An analysis of the Swedish green car rebate

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Abstract

In this study we use market level data from the Swedish automobile market to estimate the effect of the green car rebate on the market shares of green cars. We find that the rebate has had a positive impact on the market shares of green cars in general. The effect differs between fuel types and the impact is largest for low emission gasoline and diesel cars. When compared to the initiative to exempt alternatively fuelled cars from the Stockholm congestion tax we find the rebate to contribute less. If assessing the rebate program only by its ability to reduce carbon emissions, we find the program to be expensive compared to the price of carbon emission rights.

Key words: Policy, Rebate, Automobile industry, Green cars, Sweden
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1. Introduction

The implications of green house gas emissions, CO_2 in particular, have been much debated in recent times. The issue has reached the political agenda, where it has been decided to take action against the emissions. The objective for the EU is to cut carbon emissions by 20 percent by 2020 compared to the levels of 1990. In Sweden, 19 percent of green house gas emissions stem from passenger car transportation. The majority of these emissions consist of carbon dioxide. It is therefore essential to reduce the emissions from passenger cars in order to meet the goal set up by the EU. One part of the solution is to make people drive less and the other is to make the cars emit less. At the moment Sweden has one of the most fuel devouring vehicle fleets in Europe with relatively old and large cars. Different measures have been taken by the Swedish government to address the issue. The most attention has been given to the green car rebate of SEK 10,000, which was introduced in Sweden in April 2007 to promote the sales of environmentally friendly cars, so called green cars. This thesis will focus on the Swedish green car rebate and its effect on the sales of green cars.

Since 2005, when the market share of green cars was only 2 percent in new car sales, the share has been increasing every year and from the start of the rebate program the increase has been even larger. In September 2008 green cars accounted for 41 percent of Swedish new car sales. The growth is also visible when observing the real numbers; the development shows an escalating trend over time starting some time in 2005 and a distinct increase in sales after the introduction of the rebate. We thus expect to find a correlation between the rebate and higher green car sales.

The objective of this thesis is to analyze the effects of the green car rebate on the market share of green cars. More specifically we investigate to what extent the increase in the market shares can be related to the rebate, when controlling for other factors which previous research has found to determine vehicle choice. Since the rebate is only offered to natural persons, this thesis focuses only on this market and disregards all sales to juridical persons. Since the program is national and the concept green car comprises various fuel types, we examine the effects of the rebate on the different regions as well as the different fuel types. As a previous study by the EU project Bioethanol for Sustainable Transport (BEST, 2009) has found the policy to exempt alternative fuel cars from the Stockholm congestion tax to affect green car sales positively, we also compare the impact of this policy to the one found for the rebate. Lastly, we investigate the cost-effectiveness of the green car rebate by determining the implicit price paid to reduce emissions by one tonne of CO_2.

Compared to the study by BEST (2009) which also investigates the relationship between the green car rebate and the market share of green cars in new car sales, we allow more car attributes to be included by estimating the market shares on a car model level. This estimation is carried out by using monthly sales data divided by car model and fuel type from January 2004 to September 2008 combined with data on car characteristics, fuel prices and average distances driven. By introducing sales data at a more detailed level and combining this data with car characteristics we expect to be able to estimate a more solid model with stronger explanatory power for the sales of green cars, which will allow us to better understand the impact of the green car rebate.

We find that the green car rebate has contributed to the increase in the sales of green cars. By computing counterfactuals for an alternative scenario without the rebate, we estimate the rebate to have increased the green car sales by 13 percent for the period April 2007 to September 2008. We find that the low emission models of gasoline and diesel fuelled cars make out the majority of the increase. This is in accordance with the results from the study by BEST (2009). The sales of ethanol cars, even though making up about half of all green car sales, are surprisingly unaffected by the rebate. The same goes for electric hybrids, whereas sales of gas cars have increased by 38 percent thanks to the subsidy. The market share of gas cars is however so small, that this increase does not affect the overall market share of green cars significantly. We find the effect on market shares to be largest for Västra Götaland and Stockholm, which are also the two regions with the largest populations in Sweden. For Stockholm, our results indicate that the exemption from the congestion tax has had a larger impact on the sales of alternative fuel cars than the rebate, which is in line with the findings by BEST (2009). Further on, the computed counterfactuals indicate a yearly decrease in CO_2 emissions in the range of 4,982 to 9,336 tonnes for all new cars sold from April 2007 to September 2008. This would imply, when weighed against the costs of the rebates, that the government has paid a price of SEK 3,535 to SEK 6,625 per tonne of saved CO_2.[1] If these numbers are compared to the price of European CO_2 credits, currently SEK 160 per tonne, the program does not appear rather cost-effective. Then we have however not considered the desired long term objective to increase the acceptance for green cars.

[1] A graph in *Appendix A.5.* depicts the development of the SEK / USD exchange rate 2004-2008.

We contribute to previous research by investigating the Swedish green car market and the rebate by examining consumer's vehicle choice with more detailed data. Furthermore, our data only contains sales to natural persons, which allows us to focus on individual choices. This thesis also differs from other international studies on governmental policies to increase the share of green cars. The main difference lies in the Swedish definition of a green car which also includes low emission gasoline and diesel models. Most studies are performed on alternatively fuelled cars in general or a certain type e.g. hybrid electric vehicles.

It is our aspiration that the results from this study will be able to provide guidance on appropriate structure and focus for future studies on subsidies, e.g. studies on the recently introduced tax relief for green cars which came to replace the green car rebate in July 2009.

2. Background

2.1. The Swedish automobile market

As a quick introduction to the Swedish automobile market we present some basic facts and compare Sweden to France and Germany. The numbers presented involve all passenger cars, thus including those owned by juridical persons.

	Sweden	France	Germany
New passenger car registrations (2007)	306 799	2 064 543	3 148 163
Per 100 inhabitants (2007)	3.4	3.2	3.8
Passenger car fleet (2006)	4 202 463	30 400 000	46 569 657
Average car age (2006)	9.4	8.1	8.1

Table 1: Passenger car statistics, source: ACEA (2008)

2.2. The green car rebate

The Swedish government introduced the rebate program to promote green cars in April 2007. It involves a rebate of SEK 10,000[2] to all natural persons who purchase a car classified as environmentally friendly, from here on referred to as a *green car*. The program was scheduled between April 2007 and December 2009 and budgeted at a total

[2] The rebate is paid out to the consumer automatically by the government six months after the purchase (Miljöfordon.se, 2009).

of SEK 250 million; 50 million for 2007, 100 million for 2008 and 2009 respectively (Ministry of the Environment, 2007).

The program has been expanded twice; in the spring 2008 an additional SEK 240 million for 2008 were announced (Ministry of the Environment, 2008a) and in the fall another SEK 325 million for 2009[3]. With the announcement of the second expansion, it was communicated that the program will be shortened, ending already June 30th 2009 (Ministry of the Environment, 2008b). Andreas Carlgren (2008), Minister of Environment, motivated the decision by stating that the goal of the rebate program has already been accomplished by the large increase in sales of green cars.

2.2.1. Definition of a green car

To be defined as a green car and to be eligible for the rebate, a car is to belong to the appropriate environmental class[4] and comply with certain emission criteria (SFS, 2007). The cars are divided in two categories; conventional green cars and alternative fuel cars. Cars running on fossil fuels, referred to as conventional cars, can be classified as green cars if their carbon dioxide emissions lie below 120 g/km. Diesel cars must also have a particle emission of less than 5 mg/km meaning that they need to have a particle filter. These two categories are referred to as conventional green cars. Cars equipped for other fuels than gasoline and diesel, referred to as alternatively fuelled cars, are defined as green cars if their consumption lies below the energy equivalent of 0.92 l/10 km gasoline or 9.7 m^3/10 km. The main alternative fuel cars are flexible fuel cars (ethanol and gasoline) and bi-fuel (gas and gasoline). Electric cars are considered green if the consumption lies below 37 kWh/100 km. Automatic cars have higher thresholds for fuel consumption if otherwise identical to a manual car that satisfies the requirements, apart from the transmission and thereto belonging components.

2.2.2. Other incentives

In addition to the SEK 10,000 rebate, green car owners across the country enjoy various other advantages. Several Swedish municipalities have introduced rebates on parking fees for green cars to different extents with differing green car definitions. Through lower CO2-emissions the green cars also indirectly enjoy lower taxes, since the vehicle tax in Sweden is based on the level of CO2-emissions and fuel type for models from 2006

[3] Given that in 2006 more than 10,000 green cars were sold without the rebate, the original budget for the program might be seen as rather small.

[4] Environmental class 2005 for gasoline cars, environmental class 2005 PM for diesel cars, environmental class *Electricity* for electric cars and environmental class *Hybrid* for hybrid cars. The environmental class regulates emissions hazardous to the environment and health, but not green house gases.

and after[5]. Ethanol and gas car owners also enjoy the fuel tax benefits since these fuels are exempt from energy and carbon tax (Miljöfordon.se, 2009).

In Stockholm city, alternatively fuelled cars are exempt from the congestion tax that was introduced a few years ago (see *Table 2*). Since the tax has been widely debated and can affect the operating costs for motorists significantly we will take a deeper look at the results for the Stockholm case alone.[6]

		Rebate	**Congestion tax**
2006	January		Trial started
	July		End of trial
2007	March	Rebate program announced	
	April	Rebate program started	
	August		Permanent congestion tax
2008	April	Budget expansion	
	September	Program shortening and budget expansion	

Table 2: Timeline of key events

2.2.3. Vehicle tax exemption for green cars

To replace the green car rebate program that was ended on the 30 June 2009, the Swedish government has decided to exempt new green cars from vehicle tax for a period of five years (Ministry of the Environment, 2009). The new law will be enforced from 1 January 2010, but be effective retroactively from 1 July 2009 to take over right when the rebate expired. The same definition of green car will be used as in the rebate program.

2.3. The supply and sales of green cars

During the last couple of years Sweden has experienced an increased interest in green cars which has been visible in the market shares of green cars sold as well as in the number of green car models offered by the car producers. The sales development of green cars, according to the rebate definition, is demonstrated in *Figure 1*.

[5] The new tax system as of 2006 also includes hybrids/electric cars belonging to environmental class 2005, which were previously exempted from tax for five years. For other vehicles, the old system is still applied where the tax is based on weight and fuel type.

[6] Note that gasoline and diesel models with emissions of less than 120 g/km are not exempt from congestion tax. The exemption is valid for cars registered up until January 1st 2009 and will continue throughout 2012. The tax ranges between SEK 10-20 entry/exit depending on time of passing, from 6.30 am to 18.29 pm, with a maximum of SEK 60 per day.

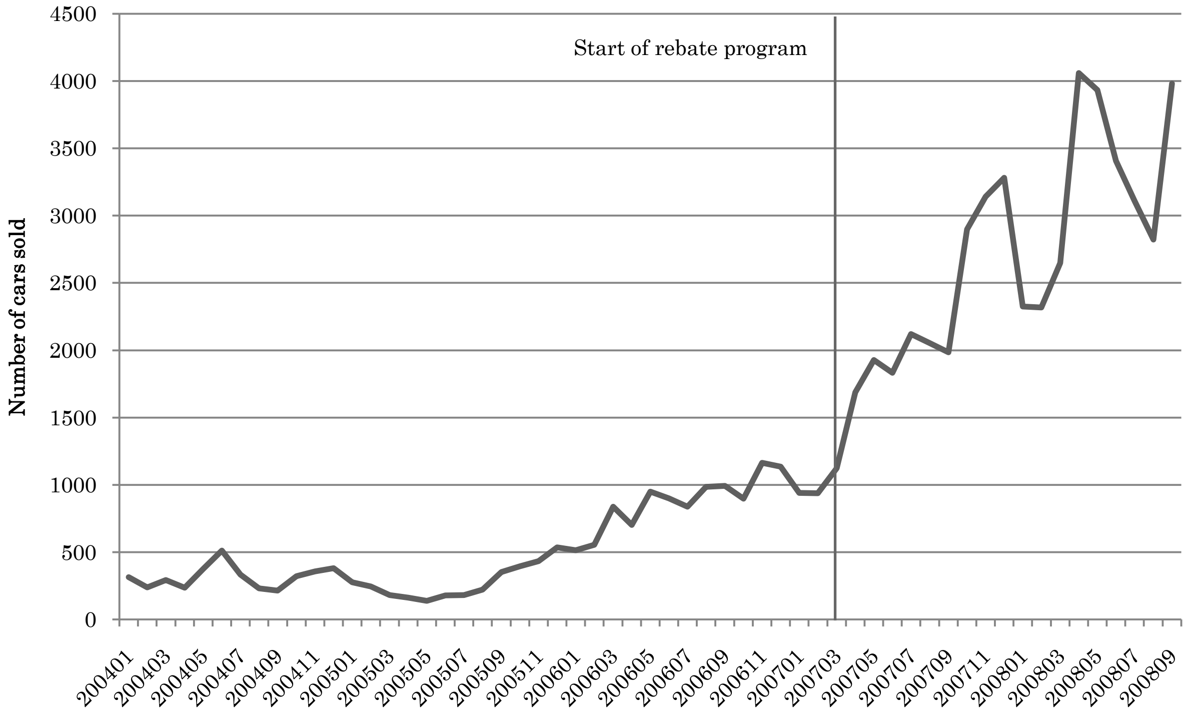

Figure 1: Sales of green cars, source: Vroom

The development shows an increasing trend over time starting some time in 2005 and a distinct increase in sales after the introduction of the rebate. We thus expect to find a correlation between the rebate and higher green car sales. Also noticeable is the relationship between fraction offered and fraction sold (see *Figure 2*).[7] The growth rate in market share outshines the growth rate in supplied share by far and it is remarkable that green cars constitute only 6 percent of the listed models in 2008 but 41 percent of all cars registered in September 2008.

The increasing gap between the fraction of green car models offered and the fraction of greens cars sold indicates that the market shares have concentrated, i.e. the market shares of green cars have increased on average.

[7] The supply is expressed in number of car models. The definition of car model used in this thesis is a certain model of a certain brand with a certain fuel type, e.g. a Volvo V70 diesel. We do however not treat two Volvo V70 diesels with different engine power or transmission as different models.

