of the currently available renewable fuel alternatives, i.e. E85 and biogas, E85 is by far the cheapest to adopt. Equipment for E85 cost 300 000 SEK to install, compared to 2.5-3.5 million SEK for biogas.¹⁶⁷ Svensk Bensinhandel's CEO Ingvar Persson points out that this is the main reason for choosing to install E85 fuel pumps rather than pumps for other fuels.¹⁶⁸ For this reason, E85 diffusion has benefitted by the SFS 2005:1248 law.

Relating to the above reasoning, there is an ongoing trend in the Swedish fuel station market to reduce the total number of fuel stations. This reduction in the number of fuel stations is most likely going to result in higher sales volumes per station. Instead of having a few large fuel

¹⁶⁶ SFS 2005:1248.

¹⁶⁷ Prop. 2005/06:16.

¹⁶⁸ Persson (2007).

stations and a great number of small ones, there will be a medium number of large stations.¹⁶⁹

This development will increase the number of stations that need to comply with the SFS 2005:1248 law. Thus, the rationalization of fuel stations in combination with the enforcement of this law further favours the diffusion of E85.

The second governmental involvement of compelling character has not yet taken effect.

Nonetheless, it is already a powerful force within the car industry. A new EU-proposal implies that all new-manufactured cars must limit the CO₂-emission to 120 g/km.¹⁷⁰ This proposal has met tough resistance from the car industry, particularly from the German branch with its large production of heavy vehicles, and concessions have already been made as tough lobbying has increased the limit to 130 g/km.¹⁷¹ Despite this deterioration of the original proposal, this preparation for a new EU-legislation has its effects. It directs the car industry towards producing more environmentally friendly vehicles without giving any detailed instructions. How to decrease CO₂-emissions from cars is up to the manufacturer. All interviewees has expressed that this law will affect the future market.¹⁷² However, there are still negotiations going on regarding the final specifications of the law, and the law risks to be severely watered down.¹⁷³ Because this is still an on-going process, it has not had any significant implications for E85 within the timeframe of this thesis.

Furthermore, a premium or bonus issued by the government was introduced in April 2007 with the intention to increase the sales of environmentally friendly cars. Everyone who is buying a new car corresponding to specific environmental standards decided by the Swedish Road Administration receives a 10 000 SEK funding.¹⁷⁴ This action has shown to have spurred the sales of environmentally friendly cars.¹⁷⁵ The sales of environmentally friendly cars have also been encouraged through special rules for parking and the recently introduced congestion tax in Stockholm. In an increasing number of municipalities parking is heavily subsidized or free¹⁷⁶ for environmentally friendly cars and in Stockholm these cars are exempted from the congestion tax¹⁷⁷. Furthermore, the excise duty on vehicles favours environmentally friendly cars as the

¹⁶⁹ Persson (2007).

¹⁷⁰ COM 2007:19.

¹⁷¹ International Herald Tribune (2007).

¹⁷² Håkansson (2007); Lööw (2007); Moldén (2007); Nilsson (2007); Persson (2007); Svahn (2007).

¹⁷³ Herald Tribune (2007).

¹⁷⁴ Vägverket (2007).

¹⁷⁵ Sydsvenskan (2007).

¹⁷⁶ Svenska Petroleum Institutet (2003, p. 20).

¹⁷⁷ Vägverket (2007).

amount is proportional to the car's CO₂-emission.¹⁷⁸ According to a survey conducted by Synovate/Temo, free parking has been a reason for people to buy flexi-fuel cars.¹⁷⁹ Unfortunately, it is not mentioned whether the 10 000 SEK funding, the exemption from congestion tax and the reduction in excise duty have had a positive effect on E85 adoption specifically. Neither has there been another study or survey that has investigated these relationships.¹⁸⁰ However, economical incentives in favour of environmentally friendly technologies are unlikely to have a negative effect on the adoption of E85. Thus, no matter whether some of the incentives initiated by the government have been of positive or no influence, it can be concluded that, in total, these governmental measures in form of economic incentives has affected the diffusion of E85 positively.

