

The effects of ethanol availability on market shares of flexi-fuel vehicles

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This thesis examines the relationship between the availability of ethanol to consumers and the sales and market shares of flexi-fuel vehicles, i.e. vehicles that can run on both gasoline and ethanol. We find that increased availability of ethanol leads to higher sales and market shares of FFVs. We also find that higher retail prices of ethanol relative to gasoline prices affect FFV sales negatively. These findings are robust to controlling for other governmental incentives aimed at stimulating demand for alternative-fuel vehicles. The study has been made possible through the so called Swedish pump law, which led to the emergence of an ethanol fuelling network in Sweden during the three year period April 2006 to March 2009.

Key words: ethanol, flexi-fuel, biofuels, pump law

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1. Introduction

For the last decade the need to curb global CO₂ emissions has become an increasingly important part of the political agenda. In one of several attempts to stem the greenhouse effects from personal driving, the European Union has imposed a law forcing the European automobile industry to decrease the average emission of CO₂ from new cars to 130g/km by 2015 (European Union, 2009).

There are essentially two ways to curb the polluting effects from private car use: drive less or drive cars that are less polluting. While technology has brought improvements in fuel efficiency, researchers and politicians agree that a long term solution must involve renewable fuels. Several models of so called flexi-fuel vehicles (FFVs) have been presented, but still remain a relatively rare phenomenon. Researchers and policymakers have been grappling with what has become known as the chicken-and-egg problem of biofuels. In essence, the argument is that without wide availability of biofuels, the utility of biofuel vehicles to consumers is significantly reduced. Without consumer demand there are no incentives for car

makers to market FFVs at any larger scale. Similarly, without a substantial fleet of FFVs, there is no incentive for filling stations to offer ethanol.

In a bid to break this cycle, Sweden in 2005 adopted a new law, requiring gasoline stations with a certain sales volume to offer at least one biofuel by March 2009. The legislation, commonly known as the pump law, brought a sharp increase in the availability of ethanol. The emergence of this ethanol network constitutes the natural experiment on which our study is based.

We propose that an FFV can be described as a consumers' real fuel option: As an FFV can run on both ethanol and gasoline, the owner of an FFV, unlike the owner of a regular car, has the advantage of being able to choose the most attractively priced fuel each time he fills his tank. Two main factors should influence the attractiveness of this option: Firstly, exercising the option requires access to ethanol so the higher the availability, the more likely the owner is to be able to realize his option value. Similarly, the shorter he needs to drive in order to find an ethanol station, the lower is the transaction cost of exercising. Secondly, the higher the price of ethanol relative to gasoline, the further "out of the money" is the option and the lower its value. Taken together, for a given price of acquiring the option, its attractiveness should be positively correlated to the availability of ethanol and negatively correlated to the relative price of ethanol to gasoline. We argue that the same can be expected for FFVs.

The main purpose of this thesis is therefore to investigate the relationship between the availability of ethanol to consumers and the sales and market shares of FFVs. In addition, we test the extent to which the price of ethanol relative to gasoline affects FFV sales. Our primary and secondary research questions are:

1. *Does an increase in the availability of ethanol to consumers lead to an increase in the sales and market shares of FFVs?*
2. *Does the relative price of ethanol to gasoline affect sales and market shares of FFVs?*

While the literature to date appears to take the link between biofuel availability and biofuel demand for granted, the only study known to us that formally tests this relationship is Corts (2009). However, Corts study represents the opposite case to ours as he examines the

potential of starting with a government driven increase in demand for ethanol. Using the natural experiment created by the Swedish pump law, our research contribution consists in formally studying the potential of the opposite strategy, namely to start with supply as a way of stimulating demand.

2. Background

2.1 Flexi-fuel vehicles

FFVs are vehicles designed to run on gasoline and an alternative fuel, typically bioethanol¹. The internal combustion engine of a FFV differs from that of a traditional car in automatically adjusting fuel injection and spark timing. This allows the engine to run on any blend of bioethanol and gasoline (BEST, 2010). However, as will be described in more detail below, most FFVs are optimized to run on a mixture of 85% gasoline and 15% bioethanol, commonly known as E85. Apart from FFVs' lower mileage per gallon, resulting from ethanol's lower energy content relative to gasoline, there are no significant differences in vehicle performance.

FFVs are distinguished from bi-fuel vehicles (BFVs), which store two types of fuels in separate tanks, commonly gasoline and compressed natural gas. Unlike FFVs, bi-fuel vehicles only run on one fuel at a time. FFVs are also distinguished from hybrid electric vehicles (HEVs), which combine a conventional internal combustion engine with an electronic propulsion system. The split between different types of cars can be seen in Figure 1. The development of newly registered cars and the fleet of cars over time can be seen in Figure 2 and 3.

¹ Throughout this thesis, FFV refers to a car that can burn gasoline and ethanol.