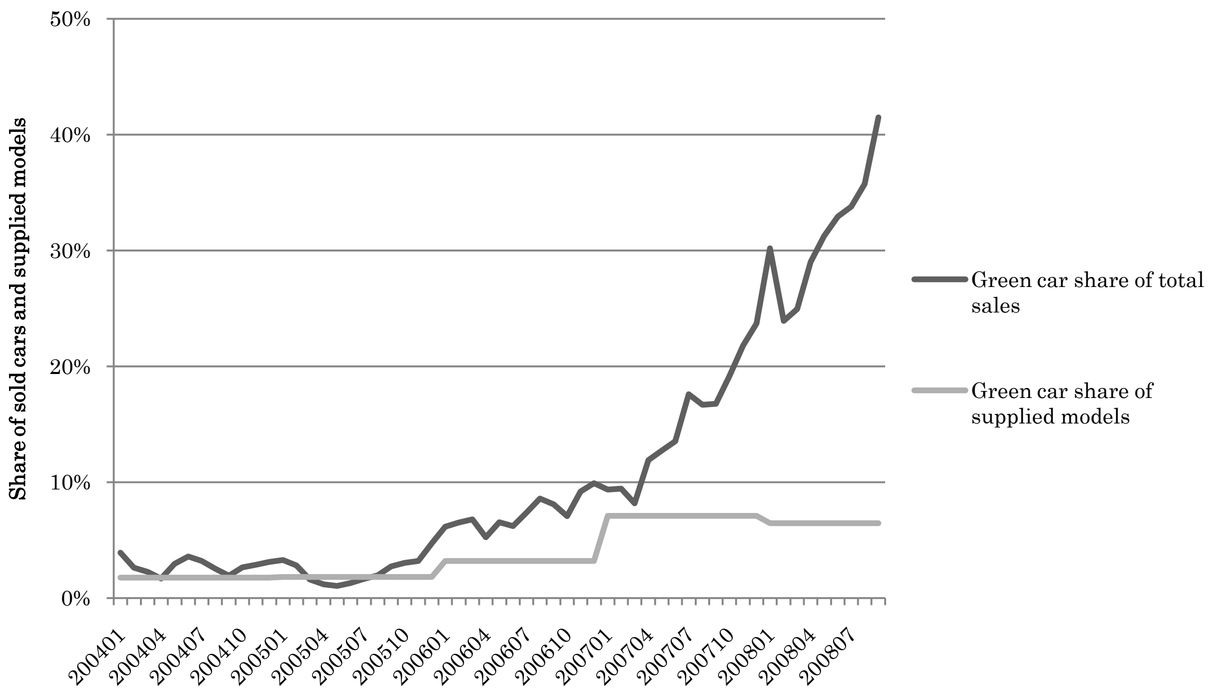

Figure 2: Share of green cars sold and share green cars supplied (models), source: Vroom and The Swedish Consumer Agency

If current policies are believed to have a large effect on the choice of car type for consumers, then these will also determine the direction of the supply and the focus of the pipeline. Since it is an industry with quite long development timelines that require large investments, the policies applied to the industry's market need to be long term in order to allow for a sufficient adjustment time. This can explain the frustration expressed by some companies when the rebate program was announced to be shortened. The frustration can be interpreted as a sign of the industry's, or at least parts of it, belief in the rebate as a driver of green car sales and of an adjustment of the model portfolio to accommodate demand preferences[8]. From 2004 to 2008, the number of green car models offered increases from 33 to 127. This development is illustrated in *Figure 3*.

[8] The frustration could also be a sign of the belief that the rebate has had a positive effect on the industry as a whole. A possible link between total sales and the rebate is examined in *Appendix A.2*.

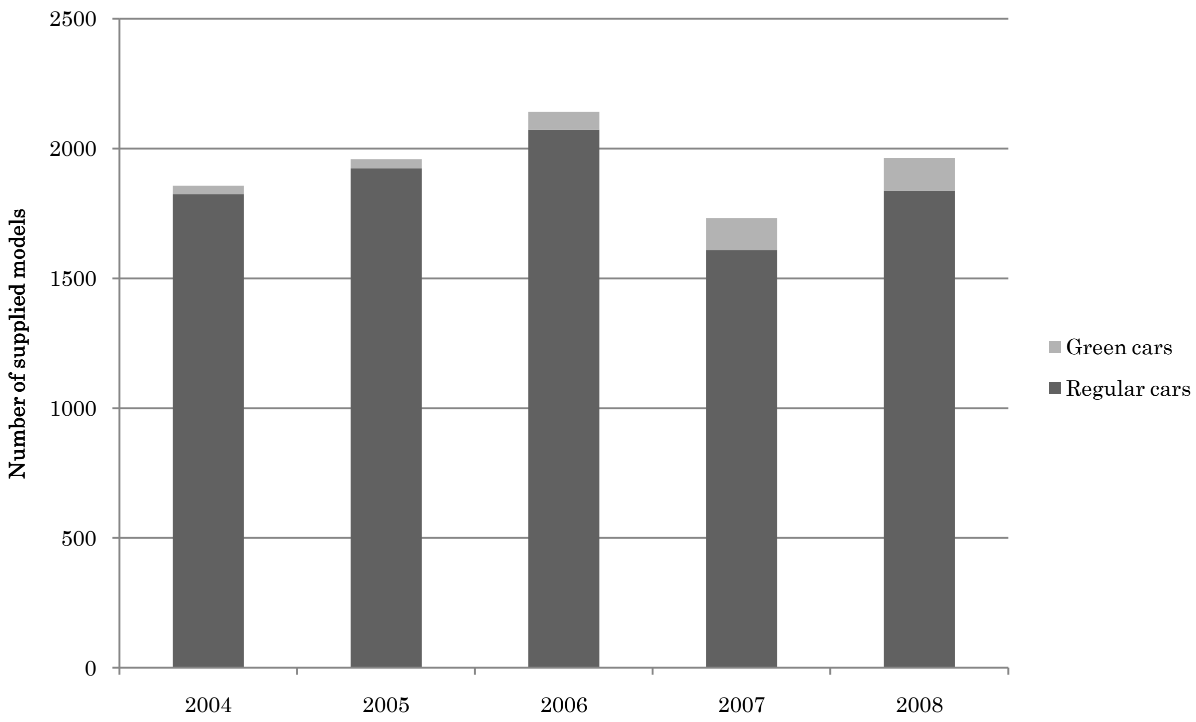

Figure 3: Supply of green car models as part of total supply, source: The Swedish Consumer Agency

Although not in the same magnitude as for sales, there is a clear upward trend in the number of green car models offered. This implies that the gap between supply and sales when examining the fraction of green cars might not be that serious but that the industry is heading in the same direction as the market. In fact, the introduction of the rebate does not seem to have shifted the positions of the largest players on the Swedish market. *Figure 4* and *Figure 5* depict the market shares for these players and their sales of green cars relative to total sales for 2004 and 2008 respectively. The graphs show that the major players are more or less the same in 2008 as in 2004. Since 2004 these players have significantly increased the share of green cars in their sales, proportional to the demand of the Swedish market.

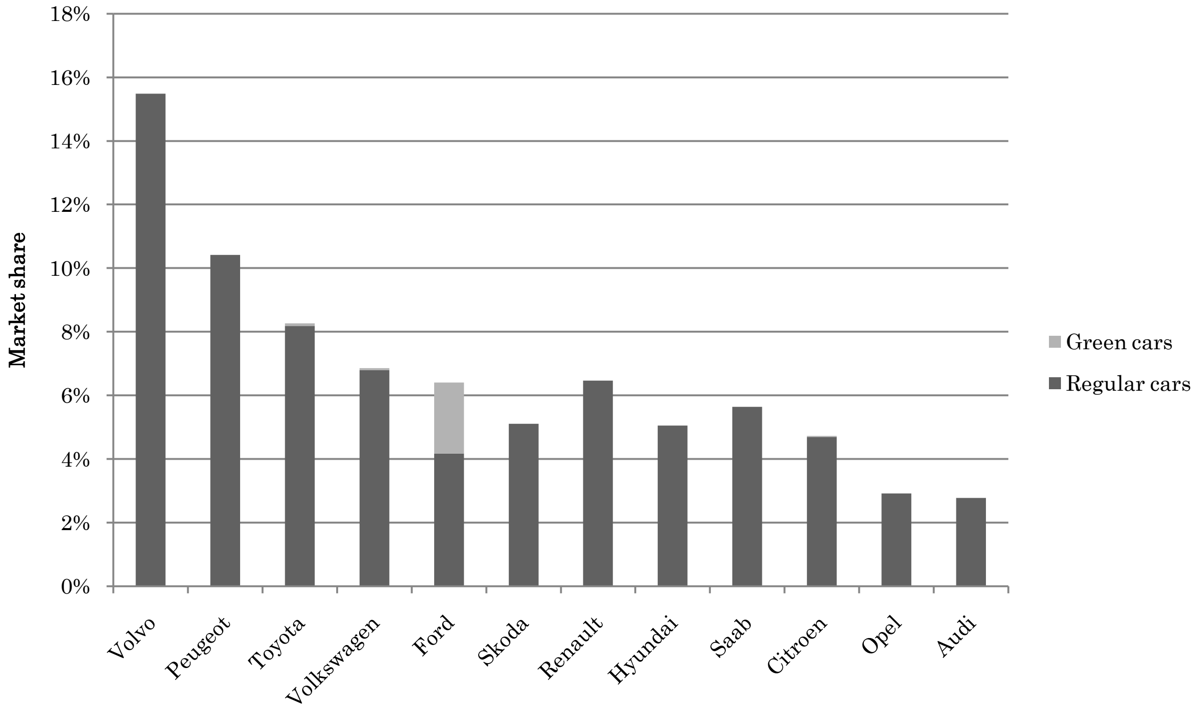

Figure 4: Brand market shares divided into green and regular cars, 2004, source: Vroom and The Swedish Consumer Agency

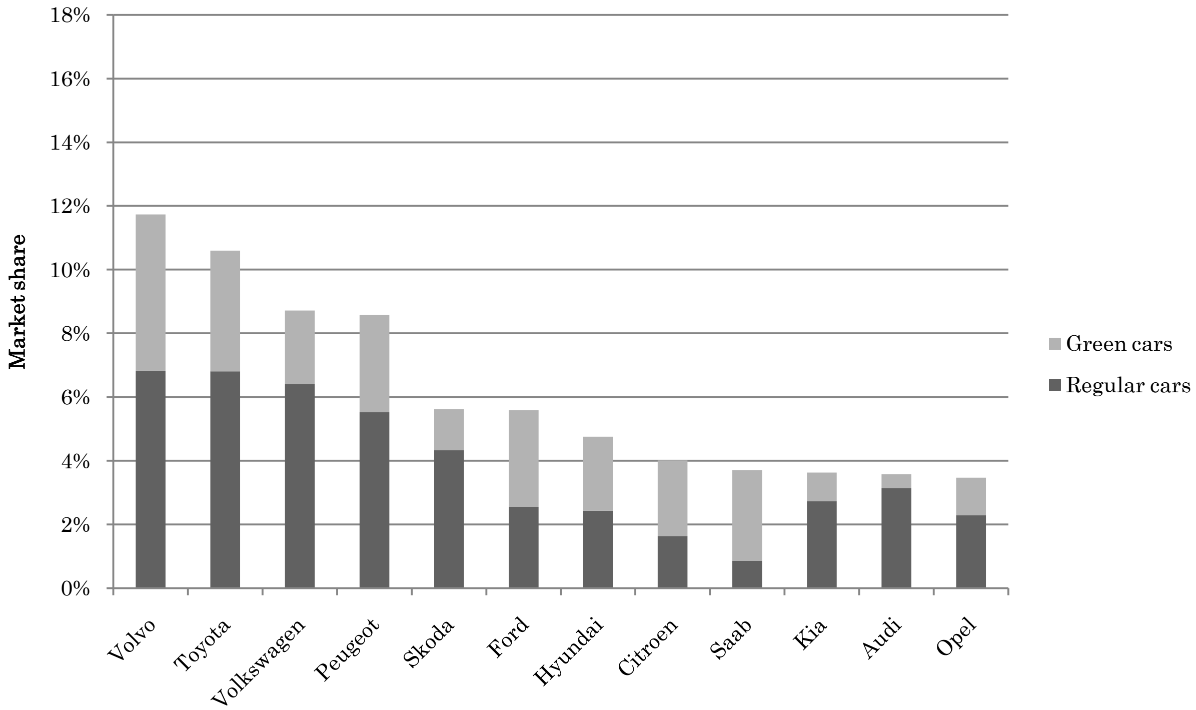

Figure 5: Brand market shares divided into green and regular cars, 2008, source: Vroom and The Swedish Consumer Agency

Continuing with the comparison of supply and sales, the development is actually rather similar if we study the supply and sales of green cars in absolute numbers as opposed to relative shares; supply and sales do in fact develop rather proportionally (*Figures 6 and 7*). Examining the numbers divided by fuel types, we find that the shares of the fuel types differ in size both concerning sales as well as supply. It is visible that there is a lack of certitude regarding which technology that will be the future of green cars.[9]

Ethanol is the dominant fuel type with a share of more than 50 percent of green car sales in 2008. Low emission gasoline and diesel follow with 25 percent and 21 percent respectively, whereas the sales of the two remaining alternative fuel cars, electric hybrids and gas cars, are marginal. We thus suspect the rebate to foremost have increased the market shares of low emission gasoline and diesel cars together with ethanol cars. We see an equal pattern for the number of supplied models as for market shares, with only a few gas and electric models.

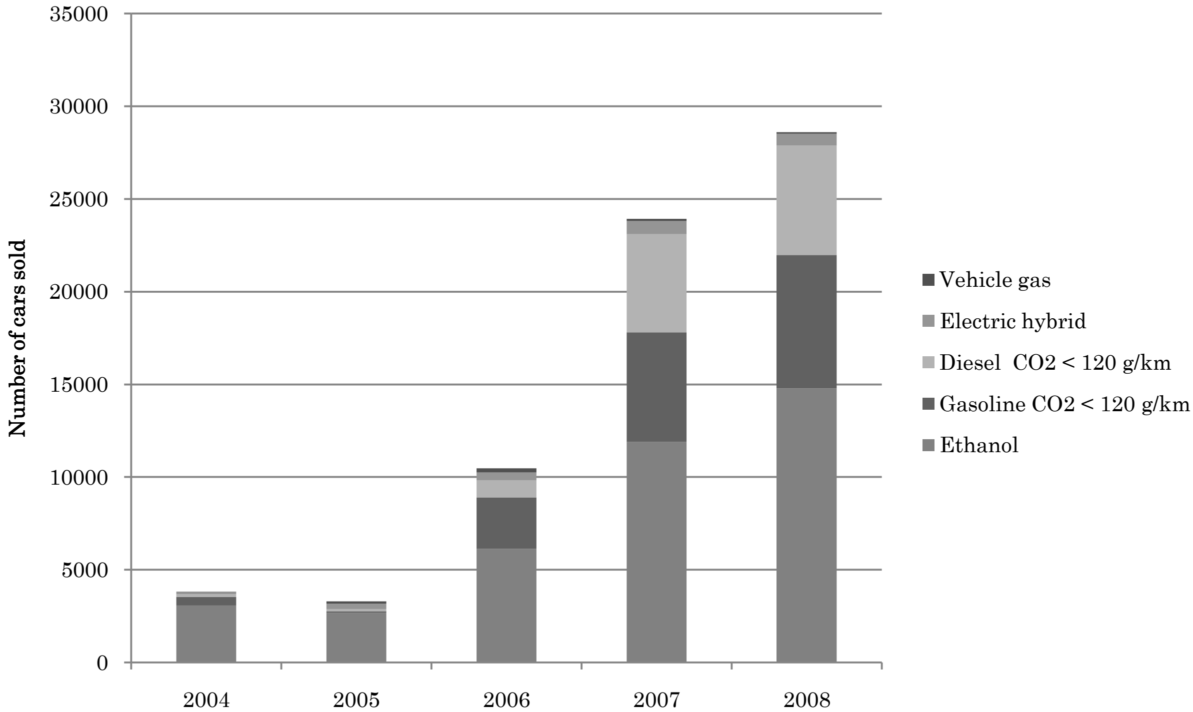

Figure 6: Sales of green cars divided by fuel type, 2004-2008[10], source: Vroom

[9] Many of the technologies occurring in current speculations, e.g. hydrogen and electric cars, do not appear in our sales data since the products were not available at the time.
[10] From here on sales numbers for 2008 refer to the period January to September only.