The government has allowed tax subventions, which affects the diffusion of E85. Ulf Svahn, the CEO of the Swedish Petroleum Institute, expresses a deep regret for this governmental measure. He believes that no interventions of preferential character should be applied at this early stage of development on the fuel market. Instead all technological possibilities should be investigated and the market will eventually decide for itself what fuel alternative is the best to adopt.¹⁸¹ Currently, ethanol is exempted from energy and CO₂-tax. This indirect subvention lowers the price of E85 by approximately 1 SEK per litre in relation to fossil fuels and cost the Swedish government 1.3 billion SEK annually (2006 number).¹⁸² Thanks to a lower price, E85 has been competitive on the fuel market and more users of flexi-fuel cars have refuelled with E85 to a larger extent compared to gasoline as showed in section 5.7.

Government involvement has affected the diffusion of E85 in several ways. First of all, the SFS 2005:1248 law has directed the biofuel adoption by fuel stations toward E85. Secondly, the EU-proposal of limiting CO₂-emissions from cars is a great power but it is too early yet to tell the exact effects. Finally, preferential funding, parking and tax subventions as well as exemption from congestion tax have helped the diffusion of E85.

¹⁷⁸ Borup (2007).

¹⁷⁹ Svenska Petroleum Institutet (2007b).

¹⁸⁰ Conducting the necessary study/survey ourselves is beyond the scope of this thesis. See section 5.3 for details.

¹⁸¹ Svahn (2007).

¹⁸² Svenska Petroleum Institutet (2003, p. 19); Regeringskansliet (2007a).

5.9. Has there been organisational interaction that has affected the diffusion of E85?

The Swedish government has increased its attention towards international cooperation during the last years to solve environmental issues in general. On the homepage of the Ministry of the Environment, the EU system for emission allowance units that was introduced in 2005 is lifted as an important ingredient in Swedish climate politics. Moreover, the discussions in Spring 2007 between the EU prime ministers is also lifted as an example of the increased international development. Furthermore, the Kyoto protocol also described a instrument for global cooperation.¹⁸³

As EU is lifted as a main instrument for achieving change in environmental issues, we investigated whether there have been projects focusing on alternative fuels in general or E85 in particular to understand if there had been a will to uniform the systems that could have affected the Swedish E85 development.

The EU has set goals to increase the share of energy coming from renewable energy. The share should increase from 5.4% in 1997 to 12% by 2010.¹⁸⁴ One of the areas where there is need for an increase of renewable energy is the transportation sector, and in 2003 a goal was set that 5.75% of diesel and gasoline should be replaced by biofuels by 2010.¹⁸⁵ To achieve this, the European Biofuels Technology Platform was established in October 2006. The goal of the Platform is to implement those measures recommended by the Biofuels Research Advisory Council in its Vision Report.¹⁸⁶ The Vision report was presented in March 2006.¹⁸⁷ However, it takes time for a uniform system to be created, and it does not appear as if this organizational interaction has resulted in a significant effect on the diffusion of E85 in Sweden during the timeframe that is in focus in this thesis.

¹⁸³ Regeringskansliet (2007b).

¹⁸⁴ European Commission (2007).

¹⁸⁵ European Commission (2007).

¹⁸⁶ Biofuels Technology Platform (2007).

¹⁸⁷ Biofuels Research Advisory Council (2006).

6. Conclusions and discussion

This chapter starts by discussing issues that provide a deeper understanding of the problem discussed in this thesis. Secondly, some shortcomings of the thesis will be discussed. Thirdly, theoretical and managerial implications are provided, and finally, suggestions for further research are presented.

6.1. Conclusions

The research questions this thesis has aimed to answer are which market factors that have affected the diffusion of E85 in Sweden, and how. This has been done to explain why E85 has its current market position, and by that potentially develop an understanding of the mechanisms behind the diffusion of a technology.

A large number of factors have affected the diffusion of E85 **positively**.