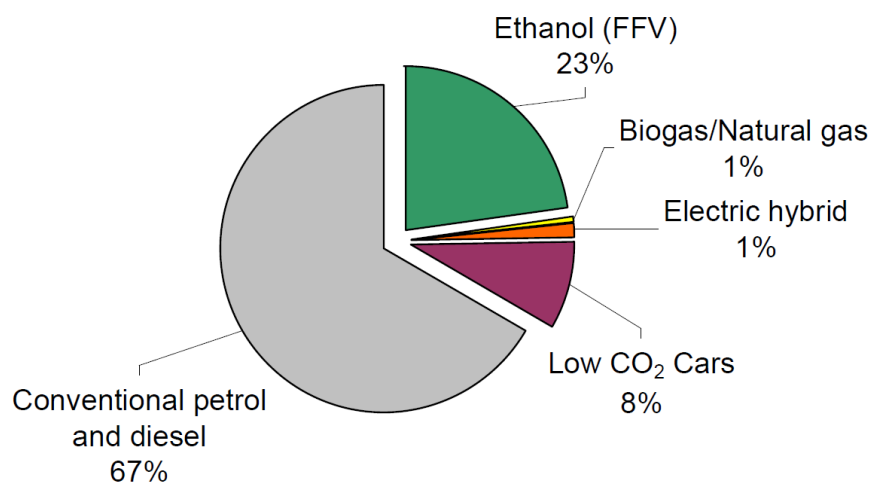


Figure 1: Share in new registrations in Sweden 2008. Low CO₂ cars are those with CO₂ emissions of less than 120g/km. Source: BilSweden

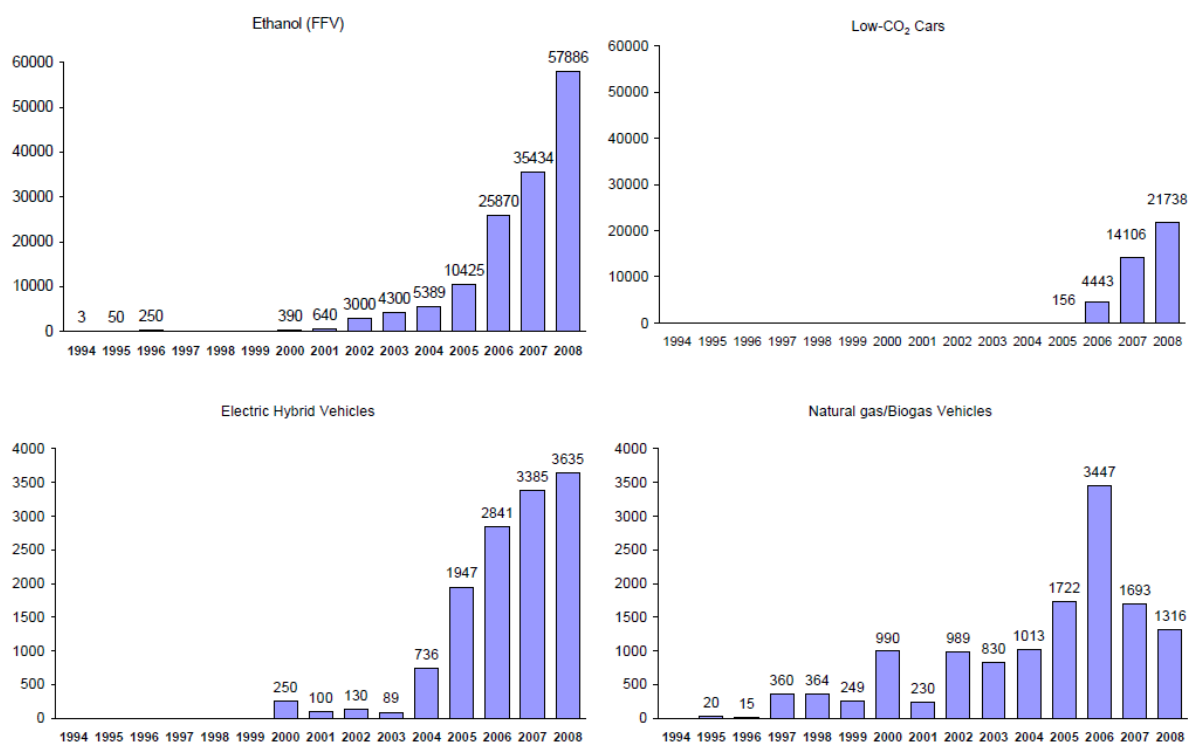


Figure 2: New registrations of clean passenger cars in Sweden. Low CO₂ cars are those with CO₂ emissions of less than 120g/km. Sources: Statistics Sweden (SCB), BilSweden, Svenska gasföreningen