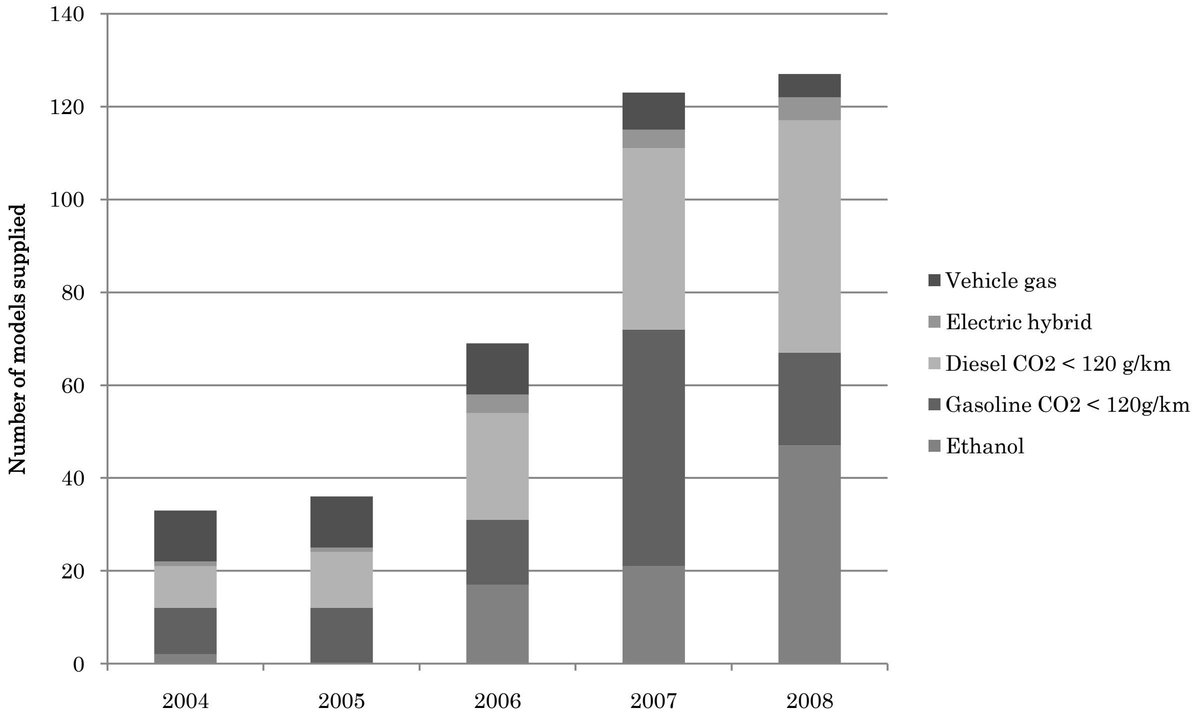

Figure 7: Supply of green car models divided by fuel type.[11]
Source: The Swedish Consumer Agency

The largest range of green car models offered are found among ethanol and diesel cars. Except for the relatively small range of green gasoline models we find a close match between model offering and sales for 2008. This could be interpreted as if the car producers have been able to successfully foresee the demand for different green cars. On the other hand is it possible that the causality is reversed, i.e. the number of models affects the market shares, or that there is actually double causality. We return to this in the section treating previous literature.

2.4. Alternative fuel cars

To better understand possible reasons for the difference in market shares, in particular between the different alternative fuel types, we continue by providing a background to the alternative fuels and the different circumstances that they face.

The supply of alternative fuels varies over the country. The pump law states that, from the 1st of January 2006, all gas stations with sales exceeding a certain limit are by law required to offer at least one environmental fuel for sale (SFS, 2005). This law has been criticized, by The Liberal Party of Sweden among others, for causing a close down of

[11] Information on the number of ethanol models for 2005 is missing.

smaller gas stations across the country who cannot afford to install a pump for environmental fuel that potentially no customers will purchase. Since an ethanol pump is the cheapest option among the alternative fuels, the law is also accused of causing a skew towards ethanol in the supply of environmental fuels across the country at the expense of mainly vehicle gas. This could be one plausible explanation for the observed skew towards ethanol cars in both supply and sales.

The most widespread alternative fuel cars are the ethanol cars. The ones sold in Sweden are flex fuel cars built to run on both gasoline and ethanol or a mixture of the two fuels. This allows ethanol car owners to arbitrage between the fuels taking into account the price levels of the two fuel types as well as the different energy levels.[12] Since a few years back ethanol is readily available across the country, much due to the pump law. We therefore expect that part of the increase in the sales of ethanol cars could be related to the law rather than the rebate.

The ethanol sold at gas stations in Sweden is called E85 and is a mixture of 85 percent ethanol and 15 percent gasoline in which the gasoline works as a lubricant and makes the engine start easier. During the winter the mixture is actually closer to 25 percent gasoline to avoid start-up problems at low temperatures. The switch by all gas stations to "winter quality" in 2008 took place on 1 November and at the same time the price was increased by 0.90 SEK/l to compensate for the higher degree of gasoline (gasoline and ethanol prices 2004-2008 are depicted in *Figure 8*). According to the Swedish Energy Agency, the fact that ethanol prices were higher than gasoline prices during November and December 2008 lead to a drastic decrease in ethanol sales. This is illustrated in *Figure 9.*

The price of an ethanol car is on average slightly higher than for a comparable gasoline or diesel model but the second hand value is equal to that of a comparable gasoline model. The initial higher price is normally compensated by cheaper fuel costs, but as noted above this is not always the case during the winter.

[12] According to the Swedish Environmental Protection Agency (2008), one liter of ethanol contains about 26% less energy than one liter of gasoline.

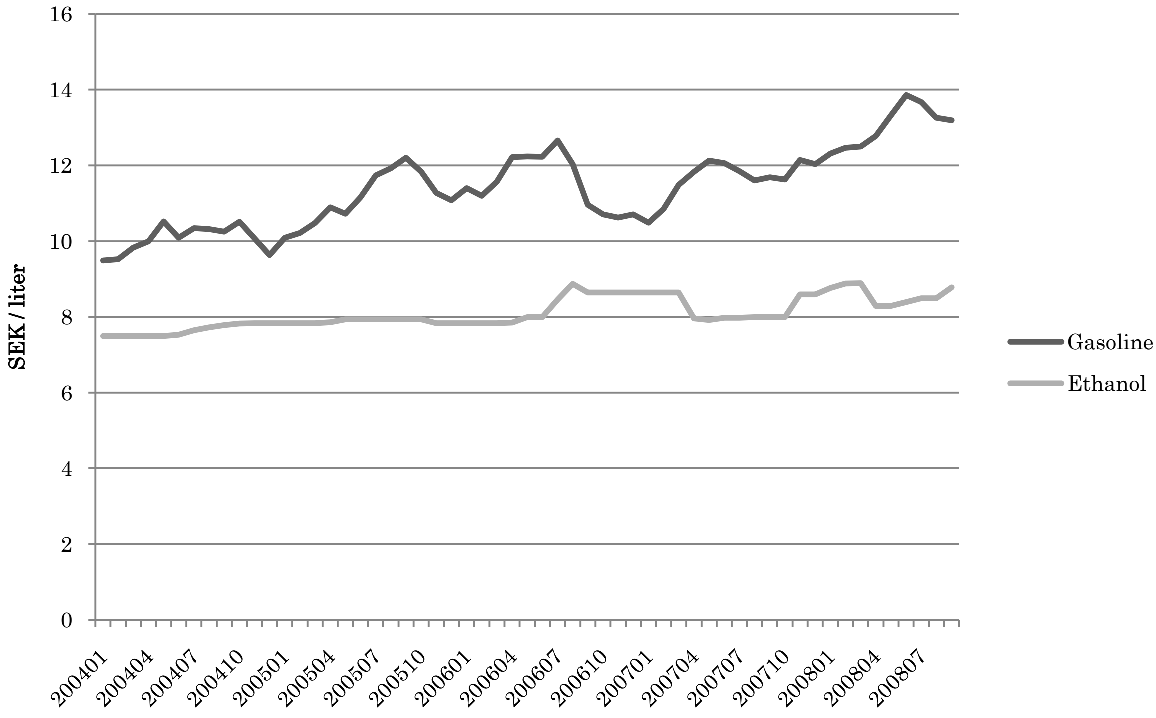

Figure 8: Gasoline and ethanol prices January 2004 to September 2008, source: OKQ8

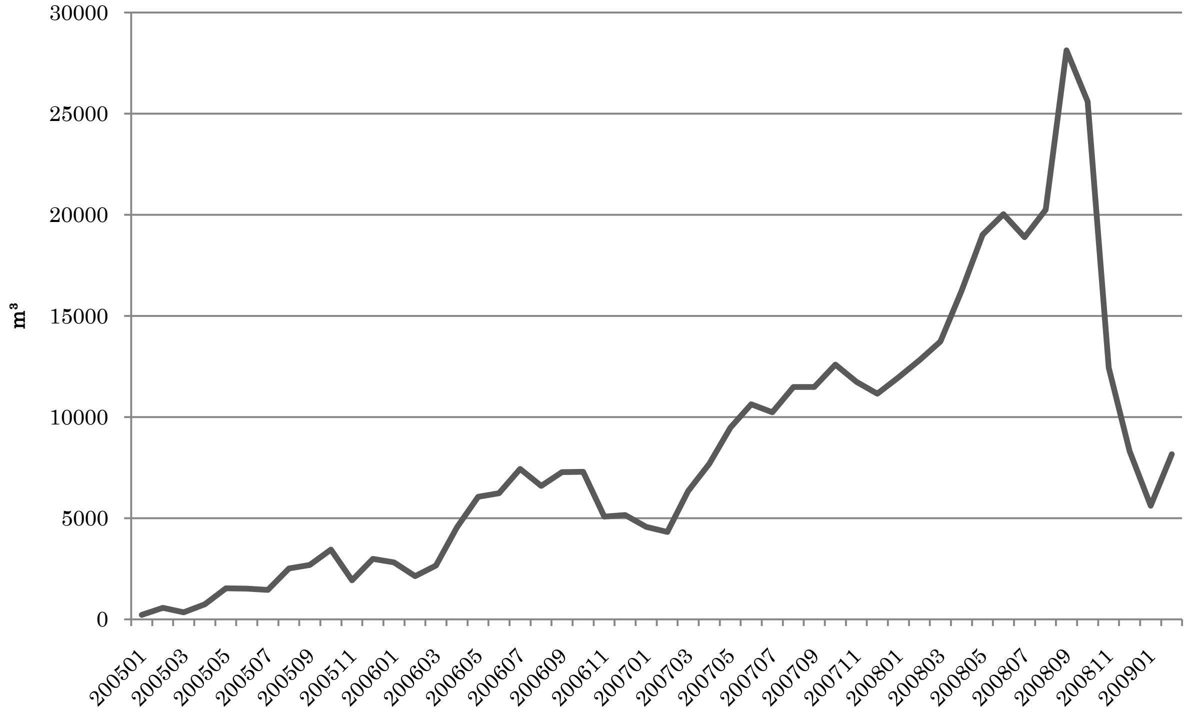

Figure 9: Monthly E85 volumes (delivered m³), source: Swedish Petroleum Institute (2009b)

The possibility to switch between gasoline and ethanol might be another reason to why ethanol cars are the most common alternatively fuelled cars, as these allow you to use conventional fuel and thus might reduce the level of perceived risk in choosing an alternatively fuelled car. *Figure 10* illustrates a comparison of the fuel economy for a *Ford Focus Flex-fuel 2004* depending on the choice of fuel type.

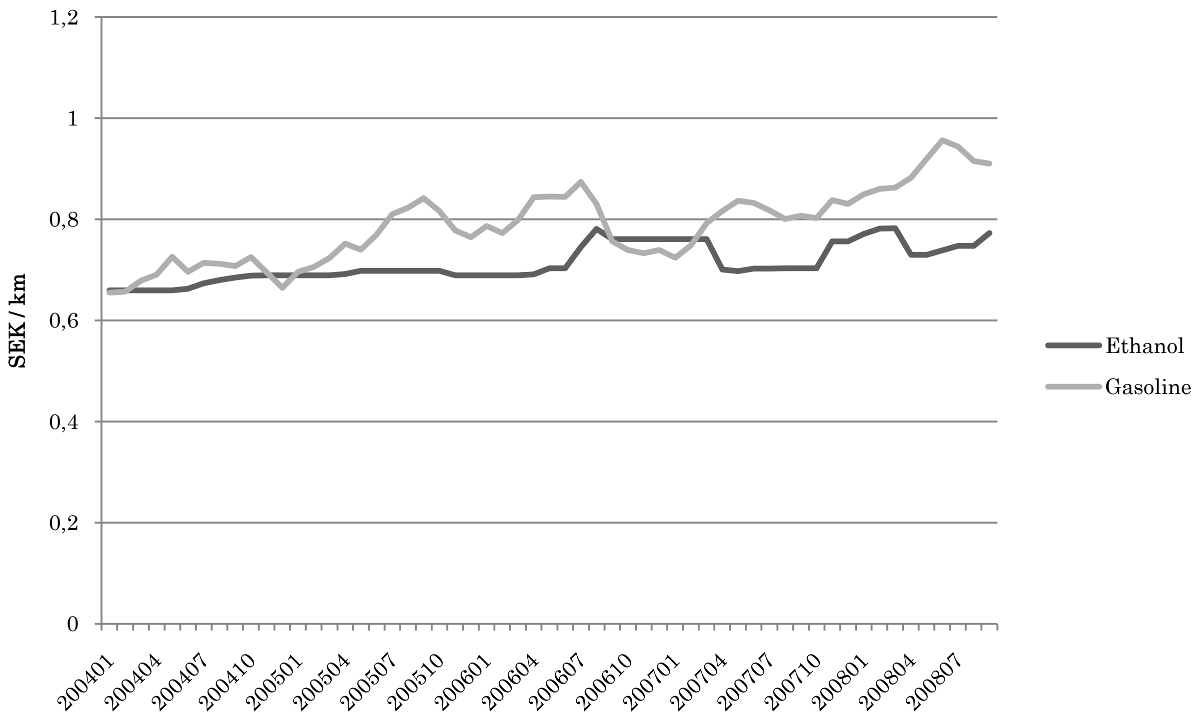

Figure 10: Fuel economy 2004-2008 in SEK/km for a Ford Focus Flex-fuel 2004 (Ethanol hybrid) depending on the choice of gasoline or ethanol, source: The Swedish Consumer Agency and OKQ8

The electric cars available in Sweden today are electric hybrid cars that all have one engine running on gasoline, one or more electric engines and a battery that allows the car to recycle energy when braking, thus reducing the fuel consumption. The gasoline engine automatically shuts off when the car stands still and thus the electric hybrid cars are most suitable for city traffic where the car frequently stops and starts. Prices are higher than for comparable gasoline or diesel models, but fuel costs are lower and the second hand value is equal to that of a comparable gasoline model. Electric hybrid vehicles purchased before 1 October 2006 are also exempt from vehicle tax for five years (The Swedish Tax Agency, 2009).