Technological superiority with regards to the degree of E85's environmental friendliness can be concluded as positive for the level of technological superiority. In terms of driving range, E85 provides a sufficient driving range, which should thus be regarded as positive for the technological superiority. With regards to distribution features, E85 also has superior features. In conclusion, the sum of the technological features should be regarded as having had a positive effect on the diffusion of E85.

It could further be concluded that it has been possible to reproduce a sufficient amount of ethanol, even though the main volumes have been imported from Brazil. **Reproducibility** does not necessarily need to be done within national borders, and thus the conclusion can be drawn that the reproducibility has been sufficient.

The car was identified as the main **complementary product**. It could be concluded that the availability of flexi-fuel cars has enabled the diffusion of E85.

With regards to **user preferences** the preference for E85 above other environmentally friendly alternatives has had a positive impact on the diffusion of E85. Moreover, the user preference to use fuels that have a high availability have been satisfied by the increase E85 fuel stations, and thus this user preference can also be concluded to have affected the diffusion of E85 positively.

Economical forces with reference to the both fuel itself and prices on complementary products were investigated. It can be concluded that the prices on E85 have clearly favoured the diffusion of E85, and that prices on other biofuel car technologies have tilted consumer choice towards flexi-fuel cars.

A large number of issues were discussed in connection to **government involvement**. The law concerning fuel stations has had a positive effect on the diffusion of E85. Moreover, the premium of 10 000 SEK and other monetary exemptions for environmentally friendly cars has also affected the diffusion of E85, even though only at a later stage. Also, the exemption of energy tax has lowered the price to the consumer which in turn has had a positive impact on the diffusion of E85.

Even though the main findings have had a positive impact on the diffusion of E85, there were also a number of factors with **negative** impact.

Environmental friendliness of E85 have in some cases imposed negative influences on **technological superiority**. This relates to the issue of what input the ethanol is produced from and what production methods are used. Also, **user preferences** show an increasing interest in large cars which has affected the diffusion of E85 negatively.

Interestingly, there were also a number of factors that showed to have **no impact** on the diffusion of E85.

Both direct and indirect **network effects** were analyzed, and direct network effect could not be observed. Indirect network effects could neither be observed in relation between the increasing number of users and the E85 price, nor in relation between the number of sold cars and the car prices. Thus, it can be concluded that neither direct nor indirect network effects have had an impact on the diffusion of E85.

The EU proposal concerning car emissions was one of the issues investigated concerning **government involvement**. This proposal has not had any impact on the previous market development, but is likely to affect the future market. However, as this study focuses on the already existing market this law is regarded as not having had an impact on the diffusion of E85.

Organizational interaction could be identified, but as it had started recently, it was concluded that it is unlikely that the identified collaborations have had an effect on the diffusion of E85 in the time period that is in focus in this thesis.

Finally, a number of **not confirmed** effects have been detected.

The risk of insufficient future **reproducibility** could have had some negative impact on the diffusion of E85. Furthermore, **probability of obsolescence** could have encouraged or discouraged the adoption of E85 and thus affected the diffusion positively or negatively.

These findings are depicted in Table 6 and Figure 10 below.

Market factor	Positive impact	Negative impact	No impact	Not confirmed impact
Technological superiority	x	x		
Reproducibility	x			x
User preferences	x	x		
Complementary products	x			
Economical forces	x			
Government involvement	x		x	
Probability of obsolescence				x
Network effects			x	
Organizational interaction			x	

Table 6: Findings of the thesis.

Table 6 clarifies that some market factors have multiple effects on the diffusion of E85 and that the effects sometimes work in opposite directions to each other. The dual effect derives from the fact that these market factors contain several sub-factors which pull in different directions.