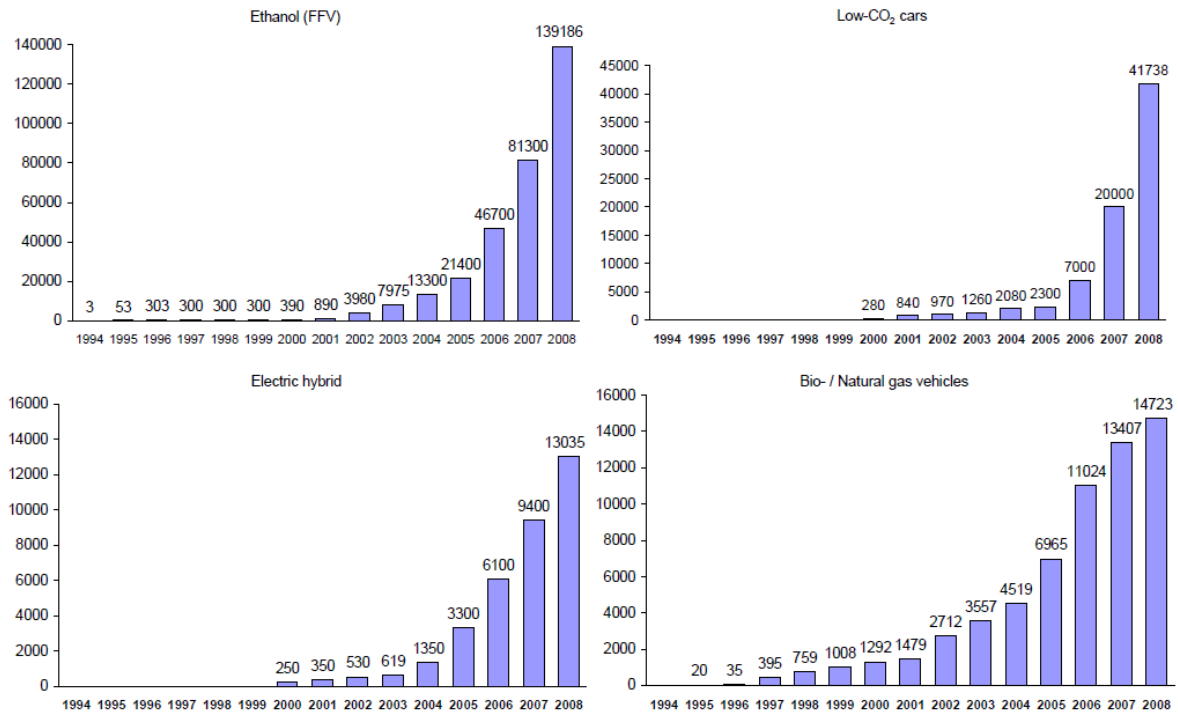


Figure 3: Total fleet of clean passenger cars in Sweden (2008 equals stock 2007 plus new registrations 2008). Low CO₂ cars are those with CO₂ emissions of less than 120g/km. Sources: Statistics Sweden (SCB), Miljöfordon.se, Svenska gasföreningen, BilSweden

2.2 Ethanol as a fuel

Unlike gasoline, ethanol is a renewable source of energy as it can be produced from agricultural feedstock such as sugar cane, potato and corn. About 60% of all ethanol used as fuel in the world is made from sugar cane. In Sweden, approximately 90% of the ethanol is imported. There are two companies in Sweden producing ethanol in a larger scale, mostly based on grain (Committee on Transport and Communications, 2009).

The most common form of ethanol-based fuel, both in Sweden and globally, is E85 – a blend of 15% gasoline and 85% ethanol. Gasoline has a lower freezing point than ethanol. That is why, in colder regions such as Sweden, the mix is adapted to winter conditions by increasing the gasoline component to 25% (E75). Regular gasoline sold in Swedish filling stations typically contains around 5% ethanol. Blends of more than 10% ethanol require a specialized engine, such as those used in FFVs.

Ethanol contains approximately 30% less energy per unit volume than gasoline. Therefore, in theory, mileage per liter is lower for E85 than for unleaded gasoline. Consequently, driving on E85 also requires more frequent refueling. Compensating for the lower energy content, FFVs are up to 26% more energy efficient than gasoline engines (BEST, 2010). Figure 4 shows the sales price of ethanol compared to gasoline and diesel.