The third of the common alternative fuel cars is the gas car. It runs on vehicle gas, which is a term used for both biogas and fossil gas. A gas car is able to run on both types of gas, but if you consider the whole production process, biogas causes significantly less CO2 emissions. On the other hand the energy level of fossil gas is somewhat higher. All gas cars on the Swedish market use gasoline for start up and then switch to run on gas. Some models have larger gasoline tanks and thus are able to run on both gas and gasoline. The price of a gas car is higher than for a comparable gasoline or diesel model, but the fuel costs are significantly lower and the second hand value is equal to that of a comparable gasoline model.

The supply of vehicle gas is limited to certain regions in Sweden (see *Figure 11*) and the available gas type also depends on region. Biogas is mainly available in the Stockholm region whereas you find fossil gas in the south west of Sweden. The so far limited supply of vehicle gas naturally causes the use of gas cars to be limited mainly to the south of Sweden (see *Table 3*).

Figure 11: Vehicle gas stations in Sweden, source: FordonsGas

Norrland		**Götaland**	
Gävleborg	1	Blekinge	6
Jämtland	4	Gotland	2
Västerbotten	1	Halland	20
Västernorrland	1	Jönköping	8
		Kalmar	5
Svealand		Kronoberg	1
Stockholm	259	Skåne	58
Södermanland	5	Västra Götaland	163
Uppsala	3	Östergötland	32
Västmanland	5		
Örebro	6		

Table 3: Gas cars sold per region 2004-2008, source: Vroom

3. Literature review

With the sales data on a car model level combined with data on car characteristics, we need to specify a suitable econometric model. The automobile industry has long been a popular industry for researchers and we find a broad literature discussing vehicle choice and the importance of observable and unobservable characteristics of cars. We also study a paper considering the link between fuel price and car sales. More closely related to our purpose is a Canadian study on tax rebates for hybrid electric vehicles. In addition, we also look at a Swedish study of factors inducing purchases of green cars.

3.1. Vehicle choice

Train and Winston (2007, hereafter TW) examine the vehicle choice of consumers in the light of declining market shares for U.S. car manufacturers. They use consumer level data on car purchases, including both consumer attributes as well as vehicle attributes.

They consider unobserved taste variation, but take in regard that this might affect not only which new car consumers choose, but also that they choose a new car. TW consider the modeling of all other alternatives as an outside good as done in Berry, Levinsohn and Pakes (1995, hereafter BLP) to be problematic since no characteristics can be attributed to this group while they are still likely to affect the choice. Therefore, they study vehicle choice conditional of having bought a vehicle. This is done by examining the distribution of preferences on a sample of new car buyers by a customized survey. This is possible since their interest lies in the market shares and they therefore do not need to account for the changing market size.

TW find that the loss in market share of the US automobile industry can be almost entirely explained by relative changes in basic attributes; price, size, power, operating cost, transmission type, reliability and body type. This finding indicates that the concerns regarding unobserved characteristics are overrated since their effect on consumer choice is trivial.

3.2. Gasoline prices and car sales

In their paper *Pain at the Pump: how gasoline prices affect automobile purchasing* Busse, Knittel and Zettelmayer (2008, hereafter BKZ), examine the effect of policies aimed at increasing gasoline prices. Using consumer level data on individual new car transactions and monthly ZIP code level data on gasoline prices, they examine the effect of fuel prices on four aspects of the US automobile market: market shares, new car prices, trade-in utilization and new car inventories.

Beyond using gasoline price as a regressor, their model also considers demographic variables, purchase timing and seasonal preferences. Fixed effects are used to capture the individual effects of different car types based on characteristics like model, model year, make, trim level, doors, body type, displacement, cylinders and transmission.

BKZ assign all observations into segments depending on model (compacts, midsize, luxury, sport cars, SUVs, pickups and vans) and into quartiles depending on fuel efficiency, defined as miles per gallon (MPG), and analyze the findings per MPG quartile and segment. They find a positive correlation between gasoline prices and the sales of fuel efficient cars and smaller cars. They find negative correlation for sales of fuel inefficient cars and larger cars.

The data used by BKZ differs from ours in that they have ZIP code level and data on individual purchases, thus knowing both exact product characteristics and, more importantly, consumer characteristics.

3.3. Hybrid car rebate

More closely related to our topic is a paper by Chandra, Gulati and Kandlikar (2009, hereafter CGK), where they study the effect of Canadian tax rebates for hybrid electric vehicles (HEV's). They use sales data on the market level combined with rebate data for the different provinces. Their initial model is a multinomial logit, but having found that the total car sales are not only unaffected by the rebates but also constant over time, they exclude the outside good from the specification ending up with a model that only accounts for substitution within sales.

They find that the rebates increased the market shares of HEV's at the expense of other models. As an attempt by the government to reduce CO2 emissions, CGK however find the program to be much more expensive compared to the option of simply buying CO2 credits at a climate exchange.

3.4. Green car adaptation

In a report with the title Promoting Clean Cars, produced within the project Bioethanol for Sustainable Transport (BEST, 2009), the factors influencing the adaptation of green cars in the Stockholm region are studied. The study finds that the will to reduce the environmental impact is the strongest reason for households choosing an alternatively fuelled car or a low emission gasoline or diesel car. All factors, in order of preference, are presented in *Table 4*.

	Alternative fuel car owners	Conventional green car owners
Will to reduce one's own negative impact on the environment	4.5	4.5
Lower driving costs for clean cars	3.8	4.5
No congestion tax for clean cars	3.8	3
Expectations of higher price for gasoline and diesel	3.4	3.9
Green car rebate	3.1	3.9
Free residential parking	3	3.3
Other	2.8	3
Trendy	2	2

Table 4: Survey results on factors influencing the choice of a green car. Factors rated on a scale 1-5, source: BEST (2009)

The results from the survey give an indication on other factors that are important to account for when estimating the effect of the rebate on the sales of green cars. Even though there are no large deviations in the results between alternative fuel cars and conventional green cars, we see an indication of a stronger interest in the economic incentives from the conventional green car owners. This fact supports the relevance of estimating the effect of the rebate separately for different fuel types. It is also interesting, as the authors of the study point out, to note that the congestion tax exemption has induced purchases of conventional green cars even though these are not exempted from the tax. The authors relate this result to the discussion on whether to include the conventional green cars in the exemption and an expectation among some consumers here for.

The quantitative study in the report uses monthly sales data for Stockholm from October 2004 to October 2008 on a fuel type level (also distinguishing conventional green cars from regular gasoline and diesel) and includes cars purchased by both natural and juridical persons. Since the study is focused on Stockholm the main results concern the impact of the congestion tax, which is found to be positive on the overall sales of green cars. The authors estimate the increase in sales for 2008 to 23 percent.

The impact of the rebate is found to be largest on the sales of conventional green cars with the end of the rebate expected to cause a 10 percent decrease in sales. No numbers for the impact on alternative fuel cars are presented, only a statement that the effect is smaller than for conventional green cars.

The study regresses the sales data on the following explanatory variables: ratio of gasoline price over E85 price, number of petrol stations, number of supplied car models and dummies for free parking, congestion tax exemption and rebate. The number of petrol stations, number of supplied car models and the free parking dummy were all found to be non-significant. In our study, we choose to exclude fuel availability, model supply and parking fee exemptions since it has proven difficult to obtain the data on a desired detail level. The results from BEST regarding the insignificance of these variables do however suggest the negative influence on our estimations to be limited.

4. Data

In our study, we combine different types of data. Firstly, our main data is a set of market level sales data, by car model and fuel type for the period Jan 2004 to Sep 2008 on a monthly basis divided by regions (sv. län). With 21 regions and a period of 57 months, we end up with a total of 1,197 markets. We observe the number of units sold of a certain model in each market. This data comes from a consulting firm focused on the automobile market, *Vroom*.

Secondly, we add attributes of the different car models. These are gathered from the consumer guides *Nybilsguiden 2004-2008* produced by *The Swedish Consumer Agency*. The data contains car characteristics, price and vehicle tax on a yearly basis for the different models. The characteristics we initially choose to include in our data set are: price, vehicle tax, fuel consumption, CO2-emissions, kerb weight, doors, cylinders, cylinder volume and engine power. Since the numbers for fuel consumption are not comparable between cars of different fuel types, we compute a variable for fuel economy, km/SEK, combining fuel consumption with fuel prices.

Thirdly, we retrieve recommended fuel prices for gasoline, diesel and E85 on a monthly basis from the largest provider of motor fuels in Sweden, *OKQ8* (The Swedish Petroleum Institute, 2009a). The gasoline companies do not provide actual prices which would naturally vary by region and even by station, and would probably have given us better estimates for the effect of fuel price on car sales. We obtain recommended gas prices from *FordonsGas*, also on a monthly basis. The prices are valid for a mix of biogas and fossil gas.

Finally, we acquire data on yearly average distances covered by Swedish passenger cars, divided by brand and fuel type. This data comes from the *Swedish Motor Vehicle Inspection Company*. In addition we will also use average distances based on weight from *Statistics Sweden*, since it is uncertain whether brand and fuel type or weight has the most influence on the distances covered.

To make the vehicle tax, car and fuel prices comparable over time we deflate them using Consumer Price Index from *Statistics Sweden*. For car prices and vehicle tax we use the yearly average with 2004 as base year and for fuel price the monthly average with January 2004 as base month.

For more detailed explications of the adjustments of the data, please see *Appendix A.4*.

5. Method

5.1. Background

In order to estimate the demand for different car models, we need to define a suitable econometric model. Firstly, to make the model consistent with both economic theory and empirical data we are looking to define a structural economic model. Economic theory allows the dependent variable to be related to unobserved product characteristics (Reiss Wolak, 2005), which is often the case in differentiated product markets. There will always exist more product characteristics relevant to consumers than can be observed by an econometrician or characteristics, such as style, that are simply impossible to quantify and we will therefore not be able to capture all demand factors determining car sales.

Secondly, we want our demand model to be discrete since there is no rationale in a consumer purchasing fractions of a car. Non-continuous models are normally modeled using the cumulative distribution function and the most common model is called the logit (Gujarati, 2003). We have decided to follow a method developed by Steven Berry (1994) that allows you to estimate the logit using a standard instrumental variables regression while still allowing for unobserved characteristics.

As our dependent variable we will not use the actual numbers of cars sold but rather the market share of each car model. In our model, market is restricted by both time and region – every region in each month is defined as one market.

5.2. Model definition

We will study the demand of individual consumers rather than the demand of households, a choice further developed in the section covering the market. In Berry's approach demand is estimated using a utility function. This means that in our model every person in a market will choose to purchase the car that maximizes the person's utility.

In our model we have R regions and T time periods, giving us $R*T$ markets with $N_{r,t}$ firms in each market, each firm selling one product[13]. The product j in market rt is a certain model of a certain fuel type by a certain car brand. The firms are modeled as price-setting oligopolists, meaning that firms will face a steeper demand curve than would be the case in a market with perfect competition where the consumers are more sensitive to price changes.

The econometrician is not able to observe all characteristics or any decisions of individual consumers, but has a complete view of prices and quantities sold by each firm. The individuals forming the market are modeled to buy exactly one product each, basing their choice on product characteristics. This product is either one sold by one of the firms $j = 1, \dots, J$ or the outside good, $j = 0$. The outside good is the alternative to the J products sold by the firms and its price is not correlated with the price of the "inside" goods. In our study the outside good constitutes the option to buy a used car or to not buy a car at all.

The observed characteristics, including price, that affect the demand are denoted by z_j and the unobserved by ξ_j. Characteristics of all products in a market are included in the vectors $z = (z_1, \dots, z_N)$ and $\xi = (\xi_1, \dots, \xi_N)$ respectively. Despite being a much simplifying assumption, these are assumed to be exogenous to the firms pricing decisions.

An individual has a utility for product j depending on the characteristics of both the product and the consumer: $U(z_j, \xi_j, v_i, \theta_d)$ where θ_d are demand parameters. In Berry's example the utility of consumer i for product j is given by:

$$u_{ij} = \beta z_j + \xi_j + v_{ij}, \tag{1}$$

[13] The subscript r,t will from here on often be left out to facilitate the reading.

where v_{ij} is a mean-zero, possibly heteroskedastic error that captures the effects of the consumers' random taste parameters. Thus the mean utility level of a product j can be denoted as:

$$\boldsymbol{\delta_j \equiv \beta z_j + \xi_j}. \tag{2}$$

Since we only have market level data and no data on the individuals and their preferences we will estimate the market shares of the firms based solely on their respective mean utilities (defined as above) with the unobserved characteristics alone constituting the error term.

The market share function is defined using the multinomial logit model:

$$\varsigma_j(\delta) = e^{\delta_j} \Big/ \sum_{k=o}^{N} e^{\delta_k} \tag{3}$$

If the mean utility of the outside good is normalized to zero we can compute the mean utility of a product based on observed market shares as

$$\boldsymbol{\delta_j = \ln(s_j) - \ln(s_o)}, \tag{4}$$

where $\boldsymbol{s_j}$ is the market share of firm *j* and $\boldsymbol{s_o}$ the market share of the outside good. Our complete model specification would thus be:

$$\boldsymbol{\ln\left(\frac{s_j}{s_0}\right) = \alpha + \beta z_j + \xi_j} \tag{5}$$

5.3 Variables

More specifically we estimate

$$\boldsymbol{\ln\left(\frac{s_j}{s_0}\right) = \alpha + \varphi GCR_j + \beta x_j + \gamma_j + \xi_j} \tag{6}$$

where $\boldsymbol{GCR}$ represents the rebate dummy, $\boldsymbol{x}$ contains the price, the different product characteristics, fuel economy and dummies for congestion tax relief and electric hybrid vehicle tax relief and $\boldsymbol{\gamma}$ contains the different fixed effects. We find it important to include the fuel prices in order to account for the effects found by BKZ (2008). Since we have cars running on four different fuels, we cannot use fuel consumption in itself as a variable since it would not be comparable between different fuel types. We therefore choose to include the variable fuel economy, expressed as $\frac{1}{fuel\ consumption\ \ \times fuel\ price}$ with the unit km/SEK, which also accounts for the current fuel price.

We include different combinations of fixed effects. Regional fixed effects are included to consider regional differences both concerning observables like fuel supply as well as unobservables like taste. Time dummies are included to capture time specific events that might affect the outcome. Brand dummies capture unobservable preferences for certain brands not related to the included car characteristics. The final set of fixed effects included is fuel type fixed effects. These are to capture differences between the fuel types, e.g. their market sizes.

The rebate dummy is set to 1 for all green cars from April 2007 and onwards and the dummy for congestion tax is set to 1 for all alternative fuel cars in the region of Stockholm for the period January to July 2006 and from August 2007 and onwards. The dummy for the hybrid vehicle tax relief is set to 1 for all electric hybrid cars from January 2004 until October 1st 2006 when the relief was disposed. All cars with a price higher than SEK 400,000 are considered as outliers and are thus dropped. To obtain more convenient coefficients, prices are divided by 1000.