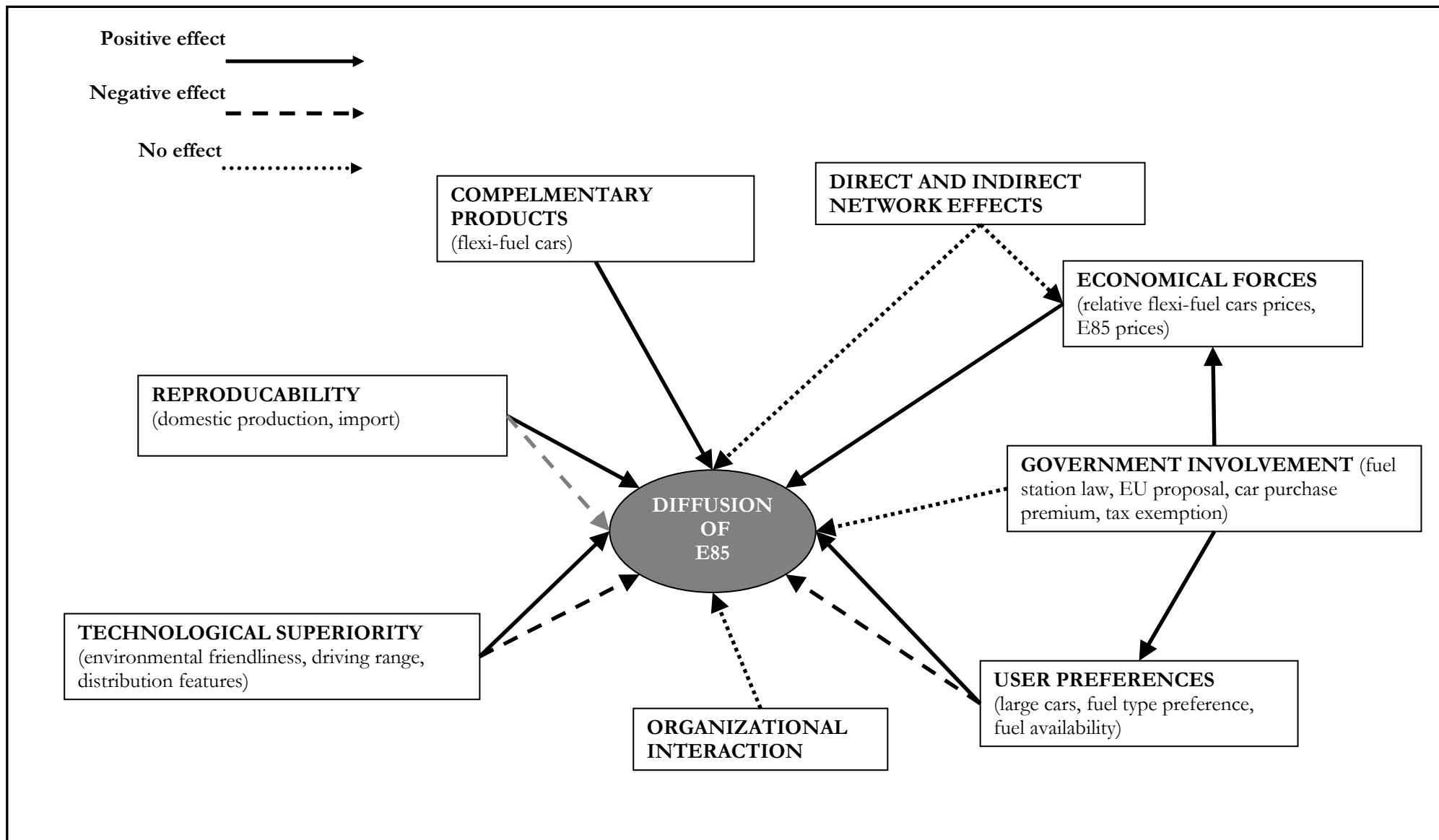


Figure 10: Findings of the thesis. (Which market factors have affected the diffusion of E85 in Sweden? How have market factors affected the diffusion of E85 in Sweden?)

Figure 10 provides an important insight regarding the mechanisms behind technology diffusion. Out of the identified factors, the following factors showed to have an effect on the diffusion of E85: technological superiority, reproducibility, user preferences, complementary products, economical forces, and government involvement. Moreover, it should also be noted that governmental involvement has not had any direct effects on the diffusion. Rather, it is of indirect character, affecting diffusion positively through user preferences and economical forces. Finally, it should also be noted that the negative arrow pointing from reproducibility is coloured in grey, symbolizing the fact that the effect has not been confirmed.