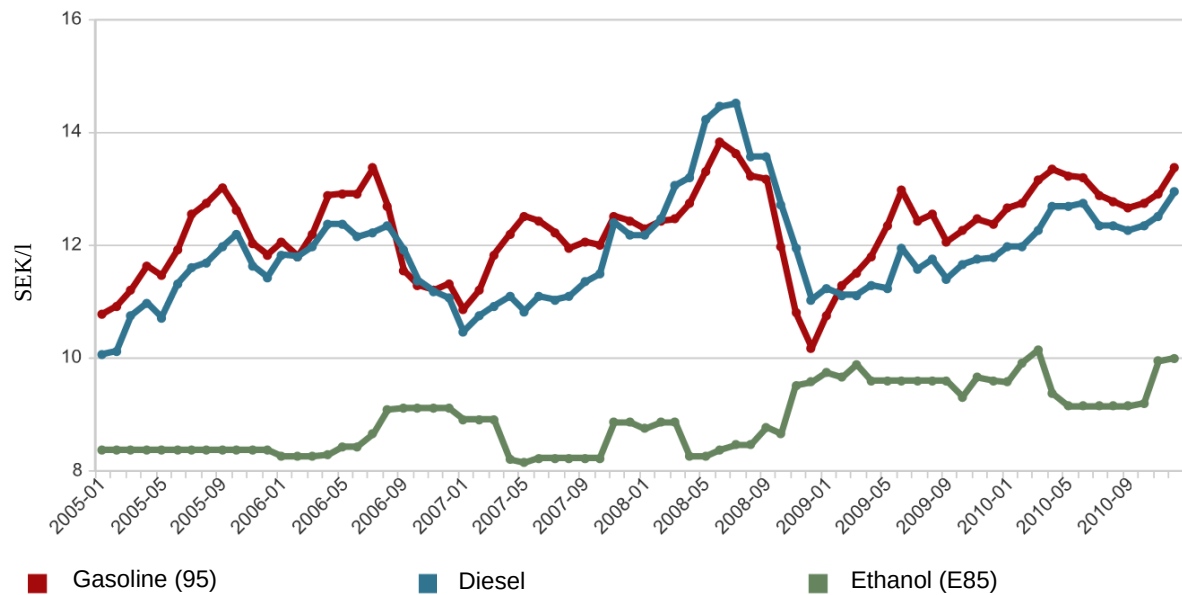


Figure 4: Average sales price at staffed station for gasoline, diesel and ethanol. Source: Swedish Petroleum Institute (SPI)

2.3 The pump law

In December 2005 the Swedish parliament passed the legislation commonly known as the pump law (SFS 2005:1248). The stated purpose was to reduce the emissions of carbon hydrates by expanding the availability of biofuels. No financial support was given from the state for installation of ethanol pumps. For stations that instead installed biogas, a contribution of up to 30% of the investment cost was available from the Environmental Office. Despite this, due to the several times higher installation costs of natural gas pumps, the vast majority of stations chose ethanol and a significant part of the governmental grant funds has not been used (Committee on Transport and Communications, 2009). The effects of the pump law on fuelling infrastructure will be discussed below.

The law was implemented in four steps where all stations with annual sales volumes in excess of 1000 m³ of diesel or gasoline were required to offer at least one biofuel by March 2009. The implementation stages were as follows:

Stations with annual sales in excess of:	During year:	Required to offer biofuel by:
3,000 m ³	2004	1 st April 2006
2,500 m ³	2005	1 st March 2007
2000 m ³	2006	1 st March 2008
1000 m ³	2007	1 st March 2009

Table 1: Implementation stages of the Pump Law

The Swedish Transport Agency can in certain cases grant a time limited dispense from the requirements to offer a biofuel if certain conditions apply. Decisions by the Transport Agency can be appealed to the Administrative Court (SFS 2005:1248). From March to December 2009, 650 applications were submitted to the Transport Agency, whereof a majority was granted dispense. Of those which were refused, 24 were appealed to the Administrative Court (Committee on Transport and Communications, 2009).

2.4 The Swedish fuelling infrastructure and the impact of the pump law

With approximately 3250 stations nationwide by yearend 2009, the Swedish fuel retail market is dominated by four large chains, together comprising roughly 65% of all stations. OKQ8 stands out as the single largest chain with approximately 25% market share in 2010. Figure 5 below provides a market overview by brand where *other* represents the stations not captured in our data. In 2008 approximately 50% of all stations were both owned and operated by an oil company. The second most common structure is to have an oil company owning the station, but a private dealer operating it. A small minority of stations are entirely independent from the major chains (Committee on Transport and Communications, 2009).