5.4. Market

To go from observed quantities to observed market shares we need to define the size of the relevant market, $M_{r,t}$. This number can either be estimated or defined as a certain population. The quantity of a firm j is then

$$q_j = M\varsigma_j(x, \xi, p, \theta_d). \tag{7}$$

The ideal way to obtain the numbers for the potential market would be by estimating them. However, the required information, such as GDP and CPI, is hard to obtain on a monthly and regional basis rendering the use of the model highly insecure. Based on this we choose not to model the market but to find a set of actual figures based on certain criteria. There are different ways of defining the size of the market by using actual figures. In BLP (1995), the total number of households constitutes the potential market. According to Reiss Wolak (2005), this definition has some shortcomings. Not all households can afford a new car and other entities than households can purchase cars. Since we only examine car sales to natural persons, only the former poses a possible problem. It is not realistic that all households can afford to purchase a new car, therefore this would be an overestimation of the market. It is however difficult to find data on the number of Swedish households divided by income. Therefore we define the market as the number of individuals in a region of or above the age of 20 with a yearly income of SEK 200,000 or more. These are the potential purchasers of a new car. It is however unlikely that they can consider buying a new car each month. We therefore assume that consumers generally consider buying a new car every fifth year, thereby dividing our numbers by 60.

The market share of the outside good for each market is calculated as the residual, i.e. one minus the sum of the shares of all other products in the market.

5.5. Instrumental variables

When firms are modeled as price setting oligopolists it is often the case that the unobserved characteristics are correlated with price, since the firms can adjust their prices as a response to observed demand. In that case, choosing to ignore the endogeneity of prices has previously been proven to lead to anomalies such as upward sloping demand curves (Trajtenberg, 1989). Since our data consists of list prices rather than actual reselling prices and we only have these prices on a yearly basis, we might not face the problem of firms adjusting price. But in addition to the regular OLS we will nonetheless estimate the demand using a set of instrumental variables. With the method commonly referred to as a instrumental variables regression (IVREG) the problem of endogeneity among the independent variables is solved by choosing a set of instrumental variables that are correlated with the endogenous variable, often the price, but uncorrelated with the unobserved product characteristics. The method we use is called two-stage least squares (2SLS) and is performed in two stages, with the first stage regression being an estimation with price as the dependent variable. The second stage regression is then the same procedure as a regular OLS but with the price variable replaced by the fitted values from the first stage regression.

First stage regression:

$$\boldsymbol{p_j = \Pi_0 + \Pi_1 Instruments + \Pi_2 GCR_j + \Pi_3 x_j' + \gamma_j + u_j} \qquad (8)$$

with $\boldsymbol{p}$ being price, $\boldsymbol{GCR}$ the rebate dummy, $\boldsymbol{x'}$ containing the different product characteristics, fuel economy and dummies for congestion tax relief and electric hybrid vehicle tax relief and $\boldsymbol{\gamma}$ containing the different fixed effects.

Second stage regression:

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \hat{p}_j + \varphi GCR_j + \beta x_j' + \gamma_j + \xi_j \tag{9}$$

In order to find the most suitable instrumental variables for our model we try using different sets of instruments as suggested by BLP (1995), namely including three instruments for every exogenous car characteristic used as regressor; BLP use the characteristic itself, the sum of the characteristic across all own-firm products and finally the sum of the characteristic across competitors' products.[14] Except for the two above mentioned criteria for instrumental variables we also want the price elasticity to be negative, since an increase in price should have a negative impact on demand, and larger than 1, since the demand should be elastic.[15]

5.6. Nested logit

A shortcoming that we will return to in the discussion session is that this model specification results in unrealistic cross-price elasticities. A common way to address this problem is to use a nested logit. The idea of the nested logit is that all cars are divided into different classes and that the market share within the own class is added to the model as an explanatory variable. We divide all cars into four different classes (quartiles), based on engine power. The estimating equation for the nested logit is specified as

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \varphi GCR + \vartheta \ln s_{jc} + \beta x_j + \gamma + \xi_j \tag{10}$$

where s_{jc} is the market share of a firm within its class in a given month and region. For the nested logit to be regarded as an improvement over previous specifications the nest coefficient ϑ must fall in the range 0 to 1 and be significantly different from both 1 and 0.

5.7. Further specifications

5.7.1. Adjusted price

In addition to the above estimations we also model the rebate as a pure price reduction. Under the assumption that only the monetary incentive of the rebate affects customers' purchasing decisions, we remove the rebate dummy from the estimating equation and

[14] Characteristics are summarized within the defined markets only.
[15] The formula $\frac{(p-c)}{p} = \frac{1}{|E|}$, with p as price, c as cost and E as elasticity, and the criteria that the margin should be smaller than the price, $p - c < p$, gives us $|E| > 1$.

replace the price variable by adjusted price where the list price is reduced by SEK 10,000 for affected models during the period of the rebate;

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \vartheta \ln s_{jc} + \beta x_j^* + \gamma + \xi_j \tag{11}$$

where x^* contains the attributes as earlier and the adjusted price variable.

5.7.2. Regions

By only using one countrywide dummy for the rebate we are not able to capture whether the impact of the rebate varies for different regions. If we instead estimate a specification with one specific rebate dummy for every region, we are able to estimate the regional effects of the rebate;

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \varphi GCR_r + \vartheta \ln s_{jc} + \beta x_j + \gamma + \xi_j. \tag{12}$$

5.7.3. Fuel types

From the graphs in the background segment it has been clear that the market shares of the green cars differ between the different fuel types. To investigate how the rebate has affected the different fuel types we estimate the model with the rebate interacted with relevant fuel types. Interaction is firstly done for the five fuel types *f* separately; i.e. gasoline cars with low emissions, diesel with low emissions, ethanol cars, gas cars and electric hybrids (*Equation 13*), and secondly for the two main groups *g*; i.e. alternative fuel cars and conventional green cars (*Equation 14*).

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \varphi GCR_f + \vartheta \ln s_{jc} + \beta x_j + \gamma + \xi_j. \tag{13}$$

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \varphi GCR_g + \vartheta \ln s_{jc} + \beta x_j + \gamma + \xi_j. \tag{14}$$

5.7.4. Rebate vs. congestion tax exemption

In Stockholm the sales of alternative fuel cars have not only been affected by the rebate but also by the congestion tax that has been widely debated. We therefore chose to take a closer look at Stockholm to find out which one of the two measures that has had the largest impact on the sales of alternative fuel cars. Note that we now only consider the impact on alternative fuel cars, since conventional green cars are not exempt from the congestion tax. This is done using fuel type specific dummies for the rebate as well as the exemption from congestion tax;[16]

$$\ln\left(\frac{s_j}{s_0}\right) = \alpha + \varphi_1 GCR_f + \varphi_2 CT_f + \vartheta \ln s_{jc} + \beta x_j^* + \gamma + \xi_j, \tag{15}$$

where CT_f are the fuel type specific congestion tax dummies and x_j^* are the characteristics as above, without the congestion tax dummy.

We then compare the coefficients for the dummies of the rebate with the coefficients for the congestion tax dummies.

6. Estimation and results

6.1. Results

6.1.1. OLS and Instrumental variables

Selected results from the different specifications (one OLS and three IVREG), based on *Equation 6* and *Equation 9* (three different specifications using different instruments and fixed effects) respectively, are presented in *Table 5*. For complete regression results, see *Appendix A.1*.

The variables we choose to include are: CO2 emission, vehicle tax, engine power divided by kerb weight and fuel economy, fixed effects and dummies for green car rebate, congestion tax and electric hybrid vehicle tax relief. The rest of the characteristics in the data set have been excluded since they have either proven to be insignificant or correlated with the above characteristics. Even though fuel consumption is correlated with CO2 emission, fuel consumption is only included indirectly through fuel economy.

[16] The estimation is done on a national level. When estimating only for the Stockholm area, the correlation between rebate and congestion tax dummies is too high.

Dep. var: $\ln(s_j/s_0)$	**OLS**	**IV 1**	**IV 2**	**IV 3**
Coefficients (p-values)				
Price	-0.0000	-0.0889	0.0220	-0.0366
	(0.781)	(0.000)	(0.000)	(0.000)
Rebate dummy	0.2818	0.4858	-0.0115	0.3657
	(0.000)	(0.000)	(0.621)	(0.000)
Fixed effects				
Fuel type	yes	yes	yes	yes
Region	yes	yes	yes	yes
Brand	yes	yes		yes
Time(year and month)	yes	yes		yes
R^2	0.4338	0.9098	0.9731	0.9725
Instrument		BLP(Fuel economy)	BLP(Engine power/Weight)	BLP(Engine power/Weight)
First-stage reg. F-stat		8,617.80	19,278.46	8,627.42
Price elasticities				
Minimum	-0.01	-35.53	1.75	-14.63
Maximum	-0.00	-7.10	8.78	-2.92
Mean	-0.01	-18.76	4.64	-7.72
Median	-0.01	-18.26	4.51	-7.51

Table 5: Results for OLS and IV 1-3, p-values in parentheses

As expected we find that a regular OLS does not return realistic price elasticities. This is however solved when using instruments to estimate the price. We try different sets of the instruments suggested by BLP (1995), the sum of an attribute across all own-firm products. We find that the sum of the attribute engine power divided by weight gives us the best results taking in mind the explanatory power of the model as well as the price elasticities. Since we only use one instrument the model is exactly identified and we therefore do not report any J-test results. The results from IV 1 to IV 3 also prove it necessary to include all four sets of fixed effects. The results for estimation IV 3 show a positive significant coefficient for the rebate, indicating a positive effect of the rebate on green car sales in line with our expectations.

6.1.2. Nested logit

The estimation results from the nested logit (*Equation 10*) are presented in *Table 6* and compared to earlier results. The results are more satisfying, in particular for the explanatory power of the model when comparing R^2 as well as the fitted value for yearly total sales to the actual numbers, while the price elasticities are still within a reasonable range. We also find that the nest coefficient is in the range 0 to 1 and with a t-test we can reject the null hypothesis of the coefficient being equal to 0 as well as the null hypothesis of the coefficient being equal to 1, both at a 5 percent significance level.[17] We therefore choose to use the nested logit from here on. The coefficient for the rebate dummy is still positive and significant.

Dep. var: $\ln(s_j/s_0)$	IV 3	NL 1 Nested logit	
Coefficients (p-values)			
Price	-0.0366	-0.0116	
	(0.000)	(0.000)	
Ln(market share within nest)		0.8482	
		(0.000)	
Rebate dummy	0.3657	0.1834	
	(0.000)	(0.000)	
Fixed effects			
Fuel type	yes	yes	
Region	yes	yes	
Brand	yes	yes	
Time(year and month)	yes	yes	
R^2	0.9725	0.9953	
Nest		Engine power	
Instrument	BLP(Engine power/Weight)	BLP(Engine power/Weight)	
First-stage reg. F-stat	8,627.42	8,572.32	
Price elasticity			
Minimum	-14.63	-30.37	
Maximum	-2.92	-1.34	
Mean	-7.72	-14.90	
Median	-7.51	-14.52	
Fitted yearly total sales			**Actual total sales**
2004	93,864	114,453	133,384
2005	99,465	115,896	137,419
2006	109,668	120,218	138,350
2007	129,084	135,318	150,184
2008	83,868	82,827	88,988
Total	515,950	568,711	648,325

Table 6: Comparison of results from IV 3 and NL 1, regular and nested logit, p-values in parentheses

6.1.3. Adjusted prices

The results from the estimation with adjusted prices (*Equation 11*) are shown in *Table 7.*

[17] Full regression results and t-tests are found in *Appendix A.1.*

Dep. var: $\ln(s_j/s_0)$	NL 1 Nested logit Rebate dummy	NL 2 Nested logit Adjusted price	
Coefficients (p-values)			
Price	-0.0116	-0.0117	
	(0.000)	(0.000)	
Ln(market share within nest)	0.8482	0.8484	
	(0.000)	(0.000)	
Rebate dummy	0.1834		
	(0.000)		
Fixed effects			
Fuel type	yes	yes	
Region	yes	yes	
Brand	yes	yes	
Time(year and month)	yes	yes	
R^2	0.9953	0.9953	
Nest	Engine power	Engine power	
Instrument	BLP(Engine power/Weight)	BLP(Engine power/Weight)	
First-stage reg. F-stat	8,572.32	8,715.99	
Price elasticity			
Minimum	-30.37	-30.88	
Maximum	-1.34	-1.36	
Mean	-14.90	-15.10	
Median	-14.52	-14.70	
Fitted yearly total sales			**Actual total sales**
2004	114,453	114,588	133,384
2005	115,896	115,963	137,419
2006	120,218	120,335	138,350
2007	135,318	135,333	150,184
2008	82,827	82,827	88,988
Total	568,711	569,046	648,325

Table 7: Results from estimation NL 1 and NL 2, rebate dummy vs. adjusted price, p-values in parentheses

As there is no large difference when using adjusted prices instead of a rebate dummy, we continue using the dummy in order to be able to capture the effects of the rebate in more detail.

6.1.4. Regions

The results from the region specific estimation (*Equation 12*) are presented in *Table 8*. We find that all coefficients of the rebate dummies are positive and significant for nearly all of Sweden, with an exception for Jämtland and Norrbotten where the coefficients are negative and insignificant. The largest impact is found in the two regions with the largest populations, Västra Götaland and Stockholm.

Norrland	Coeff.	Svealand	Coeff.	Götaland	Coeff.
Gävleborg	0.1882	Dalarna	0.1240	Blekinge	0.1049
	(0.000)		(0.000)		(0.001)
Jämtland	-0.0036	Stockholm	0.2913	Gotland	0.0892
	(0.928)		(0.000)		(0.037)
Norrbotten	-0.0363	Södermanland	0.1897	Halland	0.2360
	(0.269)		(0.000)		(0.000)
Västerbotten	0.0902	Uppsala	0.1272	Jönköping	0.1490
	(0.004)		(0.000)		(0.000)
Västernorrland	0.1760	Värmland	0.1644	Kalmar	0.1778
	(0.000)		(0.000)		(0.000)
		Västmanland	0.1561	Kronoberg	0.1105
			(0.000)		(0.000)
		Örebro	0.2032	Skåne	0.1579
			(0.000)		(0.000)
				Västra Götaland	0.4466
					(0.000)
				Östergötland	0.2589
					(0.000)

Table 8: Results from NL 3, coefficients for region specific rebate dummies, p-values in parentheses

The results for the fuel type specific estimations (*Equation 13* and *Equation 14*) are shown in *Table 9* and *Table 10*.

6.1.5. Fuel types

We find that the gas cars have experienced the largest impact of the rebate, followed by low emission gasoline and diesel cars. The effect on ethanol cars is considerably smaller and for hybrids it is completely insignificant.

Fuel type x Rebate dummy	Coefficient
Gasoline CO2 < 120 g/km	0. 3225
	(0.000)
Diesel CO2 < 120 g/km	0.2580
	(0.000)
Ethanol	0.0725
	(0.000)
Electric hybrid	0.0007
	(0.991)
Vehicle gas	0.3660
	(0.000)

Table 9: Results from NL 4, rebate interacted with fuel types, p-values in parentheses

Fuel type x Rebate dummy	Coefficient
Conventional green cars	0.2860
	(0.000)
Alternative fuel cars	0.0833
	(0.000)

Table 10: Results from NL 5, rebate interacted with regular or alternative fuel, p-values in parentheses

6.1.6. Rebate vs. congestion tax exemption

The results from *Equation 15*, comparing the impact of the rebate to the on the congestion tax exemption, are presented in *Table 11*.