A distinction between direct and indirect effects has not been made in previous research. A possible explanation for this could be the fact that most of the earlier studies only examine a maximum of two or three factors. Due to this, these studies give a less dynamic view on the market and much of the market's complexity is left out. Since these factors are studied individually, their inter-dependence could not be detected. Moreover, the exact effects of market factors are highly specific for each case. If previously studied cases did not include effects of indirect character, such effects are bound to be left undetected. The existence of indirect influences is most likely correlated to the complexity of the studied market.

The lack of effect from some factors might result from the fact that different industries and markets have different characteristics making some factors less prevailing. Whether or not an identified market factors will have an effect varies with industry and markets. For example, the network effect is very obvious in the telephone communication industry. As an additional user is connected to a phone network, the utility for previously connected users increases. They can now communicate with one more person using this specific technology.

However, the fact that some factors showed to have no effect on diffusion could also be a result of the timeframe in focus. The timeframe poses key constraints to the analysis. If the same analysis would have been done 5-10 years from now, part of the findings regarding non-affecting factors would probably be different. The EU-proposal of limiting CO₂-emissions from cars has not had any significant effect on the market until now but it will most certainly have a great effect in the near future. The same argument can be applied on probability of obsolescence. If the inadequacies of the E85 technology could be solved or if the distrust in E85 increases, this factor could tilt the E85-diffusion-scale either way.

6.2. Discussion

Market factors determine the prerequisites on the market, thus constituting the “rules of the game” for consumers and suppliers. Understanding the sometimes intricate effects of market factors allows an understanding of the market.

Some of the identified market factors have essentially shaped the market prerequisites. Users’ preferences for fuel availability pose great obstacles for fuels with physical characteristics that complicate distribution. Production capacity determines if a fuel can become a major alternative or if it stays a niche fuel. Moreover, the market prerequisites established by some factors could overshadow the effect of other factors. If the probability of obsolescence for E85 increases significantly, users could be discouraged from adopting E85 despite the fact that most environmentally car models for sale on the market are flexi-fuel cars. A further implication for the understanding of E85’s market position is that some market factors created prerequisites that support or impede all environmentally friendly alternatives equally. Others factors favour or disfavour specific technologies. For example, the monetary incentives granted by the government favour all environmentally friendly alternatives while economical factors such as the lower price on flexi-fuel cars favours E85.

It is important to be aware of the possibility for market factors to bring about unexpected and unwanted bias toward a specific technology. There can be complex inter-dependencies between separate factors that results in an effect of great force. This is the case of the law SFS 2005:1248. The government did not intend to favour any specific technology when they introduced this law. The intent was to speed up the development towards a more environmentally friendly transport market. However, in combination with economical forces, this law inevitably steered the market towards E85 as it was considered as the only commercial alternative possible at that time. Acknowledging these complex inter-dependencies and the volatility they impose on the market, the developments on the market could be better understood.

We are aware of that this study has only examined the main issues for each factor. This approach means that there is a risk that some influential issues have been excluded. By discussing more issues the result could have differed. However, covering the most important issues should result in an acceptable picture of the reality.

For a few factors, the effects could not be confirmed. This is a result of that the essential information to identify those effects was not available. Such information could have been obtained through an extensive survey among flexi-fuel car owners and fuel station owners. Such a survey would require large resource, which were not available within the scope of this thesis. Such a study could have been conducted within the scope of this thesis if fewer factors had been studied. However, the fact that a large number of factors were taken into consideration constitutes one of the main strengths of this thesis, as earlier studies have not looked at so many factors at once. Thus, we see that this thesis provides a more comprehensive view of the market than previous studies despite the shortcomings in a few factors.