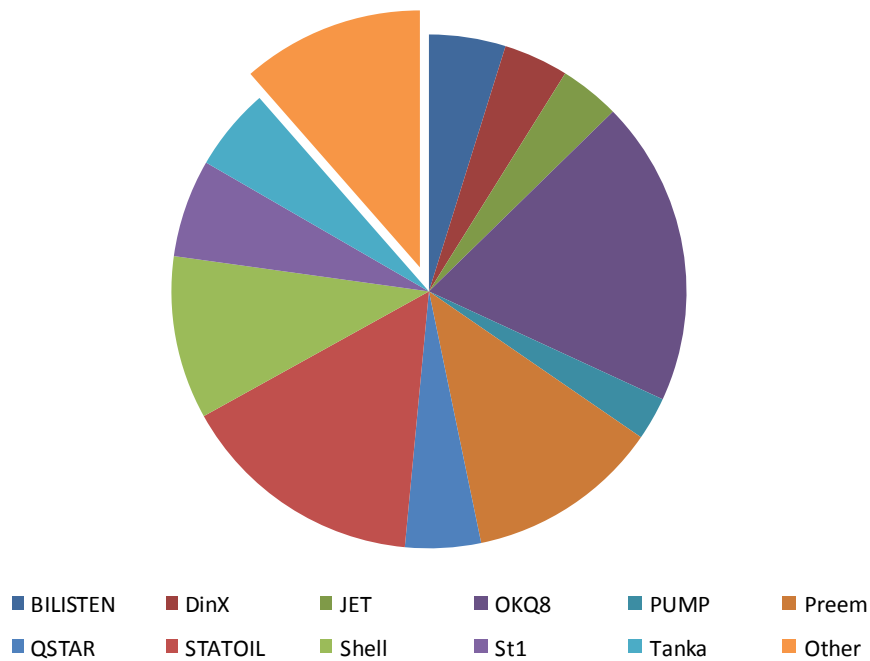


Figure 5: Filling stations by brand in Sweden 2009. Source: Each respective oil company and the Swedish Petroleum Institute (SPI)

Swedish filling stations are broadly classified into four categories: automated stations, staffed stations, staffed service stations and single units. Staffed service stations differ from regular stations in offering other car related services such as car wash. Single units are single pumps connected to mechanical workshops or grocery outlets. Gasoline prices are typically 0.1-0.25 SEK cheaper per liter in automated stations compared to staffed stations. There is no data to suggest that the distribution of automated vis-a-vis staffed stations should not be evenly distributed regionally in Sweden. However, the share of automated stations of total stations has increased following the decline in total number of stations. The development of stations by type and fuel offered over time can be seen in Figure 6 and Figure 7.

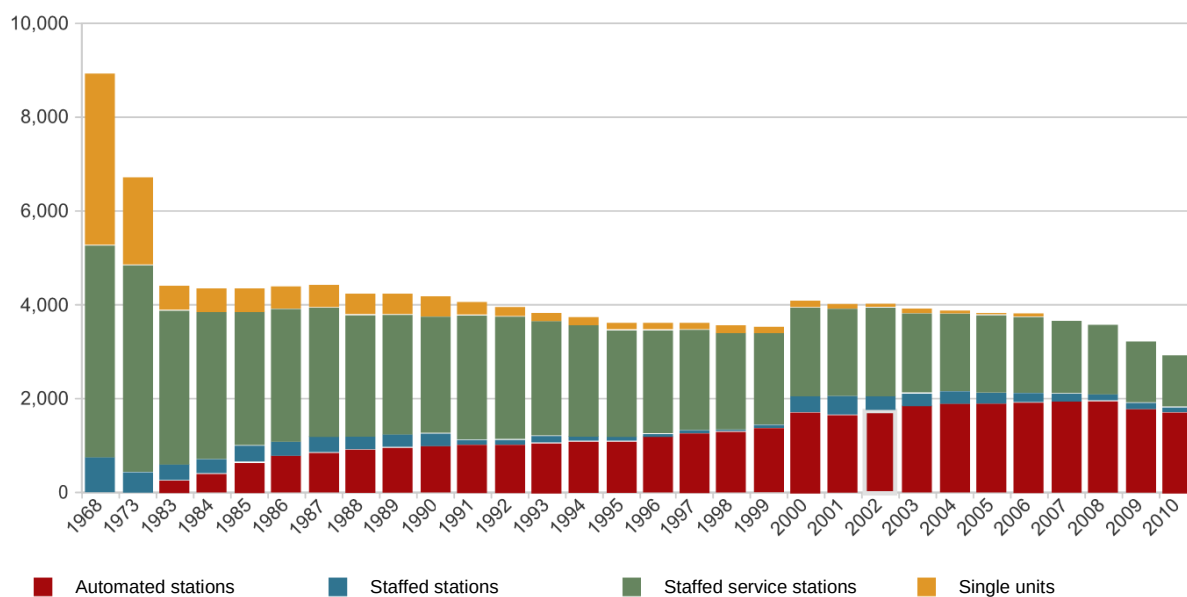


Figure 6: Number of filling stations by type in Sweden. Source: Swedish Petroleum Institute (SPI)