Fuel type x Rebate dummy	Rebate Coeff.	Congestion tax coeff.
Ethanol	0.0744	0.0961
	(0.000)	(0.002)
Electric hybrid	-0.0113	0.3032
	(0.864)	(0.000)
Vehicle gas	0.3302	0.3440
	(0.000)	(0.000)

Table 11: Results from NL 6, comparison of the influence on sales of alternative fuel cars for rebate vs. congestion tax, p-values in parentheses

The results suggest that the exemption from congestion tax has been more successful as a policy to increase the market shares of alternative fuel cars.

6.2. Results from counterfactuals

Using the estimated coefficients (from NL 4) and by setting the rebate variable to zero for all observations, we can calculate fitted market shares s^* for a scenario with no rebate, assuming the shares of the outside good to be unchanged by the rebate (see *Appendix A.2.*).[18] We divide these by the fitted market shares from NL 4 and multiply by the true market shares, $(s^*/\hat{s}) * \tilde{s}$. Using an adding up constraint to ensure that yearly total sales remain constant we then obtain the counterfactual market shares. [19]

In *Table 12* the counterfactual numbers of green cars sold are presented and compared to actual sales. Setting the rebate variable to zero will only affect the rebate period 2007 to 2008, hence the counterfactuals provide the same sales figures for the years 2004 to 2006.

	Actual sales	Counterfactual sales
2004	3,816	3,816
2005	3,309	3,309
2006	10,482	10,482
2007	23,907	21,257
2008	28,605	25,552
Total	**70,119**	**64,416**

Table 12: Actual vs. counterfactual sales of green cars

To return to the earlier results on differences between fuel types, we also present the sales figures for the different fuel types of green cars as suggested by the counterfactuals and compare these to the actual sales figures in *Table 13*.

	Actual sales					Counterfactual sales				
	Gasoline	Diesel	Ethanol	Electric Hybrids	Vehicle gas	Gasoline	Diesel	Ethanol	Electric Hybrids	Vehicle gas
2004	468	142	3,077	109	20	468	142	3,077	109	20
2005	84	123	2,684	281	137	84	123	2,684	281	137
2006	2,769	929	6,134	415	235	2,769	929	6,134	415	235
2007	5,905	5,280	11,904	719	99	4,659	4,317	11,466	736	78
2008	7,183	5,901	14,790	642	89	5,511	4,813	14,488	675	65
Total	**16,409**	**12,375**	**38,589**	**2,166**	**580**	**13,492**	**10,324**	**37,849**	**2,216**	**535**

Table 13: Actual vs. counterfactual sales of green cars divided by fuel type

[18] We choose to use the results from the specification with fuel type specific rebate dummies, since we regard the impact of the rebate on the different fuel types to be most relevant to our study.
[19] The reduction in green car sales caused by setting the rebate dummy to zero is divided proportionally over green cars and regular cars to ensure that yearly total sales remain constant.

When comparing the actual market shares with the counterfactual, we find that the green car rebate has caused an increase in green car sales for April to December 2007 of 15 percent and for the period January to September 2008 of 12 percent. The difference is depicted in *Figure 12*.

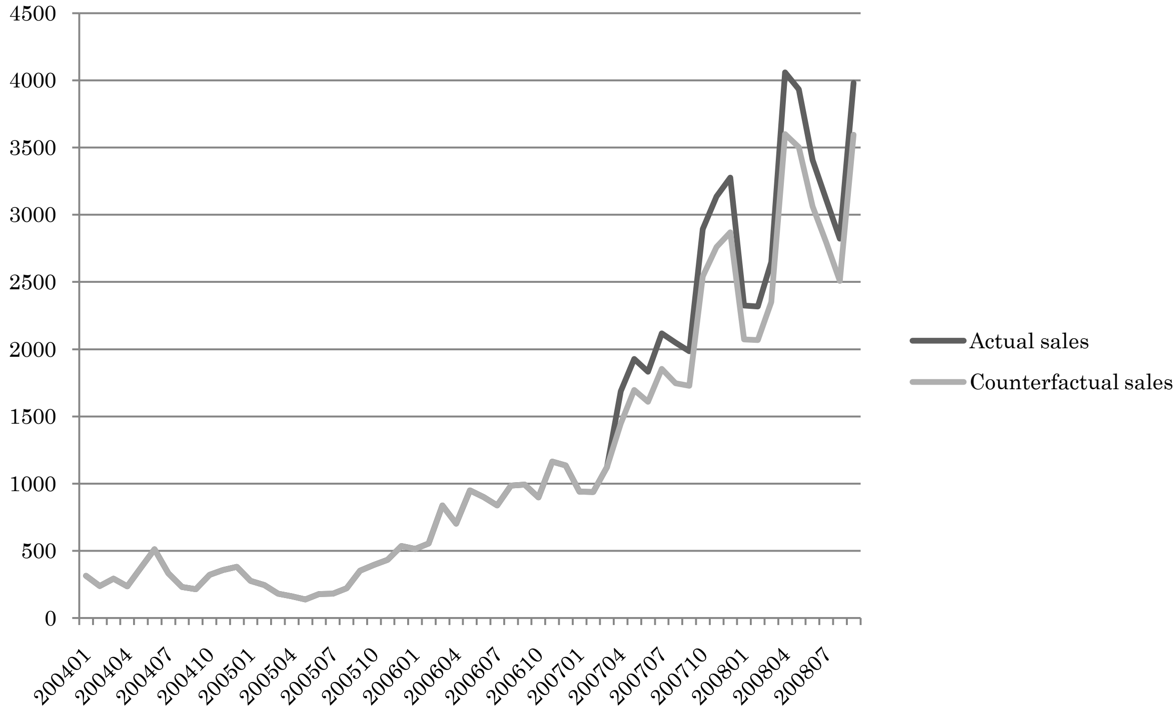

Figure 12: Actual vs. counterfactual number of green cars sold

Further the results show that the impact of the rebate has been of a different magnitude for different fuel types. In *Table 14* we present the percentage increase in sales caused by the rebate, as suggested by the counterfactuals.

	Gasoline	Diesel	Ethanol	Electric hybrids	Vehicle gas
2007	33%	25%	4%	-3%	40%
2008	30%	23%	2%	-5%	37%

Table 14: Percentage increase in green cars sold for the different fuel types affected by the rebate

The estimated difference in market shares caused by the subsidy can also be used to estimate the environmental effect of the policy. Using the car model specific information on CO2-emissions combined with data on average yearly distances driven, we can calculate the total yearly CO2-emissions of the cars sold during a certain period.

Depending on whether we choose to base our distances on weight or brand and fuel type, we attain different results, as shown in *Table 15*.

Green cars sold Apr 2007 - Sep 2008	49,510			
Rebate per car (SEK)	10,000			
Total rebate paid out (SEK)	495,100,000			
Assumed average years in traffic	15			
	Brand & Fuel type		**Weight**	
CO2 emissions from new car sales in tonnes per year	**Counterfactual**	**Actual**	**Counterfactual**	**Actual**
April-December 2007	291,308	289,062	305,802	301,313
January-September 2008	202,237	199,500	205,818	200,970
Total	**493,545**	**488,562**	**511,620**	**502,284**
Implied emission reduction (tonnes/year) from rebate for new car sales Apr 2007 – Sep 2008		4,982		9,336
Total CO2 reduction (tonnes)		74,735		140,045
Cost to reduce emissions by one tonne of CO2 (SEK)		**6,625**		**3,535**

Table 15: Calculations of carbon emission reduction

When performing the above calculation for both the actual and the counterfactual market shares for the time period April 2007 to September 2008 we estimate that the subsidy has caused a total emission reduction in the range of 4,982 to 9,336 tonnes of CO2 per year for all vehicles sold during this period. During this time, the government has paid out SEK 495 million in subsidies for the green cars sold. If we assume that a car on average is in traffic for 15 years, this implies that the government has spent on average SEK 3,535 to SEK 6,625 to reduce emissions by one tonne of CO2. These numbers can be compared to the spot price for a tonne of CO2 on the European Energy Exchange (2009), which currently is about SEK 160[20].

6.3. Interpretation & implications

Our results clearly show that the green car rebate has had a positive effect on the market shares of green cars in general. Since we use the mean utility as dependent variable we are not able to draw any detailed conclusion on the actual changes in market

[20] The spot price on May 22, 2009 was €15.30 and SEK/Euro exchange rate 10.48.

shares by just looking at the estimation results. For this we need the results from the counterfactuals, which we will return to later.

6.3.1. Adjusted prices

When comparing the results from the estimation using a rebate dummy with the estimation using adjusted prices, we find that the results are very similar. This could be interpreted as if only the monetary incentive of the rebate has affected consumers to choose a green car. It could thus be dismissed that the rebate has also functioned as a signal from the government that green cars are here to stay and a serious alternative to regular cars. Even though this result first strikes us as surprising it is easier to understand when we take in regard the results showing which fuel types have been most affected by the rebate. As the conventional green cars have seen the largest increase in market shares, it is not surprising that it has only been the monetary incentive that has induced consumers to their purchasing decisions. The conventional green cars do not differ from regular cars in any other way than their emission level and are thus not perceived as a risky or odd purchase, which explains why consumers are only interested in the SEK 10,000 rebate and do not care about the signals that the government send by promoting green cars.

6.3.2. Regions

When studying the region specific effects of the rebate, we find that the impact is the largest in Stockholm and Västra Götaland (to which Gothenburg belongs). One possible explanation could be that the use of small sized cars is more common in urban areas. Purchasing a vehicle with an emission level below the limit is more likely if you have already decided that you want a small sized car. With the rebate, consumers interested in a smaller car, have found an incentive to make sure that the car emits less than 120 g/km and thus is classified as a green car.

6.3.3. Fuel types

The different impact of the rebate on the different fuel types is in line with the results of the study by BEST (2009). The BEST report does however not go very deeply into the effect of the rebate specifically, but satisfies on stating that the impact was larger for conventional green cars than for alternative fuel cars. We find a considerable impact on the market shares of conventional green cars, but also on gas cars. It should however be noted that the market share of gas cars was less than 0.2 percent before the introduction of the rebate which makes the impact of the rebate, even though relatively large, very limited in absolute numbers. In fact, the market share of gas cars decreased in 2007. Our results thus imply that the market share would have decreased even more without the rebate. The rebate has obviously not been a sufficient incentive for consumers to overlook the downsides of gas cars. Our results point to a slow progress for the sales of gas cars since it is not likely that the number of vehicle gas stations will increase notably without an increase in sales. As long as no other incentives for gas cars are introduced we expect the ethanol cars to remain in the position of the more attractive alternative. However, depending on the development of the ethanol price relative to the price of gasoline and vehicle gas, ethanol cars may appear pointless from an environmental point of view if it will continue to be cheaper to fill them with gasoline. Then the gas cars might face better days since gas so far has been the cheaper alternative. The problem with the limited supply of vehicle gas however still remains and this is probably where we will need to see further governmental incentives if the sales of gas cars are to increase. So far the ethanol cars in Sweden also have the advantage of being flex fuel cars whereas the gas cars are bi-fuel, most of them with only a small gasoline tank, since gasoline is only used for start-up. The possibility to arbitrage between fuel types has proven to be of great importance for the economy of ethanol car owners. It is also an advantage when considering the number of gas stations with alternative fuels. If the gas cars were to be flex fuel as well, it would be less of a problem for a gas car owner in Stockholm to go on holiday to northern Sweden.

A result that strikes us as somewhat surprising is the remarkably small impact of the rebate on the market share of ethanol cars, even though these make up about half of all green cars sold and the sales of ethanol cars increased by 94 percent from 2006 to 2007. Our results imply that the increase in market share for ethanol cars would have taken place almost to the same extent even without the rebate. One possible explanation could be the low price of ethanol relative to the prices of gasoline and diesel during the period April 2007 to September 2008. In the long run a lower fuel price will be much more important from an economic point of view than the one time rebate. A second explanation could be the increased awareness of and changed attitude towards the climate change among the Swedish population found in an annual survey by the Swedish Environmental Protection Agency (2008b). The share of respondents who declare that they would absolutely be prepared to choose a more environmentally friendly model as their next car has increased from 60 percent in 2006 to 71 percent in 2007 and 74 percent in 2008. Given the dominant position of ethanol cars among alternative fuel cars on the supply side and the increased accessibility to E85 following the pump law, ethanol cars stand out as the most evident alternative when considering a more environmentally friendly car. Purchasing a conventional green car would also be an improvement to the environment but not to the same extent as purchasing an ethanol car. In 2008 the average ethanol model sold in Sweden had a CO2 emission level of 71 g/km and would thus deserve to be regarded as a more environmentally friendly option than conventional green cars.

That the rebate has not lead to a huge increase in the sales of electric hybrids is obvious already from the sales statistics, but that the rebate has no significant impact at all strikes us as surprising. One possible explanation for the still small market share of hybrids could be that Honda Civic and Toyota Prius are the only models offered on the Swedish market.

The results suggest that the rebate has mainly induced a share of consumers to purchase a low emission version of a gasoline or diesel car instead of a regular. For the objective to reduce the aggregated carbon emissions of the Swedish vehicle fleet it is of course better with a switch towards more fuel economic models than no switch at all. But for the long-term goal to reduce the use of fossil fuels the green car rebate has not been a very successful policy.

6.3.4. Rebate vs. congestion tax exemption

We continue by comparing the impact of the rebate to impact of the policy to exempt alternative fuel cars from the Stockholm congestion tax. We find that the tax exemption has had a larger impact on the increase of alternative fuel car market shares than the rebate. It is interesting to note that neither the congestion tax exemption has lead to any considerable increase in ethanol car sales. The exemption did however increase the market share of electric hybrids essentially and the same goes for gas gars where the effect is of the same magnitude as the effect of the rebate. Our findings are overall in line with the study by BEST (2009) where the congestion tax exemption is also claimed to have had the largest impact of the two. It should be noted that we come to the same conclusion even though our study differs from the one by BEST regarding both method and data. Besides having less detailed sales data and not including car characteristics, the BEST study uses data for Stockholm only. In our study of the effect of the rebate vs. the exemption from congestion tax, we choose not to use only observations from Stockholm since the correlation between the rebate dummy and the congestion tax dummy would be too high, 0.85. This could also explain why BEST chooses not to include the rebate and the congestion tax dummies in the same estimation. Based on our market level data and the inclusion of both policy dummies in the same estimation, we would regard our findings to be a contribution in addition to previous research in the field. For more detailed results on the different impacts of the two policies based on estimated counterfactuals, see *Appendix A.3*.

6.3.5. Counterfactuals

We find that the direct impact of the rebate on the Swedish CO2-emission has not been particularly cost-effective. However, we have not included any of the administration costs and alike, neither have we considered the long run effects after the expiration of the rebate program, such as a potential increased acceptance for green cars in general and alternative fuel cars in particular, which have been expressed to be part of the purpose of the program.

The comparison with emission rights is done in order to have something to compare the costs of the program to and should not be regarded as a suggested alternative. We are aware that it might not be completely fair since the program does more than lower carbon dioxide emissions and the calculations are based on certain assumptions. Moreover, emission rights would not address the problem with the aging car fleet.

Important to stress is that disregarding the cost of the carbon dioxide, the program has been successful in showing that there is a willingness among consumers to change car type. The reason for bringing the end forward is that the goal has already been reached.

6.4. Discussion

When calculating the carbon emission reduction based on the counterfactuals part of it stems from the increase in the market share of ethanol cars, which relative to fossil fuel cars emit significantly less CO2. It should however be noted that we have based our calculations on the assumption that all ethanol cars are actually filled with ethanol which leads to an overestimation of the carbon emission reduction, since ethanol cars filled with gasoline have significantly higher emission rates. It would hence imply that the program might actually be even less cost-effective than we have first estimated.