The analysis was inhibited by the fact that this thesis investigates a current process. Compared to previous studies, the final outcome is not determined. It is difficult to know what effects are key determinants on beforehand while studying a finalized process facilitates a more correct identification of major impacts. For example, Cowan¹⁸⁸ investigated the diffusion of the light water technology for nuclear power plants. The diffusion of this technology was finalized before it was studied by Cowan. Being in possession of knowledge regarding the important events during the diffusion process, events that in our case has not yet occurred, he could draw conclusion based on known causalities.

It is important to remember that the conclusions drawn in this thesis are heavily dependent on the characteristics of the market. Thus, generalizations should be done with great precaution. First of all, it should be noted that the probability is high that the issue dealt with within the different market factors are different for different industries and markets. For example, the specific law SFS 2005:1248 is unlikely to be found in other industries and markets, at least in its exact wordings. The result of varying issues is that the exact effect of each factor differs from industry (market) to industry (market). This implies that this type of analysis is highly specific for its industry and market.

However, some of the findings could be value to other industries and markets. The notion of indirect and direct influences should be possible to apply on other problem areas than the Swedish E85 market. Recognizing the existence of both direct and indirect effects could allow a better analysis of other industries and markets as well. Moreover, we also believe that the theoretical framework is a useful tool when analysing these complex markets. By using the

¹⁸⁸ Cowan, (1990).

summarizing analytical questions, main issues are addressed which in turn provides a comprehensive view of the focal industry and market.

6.3. Managerial implications

The results in this thesis do not only have implications for theory development, but also for strategy. This thesis contains valuable insights for navigating on the complex and changing market that the fuel market is. It not only provides a comprehensive understanding of the market. Furthermore, practitioners could use the findings as a tool for identifying important market mechanisms which can determine the success or failure of individual businesses. By gaining this understanding, actors could better meet competition and exploit market possibilities. In addition, it does not only allow firms and institutions to act in symbiosis with its surrounding environment, but could also provide opportunity to steer the development of the market in a desired direction. Finally, this thesis could also be of use for someone wanting to introduce a new fuel on the Swedish market. In that case, the factors in focus would need to be investigated to understand a potential future success for that fuel.

6.4. Further research

As the work with this thesis has progressed, many questions have been answered but many new questions have also been raised. This provides the basis for the recommendations for further research. As discovered during the progress of this thesis, an extensive study among fuel station owners and flexi-fuel car users would be of great value for an even deeper understanding of the E85 development. By conducting such a study, a more exact analysis for some factors could be provided. Furthermore, more detailed studies of each factor would provide a more in-depth picture of their effects on the Swedish E85 market. More narrow studies of the described character would also be of interest with regards to the indirect effects identified in this thesis. Additional important inter-dependencies could potentially be detected.

It would be valuable to examine whether some factors tend to have a greater influence on market developments than others. It could be suspected that governmental involvement in terms of legislation often, if not always, have a greater impact than other factors due to its compelling character. Deriving from this reasoning, a quantitative approach could be of interest in order to determine the strength of each factor and the strength of different factor combinations.

Finally, departing from a different theoretical field such as the network approach could provide valuable insight on how individual or collectives of actors have affected the diffusion of E85 on the market. Applying the tools of another theoretical field could shed light on issues that could have been neglected by the innovation and dominant design perspective. Different theoretical fields could complement each other and hence, investigating the problem area using a variety of theoretical tools could further develop the understanding for the issue.

A comment regarding the future of E85 will end this thesis. Despite the fact that E85 has been diffused on the Swedish market, there is still a long way to go before a great part of the cars in Sweden is run by E85. If the development continues in the same positive trajectory as until now, it is possible that E85 will be a major fuel in the future. However, key industry actors express a serious distrust in E85 and its ability to solve the environmental problems deriving from modern motoring. Moreover, few industry actors seem to believe that the dependence on fossil fuel will be reduced by a great extent in the next 20-30 years. No doubt E85 will be present in the future fuel market given the developments in recent years, but the question is to what extent. If production methods are improved E85 might even become the dominant design for car fuels. If not, E85 might end up as a niche fuel similar to the current application of biogas.

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