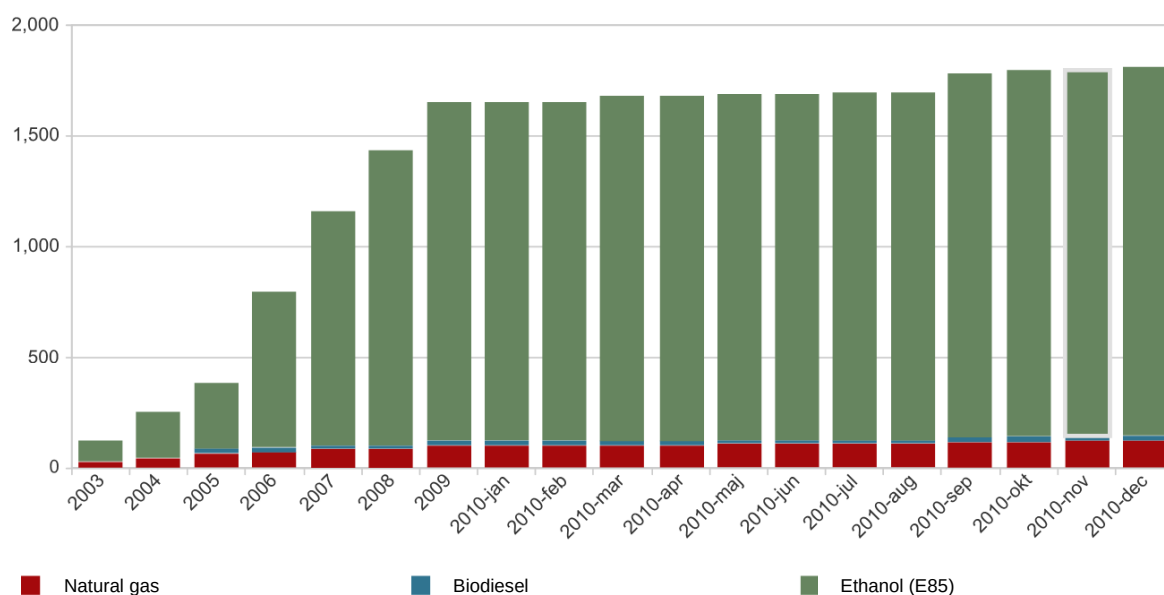


Figure 7: Number of filling stations by fuel offered in Sweden. Source: Swedish Petroleum Institute (SPI)

As can be seen in figure 6, the number of filling stations in Sweden has been declining from just over 4000 in early 2000 to around 3000 in 2010. The reason for the decline has been subject to public debate with critics blaming the pump law for forcing small station owners out of business (Committee on Transport and Communications, 2009). As part of this critique, it has been argued that the reduction in stations has been disproportionately larger in rural areas. According to the Swedish Ministry of Enterprise, Energy and Communications (2009) there is no data to support claims that the pump law is the root cause of the decline in

filling stations or that the decline should be worse in non-urban areas. Instead, structural changes in the industry following historical oversupply and diminishing profitability are said to be the main drivers. According to a report from the Swedish government evaluating the effects of the pump law, the stations to which the installation costs of an ethanol pump could force a closing of the business, are typically those owned and operated by private entrepreneurs, i.e. not connected to a major oil company (Committee on Transport and Communications, 2009). As the independent stations tend to be small, the vast majority of them fall below the limit of 1000 m³ of annual sales, and thus are not affected by the pump law.

2.5 The economy of selling ethanol

The Swedish Head of Sales at one of the four largest Nordic oil companies stated in a personal interview that offering ethanol is not in itself commercially viable and would not have been widely undertaken voluntarily by the oil companies in the foreseeable future had it not been for the pump law. The main reason given was the lack of scale in demand, i.e. the insufficient volume of ethanol that can be sold in relation to the cost of installing an ethanol tank and pump. According to the same source, the investment cost of installing a new ethanol pump is at least 200,000 SEK, but may be significantly higher if a new tank must be installed. The notion that gasoline stations did not voluntarily start to offer ethanol and that the pump law therefore was the root cause of the increased supply of ethanol is important to our study as it indicates that ethanol availability is exogenous. We later test this statistically.

2.6 Other incentives for stimulating demand for FFVs

The pump law is one of many incentives introduced by the Swedish government to increase the use of biofuels. The perhaps most well-known is the green car rebate, a 10,000 SEK rebate for buyers of new, so called green cars (SFS 2007:380). Green cars include FFVs that have a maximum mixed fuel consumption of 9.2 liter gasoline/100km, BFVs that have a maximum mixed fuel consumption of 9.7 m³ gas/100km and HEVs that have a maximum energy consumption of 37 kWh/100km. Green cars also include gasoline and diesel cars with a maximum CO₂ emission of 120g/km. The 10,000 SEK was paid out to the owner of the car at the earliest six months after the purchase. The green car rebate was introduced on 1st April

2007 and ended on 30th June 2009. It was then replaced by exemption from vehicle tax for green cars for the first five years after the car is first used in Sweden (Ministry of the Environment, 2009a).

Furthermore, car models from 2006 and onwards and cars belonging to the environmental classes 2005, electricity or hybrid, are taxed based on their CO₂ emission and fuel type (SFS 2006:227). This implies lower taxes for green cars, due to their typically lower CO₂ emissions. Other cars are taxed based on their kerb weight and fuel type. Owners of FFVs and BFVs also benefit from lower fuel prices since ethanol and gas are exempt from energy and carbon tax (Swedish Energy Agency, 2009).

In the Stockholm County, FFVs, BFVs and HEVs registered before 1st January 2009 are exempt from the congestion tax. The tax was first introduced as a trial from January to July 2006 and then permanently from August 2007 and onwards (SFS 2004:629).

In addition, there are a number of regional benefits for owners of FFVs, e.g. rebate on parking. Finally, there are future incentives to come, such as continued vehicle tax exemption and a new “super green car rebate” of 40,000 SEK for the most fuel efficient cars (Ministry of the Environment, 2009b). However, the details of these suggestions are not yet decided.