Our study may furthermore suffer from some shortcomings in the data. Firstly, we only have list prices and no data on actual price paid. This means that our model e.g. will not capture increases in sales related to price reductions correctly, but instead relate the increase to something else than the price. The effect will be an incorrect estimation of the price coefficient.

As mentioned earlier, the survey by BEST (2009) shows that the highest ranked reason for purchasing an alternatively fuelled car is the own will to reduce the negative impact on the environment. It is therefore a weakness of our estimations not to take the parameter of environmental awareness in consideration. Annual studies have shown an increase in the public environmental awareness in the last years (The Swedish Environmental Protection Agency, 2008b). It is therefore possible that a part of the impact which is related to the recently introduced green car rebate could actually be related to increased environmental awareness and a will among consumers to reduce their own carbon footprint non-related to any monetary incentives. The main reason for not including an environmental awareness variable is the difficulty in quantifying this factor. Moreover, the research on the subject that we have looked at consists of studies performed on a yearly basis at most and yearly data would contribute little to our data set of monthly observations.

We are also aware that our model of choice has some shortcomings. The fact that the variation in consumer tastes enters the model only through ϵ_{ij}, which is assumed to be identically and independently distributed across consumers and choices, leads to strong restrictions on the pattern of cross-price elasticities from the estimated model. More specifically, nothing but the mean utility levels will differentiate two products. This results in all properties of market demand such as market shares and elasticities being determined by δ_j only. This, in turn, implies that any pair of products (j, k) with the same market shares will have the same cross-price elasticity with any given third product. To use the example by Berry, Levinsohn and Pakes (1995), an implication would be that the market shares of a more expensive car like Mercedes and the one of a cheaper car like Skoda (or Yugo in BLP's paper) would be equally affected by a price change of BMW. As noted by BLP the problem with the cross-price elasticities also leads to questionable own-price elasticities, since these will be linked only to market shares. We find the same pattern in our results with more expensive car models having higher elasticities than cheaper ones. Using the relation $markup = \frac{1}{1-\left|\frac{1}{elasticity}\right|}$ our model counterintuitively implies lower markups for more expensive car models.

7. Conclusion

In this study we have investigated the effect of the Swedish green car rebate on the market shares of green cars in new car sales. To estimate the effect of the rebate that was introduced April 1st 2007 we use data from January 2004 to September 2008. We find that the rebate has had a positive effect on the market shares of green cars in general. The effect differs between fuel types and we find that the effect has been largest for low emission gasoline and diesel cars. Our results indicate that the large increase in the market share of ethanol cars would have taken place even without the rebate. In line with a previous study by BEST (2009) we find that the policy to exempt alternative fuel cars from congestion tax has had a larger impact on market shares than the rebate. Using counterfactuals we estimate the increase in green car sales related to the rebate to be 13 percent for the period April 2007 to September 2008. Based on average yearly distances covered, we calculate the yearly reduction in CO_2 emissions related to the rebate to be in the range 4,982 to 9,336 tonnes. If weighed against the paid out rebates the implied price for one tonne of CO_2 is found to be 22 to 41 times higher than the current spot price of a European emission right.

7.1. Suggestions for further research

Compared to a previous study of the rebate by BEST (2009) we use a more extensive data set with monthly regional sales data on a car model level combined with data on car characteristics. We believe that the effect could have been examined even more thoroughly with individual sales data, which would make it possible to include variables such as consumer income to further explain vehicle choice. It would also be interesting to re-estimate the effect of the rebate using actual prices paid as opposed to the yearly based list prices used in our study to fully capture the price importance. Given that ethanol is one of the fuel types affected by the rebate, it would be interesting to examine the fuel choices of these car owners. Now that green car vehicle tax exemption program has been introduced, it will also be possible to compare the effects of the two programs to assess the most appropriate set up from a policy perspective. Another track that would be interesting to investigate is the implication for the automotive industry, i.e. the effect of the rebate on the automobile producers and their respective valuation, with a focus on the Swedish companies.

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A. Appendices

A.1. Estimation results

Here follow more detailed results from our estimations. We do however only present the detailed results from the fuel type fixed effects, since the results from the others would be too extensive with 21 regions, 66 brands and 57 time periods.

OLS Dependent variable: $\ln(s_j/s_0)$	Coefficients	Std. Errors	P-values
Price	0.0000	0.0001	0.781
CO2-emission (g/km)	-0.0125	0.0003	0.000
Tax	0.0000	0.0000	0.000
Green car dummy	-0.5198	0.0501	0.000
Fuel economy (km/SEK)	-1.3276	0.0298	0.000
Engine power/weight	7.3649	0.3159	0.000
Rebate dummy	0.2818	0.0181	0.000
Congestion tax dummy	0.7418	0.0496	0.000
Tax exemption for hybrid cars	-0.0649	0.0665	0.329
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	0.5810	0.0488	0.000
Diesel	-0.1102	0.0173	0.000
Diesel CO2 < 120 g/km	0.5588	0.0467	0.000
Ethanol	-0.8830	0.0543	0.000
Electric hybrid	(dropped)		
Vehicle gas	-1.9242	0.0717	0.000
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.4338		
Number of observations	132,580		

Table 16: Results from OLS

IV 1 Instrument: BLP(Fuel economy) Dep. var: $\ln(s_j/s_0)$			
	Coefficients	**Std. Errors**	**P-values**
Price	-0.0889	0.0236	0.000
CO2-emission (g/km)	0.0800	0.0246	0.001
Tax	0.0008	0.0002	0.000
Green car dummy	11.3336	3.6610	0.002
Fuel economy (km/SEK)	-2.9793	0.4447	0.000
Engine power/weight	112.6590	27.9691	0.000
Rebate dummy	0.4858	0.0702	0.000
Congestion tax dummy	0.8216	0.1245	0.000
Tax exemption for hybrid cars	2.0471	0.5845	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-8.8732	3.0250	0.003
Diesel	3.9592	1.0814	0.000
Diesel CO2 < 120 g/km	-5.2843	2.0680	0.011
Ethanol	-2.1025	0.8451	0.013
Electric hybrid	3.4266	0.4366	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9098		
Number of observations	132,580		

Table 17: Results from IV 1

IV 2 Instrument: BLP(Engine power/Weight) Dep. var: $\ln(s_j/s_0)$	Coefficients	Std. Errors	P-values
Price	0.0220	0.0006	0.000
CO2-emission (g/km)	-0.0238	0.0006	0.000
Tax	-0.0002	0.0000	0.000
Green car dummy	-5.0507	0.1288	0.000
Fuel economy (km/SEK)	0.4735	0.0262	0.000
Engine power/weight	-45.1134	1.5371	0.000
Rebate dummy	-0.0115	0.0233	0.621
Congestion tax dummy	0.6838	0.0668	0.000
Tax exemption for hybrid cars	-0.5521	0.0909	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	4.1285	0.1165	0.000
Diesel	-1.6898	0.0363	0.000
Diesel CO2 < 120 g/km	2.8347	0.0991	0.000
Ethanol	2.3774	0.0804	0.000
Electric hybrid	-0.2604	0.0948	0.006
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	No		
Time fixed effects	No		
R^2	0.9731		
Number of observations	132,580		

Table 18: Results from IV 2

IV 3 Instrument: BLP(Engine power/Weight) Dep. var: $\ln(s_j/s_0)$	Coefficients	Std. Errors	P-values
Price	-0.0366	0.0044	0.000
CO2-emission (g/km)	0.0255	0.0045	0.000
Tax	0.0003	0.0000	0.000
Green car dummy	3.2243	0.6798	0.000
Fuel economy (km/SEK)	-2.0072	0.0906	0.000
Engine power/weight	50.6845	5.1784	0.000
Rebate dummy	0.3657	0.0266	0.000
Congestion tax dummy	0.7746	0.0678	0.000
Tax exemption for hybrid cars	0.8040	0.1377	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-2.1761	0.5638	0.000
Diesel	1.5640	0.2008	0.000
Diesel CO2 < 120 g/km	-0.7126	0.3899	0.068
Ethanol	-0.2522	0.1704	0.139
Electric hybrid	2.5423	0.1226	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9725		
Number of observations	132,580		

Table 19: Results from IV 3

NL 1 Instrument: BLP(Engine power/Weight) Nested logit (nest: Engine power) Dep. var: ln(s_j/s_0)			
	Coefficients	**Std. Errors**	**P-values**
Price	-0.0116	0.0018	0.000
Ln(market share within nest)	0.8482	0.0015	0.000
CO2-emission (g/km)	0.0102	0.0019	0.000
Tax	0.0001	0.0000	0.000
Green car dummy	0.9691	0.2818	0.001
Fuel economy (km/SEK)	-0.4091	0.0380	0.000
Engine power/weight	15.3082	2.1529	0.000
Rebate dummy	0.1834	0.0110	0.000
Congestion tax dummy	0.1333	0.0281	0.000
Tax exemption for hybrid cars	0.2449	0.0571	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-0.6484	0.2337	0.006
Diesel	0.5319	0.0834	0.000
Diesel CO2 < 120 g/km	-0.1237	0.1614	0.444
Ethanol	0.2638	0.0706	0.000
Electric hybrid	0.9137	0.0511	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9953		
Number of observations	132,580		

Table 20: Results from NL 1

Nest coefficient	0.8482		
Standard error	0.0015		
Degrees of freedom	132,578		
Significance level	5 %		
Critical value	1.96		
Test if nest coefficient = 0		**Test if nest coefficient = 1**	
t-value	565.47	t-value	101.20
We can reject the hypothesis of the nest coefficient being equal to 0 at a 5% significance level.		We can reject the hypothesis of the nest coefficient being equal to 1 at a 5% significance level.	

Table 21: T-test of nest coefficient from NL 1

NL 2 Instrument: BLP(Engine power/Weight) Nested logit (nest: Engine power) Dep. var: $\ln(s_j/s_0)$	Coefficients	Std. Errors	P-values
Price* (minus SEK 10,000 for green cars)	-0.0117	0.0018	0.000
Ln(market share within nest)	0.8484	0.0015	0.000
CO2-emission (g/km)	0.0104	0.0019	0.000
Tax	0.0001	0.0000	0.000
Green car dummy	1.0187	0.2729	0.000
Fuel economy (km/SEK)	-0.4114	0.0377	0.000
Engine power/weight	15.4397	2.1352	0.000
Rebate dummy			
Congestion tax dummy	0.1468	0.0281	0.000
Tax exemption for hybrid cars	0.2010	0.0640	0.002
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-0.6521	0.2339	0.005
Diesel	0.5362	0.0829	0.000
Diesel CO2 < 120 g/km	-0.1154	0.1638	0.481
Ethanol	0.2788	0.0737	0.000
Electric hybrid	0.9418	0.0478	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9953		
Number of observations	132,580		

Table 22: Results from NL 2

Nest coefficient	0.8484		
Standard error	0.0015		
Degrees of freedom	132,578		
Significance level	5 %		
Critical value	1.96		
Test if nest coefficient = 0		**Test if nest coefficient = 1**	
t-value	565.60	t-value	101.07
We can reject the hypothesis of the nest coefficient being equal to 0 at a 5% significance level.		We can reject the hypothesis of the nest coefficient being equal to 1 at a 5% significance level.	

Table 23: T-test of nest coefficient from NL 2

NL 3 Instrument: BLP(Engine power/Weight) Nested logit (nest: Engine power) Dep. var: $\ln(s_j/s_0)$	Coefficients	Std. Errors	P-values
Price	-0.0132	0.0019	0.000
Ln(market share within nest)	0.8474	0.0016	0.000
CO2-emission (g/km)	0.0120	0.0019	0.000
Tax	0.0001	0.0000	0.000
Green car dummy	1.2067	0.2902	0.000
Fuel economy (km/SEK)	-0.4348	0.0392	0.000
Engine power/weight	17.2774	2.2154	0.000
Congestion tax dummy	0.0449	0.0354	0.205
Tax exemption for hybrid cars	0.2952	0.0590	0.000
Regional rebate dummies			
Blekinge	0.1049	0.0308	0.001
Dalarna	0.1240	0.0282	0.000
Gotland	0.0892	0.0427	0.037
Gävleborg	0.1882	0.0285	0.000
Halland	0.2360	0.0259	0.000
Jämtland	-0.0036	0.0398	0.928
Jönköping	0.1490	0.0266	0.000
Kalmar	0.1778	0.0273	0.000
Kronoberg	0.1105	0.0291	0.000
Norrbotten	-0.0363	0.0328	0.269
Skåne	0.1579	0.0225	0.000
Stockholm	0.2913	0.0255	0.000
Södermanland	0.1897	0.0267	0.000
Uppsala	0.1272	0.0268	0.000
Värmland	0.1644	0.0290	0.000
Västerbotten	0.0902	0.0309	0.004
Västernorrland	0.1760	0.0300	0.000
Västmanland	0.1561	0.0282	0.000
Västra Götaland	0.4466	0.0216	0.000
Örebro	0.2032	0.0284	0.000
Östergötland	0.2589	0.0256	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-0.8435	0.2406	0.000
Diesel	0.6059	0.0858	0.000
Diesel CO2 < 120 g/km	-0.2586	0.1662	0.120
Ethanol	0.2355	0.0731	0.001
Electric hybrid	0.9506	0.0529	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9949		
Number of observations	132,580		

Table 24: Results from NL 3

Nest coefficient	0.8474		
Standard error	0.0016		
Degrees of freedom	132,578		
Significance level	5 %		
Critical value	1.96		
Test if nest coefficient = 0		**Test if nest coefficient = 1**	
t-value	529.62	t-value	95.38
We can reject the hypothesis of the nest coefficient being equal to 0 at a 5% significance level.		We can reject the hypothesis of the nest coefficient being equal to 1 at a 5% significance level.	

Table 25: T-test of nest coefficient from NL 3

NL 4
Instrument: BLP(Engine power/Weight)
Nested logit (nest: Engine power)
Dep. var: $\ln(s_j/s_0)$

	Coefficients	Std. Errors	P-values
Price	-0.0114	0.0018	0.000
Ln(market share within nest)	0.8481	0.0015	0.000
CO2-emission (g/km)	0.0103	0.0019	0.000
Tax	0.0001	0.0000	0.000
Green car dummy	0.8840	0.2871	0.002
Fuel economy (km/SEK)	-0.3705	0.0383	0.000
Engine power/weight	15.0393	2.1272	0.000
Congestion tax dummy	0.1464	0.0282	0.000
Tax exemption for hybrid cars	0.0961	0.0596	0.107
Fuel type specific rebate dummies			
Gasoline CO2 < 120 g/km	0.3225	0.0232	0.000
Diesel CO2 < 120 g/km	0.2580	0.0192	0.000
Ethanol	0.0725	0.0158	0.000
Electric hybrid	0.0007	0.0667	0.991
Vehicle gas	0.3660	0.0616	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-0.6702	0.2433	0.006
Diesel	0.5155	0.0825	0.000
Diesel CO2 < 120 g/km	-0.1242	0.1693	0.463
Ethanol	0.4244	0.0820	0.000
Electric hybrid	1.0941	0.0835	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9953		
Number of observations	132,580		

Table 26: Results from NL 4

Nest coefficient	0.8481		
Standard error	0.0015		
Degrees of freedom	132,578		
Significance level	5 %		
Critical value	1.96		
Test if nest coefficient = 0		**Test if nest coefficient = 1**	
t-value	565.40	t-value	101.27
We can reject the hypothesis of the nest coefficient being equal to 0 at a 5% significance level.		We can reject the hypothesis of the nest coefficient being equal to 1 at a 5% significance level.	