A significant part of the governmental incentives that has been introduced in Sweden to stimulate the transition to renewable fuel is focused on demand, i.e. on motivating consumers to choose to buy and use vehicles powered by renewable fuel. The pump law represents the first example of targeting supply (Committee on Transport and Communications, 2009).

3. Previous research

Firstly, we examine the literature on fuel availability and its implications on car fleets. Related to this, we also look at a number of studies focusing on so called indirect network effects outside the car industry. Secondly, we review the literature on vehicle choice. We are especially interested in finding what factors previous research has shown to explain consumers’ choice of car as we need to control for such factors when analyzing the impact of

fuel availability. The econometric literature on modeling of consumer demand for differentiated products, such as cars, will be addressed in the methodology section.

3.1 Fuel availability and indirect network effects

Corts (2009) studies the impact of government fleet composition on retail alternative fuel infrastructure in the US. He shows that government fleet adoption of FFVs leads to an increase in retail E85 stations. His findings persist when using instrumental variables to control for the endogeneity of government FFV purchases. Corts describes the market for FFVs as being characterized by indirect network effects similar to those present in hardware-software markets, and refers to the inherent chicken-and-egg problem.

The idea of network effects has been addressed in several studies in the field of industrial organization. Gandal (2005) distinguishes between direct and indirect network effects. The former occurs when an increase in the number of consumers on the same network raises the consumption benefits for everyone on the network. Examples are communication networks such as telephone and email. The latter, which is more relevant to our case, is typically observed in hardware-software markets where the benefits of the hardware good increase in the variety of compatible software. The indirect network effect occurs as an increase in the number of hardware users increase the demand for software, which in turn increase the supply of software and, consequently, the benefits of the hardware (Katz and Shapiro, 1985). Farrell and Klemperer (2007) describe indirect network effects as improved opportunities to trade with the other side of the market; i.e. a buyer prefers being joined by more buyers as more buyers attract more sellers and the gain from increased supply off-sets the raised prices that follows from increased demand. They note that network effects create incentives to herd with other consumers and that this results in chicken-and-egg or critical mass behavior.

Clements and Ohashi (2005) examine the importance of indirect network effects in connection to the product cycle in the US video game market. They follow the approach developed by Nair et al. (2003), who measure the indirect network effects in the market for Personal Digital Assistants and compatible software. Nair et al. describe well-functioning indirect networks as *virtuous cycles*. In our setting, the availability of ethanol can be seen as the software and the FFVs as the hardware. An increase in the availability of ethanol, i.e. in the number of filling stations offering E85, increase the benefits of owning a FFV, while an

increase in the number of FFVs can be expected to increase the demand for ethanol. Note however that the analogy is not perfect as the hardware-software case refers to the *variety* of software compatible with a given hardware, whereas the ethanol case refers to the *geographical availability* of ethanol.

The link between fueling infrastructure and the use of biofuels is further discussed in Di Pascoli et al. (2001). Although focusing on natural gas powered vehicles (NGVs) rather than FFVs, they conclude that a major disadvantage of biofuel powered vehicles to consumers is the low density and uneven distribution of refueling networks. Parry et al. (2007) discuss the nature and magnitude of adverse externalities associated with automobile use and point out E85 as one of the potential solutions. In particular, they bring up the difficulty of building an alternative fueling infrastructure and that this hinders the increased consumption of alternative fuels. Kuby and Lim (2007) present a theoretical framework for designing fueling networks for alternative fuels. While the link between fueling infrastructure and adoption of alternatively fueled vehicles seem to be a presumption in all three abovementioned studies, we have not found any paper, except for Corts (2009), that specifically analyze the empirical evidence of this link. Notably, Corts' study represents an opposite case to ours; while he studies the effect of creating demand to stimulate supply, we examine the effect of creating supply to stimulate demand. We believe the reason for the lack of research in this area to be the scarcity of empirical data. Especially, the Swedish pump law represents a unique case of supply-side attempts to create a virtuous cycle in the biofuel market.

3.2 Vehicle choice and the importance of fuel prices

Busse, Knittel and Zettelmeyer (2009, hereafter BKZ) investigate the effects of gasoline prices on sales of new and used cars. They match consumer level data on individual new car purchases with monthly zip code level gasoline prices. They find that gasoline prices are positively correlated to the market share of fuel efficient and small cars but negatively correlated to the sales of fuel inefficient and larger cars. The change in market share is significantly higher for new cars, whereas the change in prices paid is significantly higher for used cars. The authors discuss differences in supply characteristics for new and used cars as possible explanations for the different effects. When regressing market shares on fuel price, BKZ include a number of demographic controls such as income, house value and ownership,

household size, vehicles per household, education, occupation, average travel time to work, English proficiency, and race of buyer. Their definition of a car model is based on the parameters make (brand), model, model year, trim level, doors, body type, displacement, cylinders, and transmission. Fuel price is specified to the month and geographic region in which the respective vehicle was purchased.