Table 27: T-test of nest coefficient from NL 4

NL 5
Instrument: BLP(Engine power/Weight)
Nested logit (nest: Engine power)
Dep. var: $\ln(s_j/s_0)$

	Coefficients	**Std. Errors**	**P-values**
Price	-0.0113	0.0018	0.000
Ln(market share within nest)	0.8480	0.0015	0.000
CO2-emission (g/km)	0.0102	0.0019	0.000
Tax	0.0001	0.0000	0.000
Green car dummy	0.9842	0.2804	0.000
Fuel economy (km/SEK)	-0.3668	0.0371	0.000
Engine power/weight	14.9883	2.1319	0.000
Congestion tax dummy	0.1546	0.0280	0.000
Tax exemption for hybrid cars	0.1604	0.0558	0.004
Fuel type specific rebate dummies			
Conventional green cars	0.2860	0.0157	0.000
Alternative fuel cars	0.0833	0.0141	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-0.7484	0.2348	0.001
Diesel	0.5127	0.0824	0.000
Diesel CO2 < 120 g/km	-0.2506	0.1638	0.126
Ethanol	0.3114	0.0693	0.000
Electric hybrid	0.9179	0.0508	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9954		
Number of observations	132,580		

Table 28: Results from NL 5

Nest coefficient	0.8480		
Standard error	0.0015		
Degrees of freedom	132,578		
Significance level	5 %		
Critical value	1.96		
Test if nest coefficient = 0		**Test if nest coefficient = 1**	
t-value	565.33	t-value	101.33
We can reject the hypothesis of the nest coefficient being equal to 0 at a 5% significance level.		We can reject the hypothesis of the nest coefficient being equal to 1 at a 5% significance level.	

Table 29: T-test of nest coefficient from NL 5

NL 6 Instrument: BLP(Engine power/Weight) Nested logit (nest: Engine power) Dep. var: $\ln(s_j/s_0)$	Coefficients	Std. Errors	P-values
Price	-0.0113	0.0018	0.000
Ln(market share within nest)	0.8481	0.0015	0.000
CO2-emission (g/km)	0.0102	0.0018	0.000
Tax	0.0001	0.0000	0.000
Green car dummy	0.8590	0.2830	0.002
Fuel economy (km/SEK)	-0.3687	0.0381	0.000
Engine power/weight	14.9485	2.1162	0.000
Tax exemption for hybrid cars	0.0905	0.0596	0.129
Fuel type specific rebate dummies			
Gasoline CO2 < 120 g/km	0.3222	0.0231	0.000
Diesel CO2 < 120 g/km	0.2579	0.0192	0.000
Ethanol	0.0744	0.0158	0.000
Electric hybrid	-0.0113	0.0662	0.864
Vehicle gas	0.3302	0.0658	0.000
Fuel type specific congestion tax dummies			
Ethanol	0.0961	0.0316	0.002
Electric hybrid	0.3032	0.0817	0.000
Vehicle gas	0.3440	0.0966	0.000
Fuel type fixed effects (base=gasoline)			
Gasoline CO2 < 120 g/km	-0.6472	0.2395	0.007
Diesel	0.5119	0.0821	0.000
Diesel CO2 < 120 g/km	-0.1046	0.1659	0.528
Ethanol	0.4415	0.0794	0.000
Electric hybrid	1.1047	0.0852	0.000
Vehicle gas	(dropped)		
Region fixed effects	Yes		
Brand fixed effects	Yes		
Time fixed effects	Yes		
R^2	0.9954		
Number of observations	132,580		

Table 30: Results from NL 6

Nest coefficient	0.8481		
Standard error	0.0015		
Degrees of freedom	132,578		
Significance level	5 %		
Critical value	1.96		
Test if nest coefficient = 0		**Test if nest coefficient = 1**	
t-value	565.40	t-value	101.27
We can reject the hypothesis of the nest coefficient being equal to 0 at a 5% significance level.		We can reject the hypothesis of the nest coefficient being equal to 1 at a 5% significance level.	

Table 31: T-test of nest coefficient from NL 6

A.2. Impact of the rebate on aggregate sales

When calculating the counterfactuals, we must have an estimate of the outside good. In order for us to be able to use the market shares for the outside good from the actual scenario, i.e. with the rebate, we must ensure that there is no correlation between the rebate and the total sales. We examine the effect of the rebate on aggregate sales by estimating the following equation:

$$\mathbf{ln}(\boldsymbol{sales}) = \boldsymbol{\alpha} + \boldsymbol{\varphi GCR} + \boldsymbol{\beta z} + \boldsymbol{\gamma} + \boldsymbol{\epsilon} \tag{16}$$

Where $\boldsymbol{GCR}$ represents the rebate dummy, $\boldsymbol{z}$ contains demographics[21] and $\boldsymbol{\gamma}$ measures time fixed effects. The results with and without demographics and congestion tax dummy are presented in *Table 32* and *Table 33* respectively. No apparent effect of the rebate on aggregate sales is visible; we can thus use the actual market shares for the outside good when computing the counterfactuals.

OLS 2 Dep. var: ln(totalsales)	**Coefficients**	**Std. Errors**	**P-values**
Green car dummy	0.1990	0.1130	0.084
Time fixed effects	Yes		
R^2	0.2256		
Number of observations	57		

Table 32: Results from OLS 2

[21] CPI and Industrial production index, source: Statistics Sweden.

OLS 3 Dep. var: ln(totalsales)	Coefficients	Std. Errors	P-values
Green car dummy	-0.0033	0 .0617	0.958
Congestion tax dummy	0 .0309	0 .0396	0.439
CPI	1.6605	0 .7852	0.040
Industrial production index	0 .0049	0 .0011	0.000
Potential market (millions)	0 .0023	0 .0003	0.000
Time fixed effects	Yes		
R^2	0.8404		
Number of observations	57		

Table 33: Results from OLS 3

A.3. Counterfactual results for rebate vs. congestion charge

To be able to make a more detailed comparison between the rebate and the congestion tax exemption, we also compute counterfactual market shares based on the results from NL 6.Using these we are able to determine the contribution of the two policies to the sales of alternatively fuelled cars in Stockholm. In *Table 34* we present the increase in market shares related to the two policies separately and jointly.

	Ethanol	Electric hybrids	Vehicle gas
Congestion tax exemption	6%	24%	32%
Green car rebate	3%	-5%[22]	33%
Jointly	10%	17%	74%

Table 34: Impact of the rebate and the congestion tax exemption separately and jointly on the market shares of alternative fuel cars in Stockholm April 2007 to September 2008

A.4. Data adjustments

A.4.1. Sales data

Vroom has adjusted new car registration data to better represent the cars that are actually used by a natural person and that do not serve as demonstration units or alike. For a registration to be included in the data set, the vehicle has to be acquired by a natural person within 30 days of the registration. The sales data is aggregated at the

[22] Not significant.

base model level for each fuel type, i.e. the item Audi A3 gasoline contains all versions of the A3 that are primarily driven on gasoline, and does not specify model year. We define seven different fuel types; gasoline, gasoline for cars classified as green cars, diesel, diesel for cars classified as green cars, ethanol, gas and electric hybrid.

The original sales data has seven observations for each time period, region and model; one for each fuel type. A lot of the observations have a value of zero either because no cars were actually sold or because the model did not exist for that certain fuel type. We drop all the zero-observations regardless of reason.

A.4.2. Car characteristics, price and tax

The characteristics data is on a more disaggregate level than the sales data, since it contains the characteristics by sub-models; there are e.g. 18 different Audi A3 gasoline versions. To be able to combine the characteristics data with the sales data, we have aggregated the characteristics over sub-models and the car characteristics over sub-models and time. Both the price and the vehicle tax are kept on a yearly basis since we know the time for each car registered but not the model year. The reason for treating price and tax differently is that we found the car characteristics to vary significantly less between different model years, than was the case for price and tax. Price and tax are more related to the time of registration than to the specific year model purchased.

As a first step, we drop all sub-models that lack the main characteristics that we initially want to use in our model, namely: price, tax, fuel consumption for mixed driving, carbon dioxide emission, kerb weight, number of doors, number of cylinders, cylinder volume and engine power. As a second step, we aggregate the characteristics to a base model level by taking the median of the sub-models. The sales data does not specify model year, therefore we cannot attribute any year specific car characteristics to these and have taken the median over time for each base model. As a third step, we chose to use the second set of tax rates for 2006 where two different sets were given, one for the beginning of the year and one for the end.

A.4.3. Combining sales data and characteristics

When combining the sales data and the characteristics data, not all sales items found a match. For those who did not find a match, we searched the characteristics of other model groups with certain criteria, enhancing the criteria if still no match was found. First we checked for the same brand, same model and same fuel type but for the following year (since most year models are released on the prior fall); second we checked for the same brand and same fuel type for the same year; next for the same brand and same fuel type for the following year; and finally for the same fuel type the same year (the standard deviation is lower within a population consisting of cars of the same fuel type but different brands than within a population of a certain brand but with different fuel types). To obtain our final complete set of data, we had to classify certain cars as green cars for the period prior the rebate. This was done by checking for all diesel cars with a particle filter and with a maximum carbon dioxide emission of 120 g/km and all gasoline cars with a maximum carbon dioxide emission of 120 g/km. Concerning the alternative fuel cars, (following the same definition as used for the rebate) all fall in the green car category except the electric hybrid cars from Lexus.

A.4.4. Fuel economy and emission data

In the consumer guides, the emission data for ethanol cars is solely based on gasoline driving. According to The Swedish Consumer Agency (2008), there are no official values for ethanol driving. However, in their report on the climate effects of new cars, the Swedish Environmental Protection Agency (2008a) develops a way to calculate emission reduction for newer cars. In their calculations, we find some of the information we need to transform our gasoline based emission data into ethanol based emission data. Firstly, E85 consumption is approximately 35 percent higher than gasoline consumption, according to lab research performed on the most common car model. Secondly, carbon dioxide emissions for E85[23] are 688.3 g/l, regardless if it is sugar cane ethanol or sulphite pulp ethanol. Using this and the data on gasoline consumption from the guides, we can calculate ethanol consumption in l/100km (*gasoline consumption*1.35*) and carbon dioxide emissions in g/km (*ethanol consumption*688.3/100*).

The emission data for gas is based on what is called certification gas, which is the same as fossil gas (Din Bil Stockholm/Hammarby, 2008). Carbon dioxide emissions from fossil gas are appreciated to be 2120 g/m^3 whereas for biogas these are appreciated to 390 g/m^3. The supply of vehicle gas in Sweden consists of both fossil gas and biogas, as well as a mixture of the two. According to Din Bil, the supply is fifty-fifty, which accords with the report by the Swedish Environmental Protection Agency (2008a) which states that in 2007 53 percent of the vehicle gas sold was biogas and 47 percent was fossil gas. The emission data for gas cars is hence not correct since it assumes all cars are driven on fossil gas, thus the general emission levels for gas cars are exaggerated. We therefore re-

[23] Assuming a yearly average mixture of 81% ethanol and 19% gasoline in the E85.

estimate these to be equal to *gas consumption per km*(2120*0.47 + 390*0.53)*, based on the numbers above.

The same adjustments are made when computing the variable for fuel economy, km/kr. For ethanol cars we use the gasoline consumption*1.35 together with the price of one liter of E85. For gas cars we use the gas consumption together with the price of one m^3 of gas.

A.4.5. Data on distances covered

The data on average distances covered are based on the trip mileage counters from all cars in Sweden and the data is collected by the *Swedish Motor Vehicle Inspection Company* during the yearly vehicle inspections. Since this data however is not readily available divided by fuel type and car brand, we were only able to receive data at that detail level for 2007 and this is the data we use in the data set for all years under the assumption that average distances remain fairly stable over our time period. The data is divided by more fuel types than our data set which leads us to aggregate the data for gas and ethanol driven cars. For gas we use the average of all different types of gas, when more than one type is available for a brand and for ethanol we use the average of ethanol and E85 regardless of whether the alternative fuel source is gasoline or diesel.

A.4.6. Market size

Since the numbers for 2008 are not yet published we use the same numbers as for 2007.

A.5. Exchange rate SEK / USD

Figure 13 shows the average monthly exchange rates for SEK / USD based on data from The Riksbank (2009).

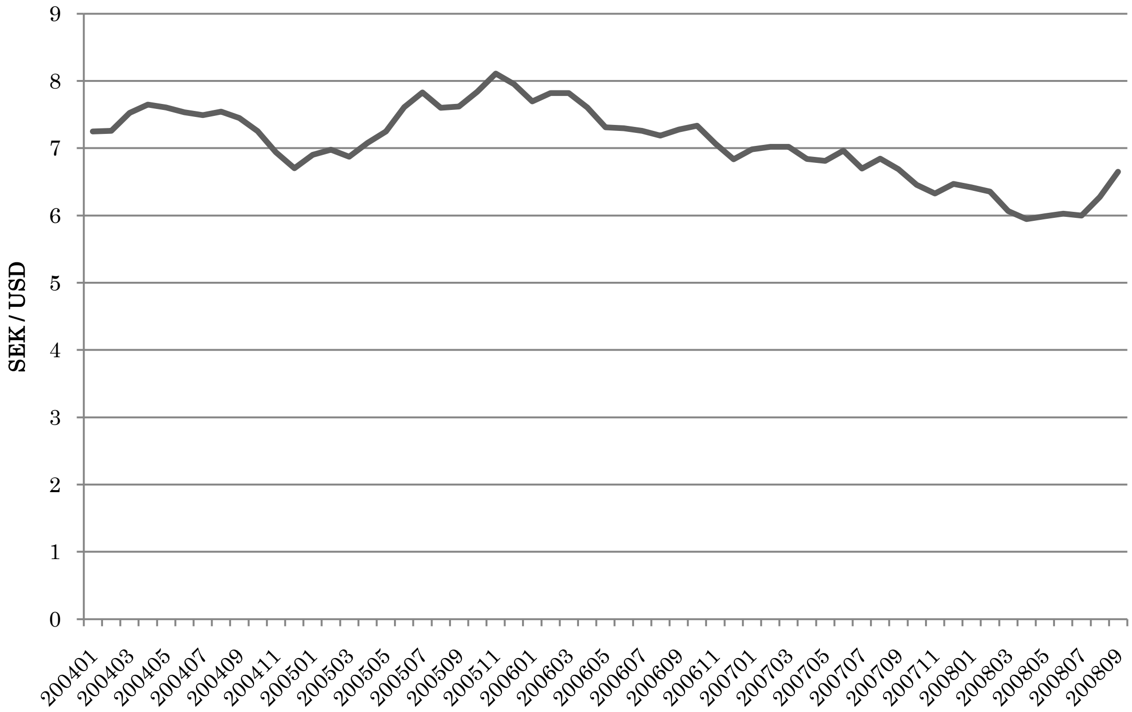

Figure 13: SEK / USD exchange rates from January 2004 to September 2008