Train and Winston (2007, hereafter TW) examine the influence of vehicle attributes in explaining the decline in market shares of US car manufacturers in the last decade. TW develop their own consumer-level model of vehicle choice, criticizing the approach taken by Berry (1994) and Berry, Levinsohn, Pakes (1995, hereafter BLP), which is also the approach we adopt in our analysis. As will be developed further in the methodology section, BLP introduces an outside good which represents all the alternatives that a consumer has to buying any of the available new car models (e.g. buy a used car or abstain from purchase). TW argue that this approach is problematic as it is difficult to specify attributes to the outside good, i.e. unobserved consumer tastes will affect a consumer's assessment of the outside good just as it will his assessment of an inside good. To solve this problem TW study vehicle choice conditional on having bought a car, by sampling the preferences of car buyers through a customized survey. Such data is not available in our case. TW find that the loss in market share can be almost entirely explained by relative changes in the basic attributes: price, size, power, operating cost, transmission type, reliability and body type. The authors argue that the effect of unobserved consumer tastes is trivial and that efforts aimed at controlling for such parameters are needless. TW do not explicitly distinguish between cars burning different fuels. It is therefore possible that their conclusion that unobserved preferences are trivial does not extend to consumer choice between a biofuel and non-biofuel powered vehicle. This notion is supported by the responses to a 2009 survey in Stockholm (BEST, 2010) in which clean car buyers stated their own environmental impact as the most influential factor in their choice of vehicle.

4. Data

4.1 Car sales data

Our car sales data comes from Vroom, a consulting firm specialized on the car market. It contains the number of cars of a certain brand, model and fuel type sold in each month in

each region (sv. län) from January 2007 to December 2009. The data includes only cars sold to consumers, i.e. excludes company owned cars. Data on total car fleet per region has been collected from Statistics Sweden (SCB).

4.2 Ethanol availability

Our ethanol availability data comes from the large filling station companies in Sweden.² We have collected data for each individual station, including if the station offers ethanol and in that case in what month it first became available. We aggregate this data by region to get total number of E85stations by region and month. In the rare cases where the exact month for the introduction of ethanol could not be obtained we assumed it to be simultaneous to the pump law deadlines (see section 2.3). Note that the data on total number of stations represents a December 2009 snapshot. Total number of stations per region as per January 2007 has been obtained from the Swedish Agency for Economic and Regional Growth (Erik Fransson, 2010). As we have not been able to obtain any data on total number of stations per region between January 2007 and December 2009, we have interpolated the total number of stations per region between these dates. We recognize that this introduces a large element of uncertainty in our data. However, the total number of stations only enters our model through what shall later be described as availability measure 1 and, as will be further discussed below, is not relevant to our final findings and conclusions.

4.3 Fuel prices

Our real fuel price data is collected from Bensinpriser.se, a user generated website to which consumers voluntarily submit data on real fuel prices per filling station through mobile text message or email. The data contains daily prices for individual filling stations. We aggregate this data to median prices per region and month.

4.4 Car characteristics

The car characteristics data comes from the consumer guides Nybilsguiden 2007-2009 from The Swedish Consumer Agency. The data contains model specific characteristics for all models sold in Sweden on a yearly basis.

² OKQ8, Statoil, St1, Preem, Shell, Pump, Qstar, Jet, din-X and Bilisten.

4.5 Regional characteristics

We collect regional demographic data from Statistics Sweden (SCB). The demographic data include population size, population density, income levels, gender distribution and various measures of education.

4.6 Additional data

To make car and fuel prices and vehicle tax comparable over time, we deflate them using the Consumer Price Index supplied by Statistics Sweden (SCB). For a more detailed description of adjustments that have been made to this data, please see Appendix A.1.

5. Methodology

5.1 The car market

To assess the effects of fuel availability on vehicle market shares we need to consider certain particular attributes of the car market. First of all, a car is a differentiated product implying that demand may be determined by several other factors apart from price. This means that models for homogenous products are not applicable. Secondly, the car has unobserved characteristics which affects demand. Examples these are style and reputation. Thirdly, the car industry more resembles an oligopoly with price-setting firms than a perfectly competitive market. Finally, it is only possible to buy a whole car, which requires the use of a discrete-choice model. Considering all these attributes, we will use a standard instrumental variables regression that allows for unobserved characteristics. This model was developed by Berry (1994) and applied to the automobile market by Berry, Levinsohn and Pakes (1995).

5.2 Model specification

Our data is organized into a large number of independent markets, R , which are combinations of regions and time periods. In each market there are N firms, each selling one product, j , which is a certain car brand of a certain model with a certain fuel type (e.g. Audi A3, gasoline). Note that the term firm here is product specific and therein differs from the standard definition under which firm would be synonymous to brand. For product j in market r , observed characteristics, including price, are denoted x_{jr} . Unobserved characteristics are

denoted ξ_{jr} . The unobserved characteristics in a market are assumed to be mean independent of the observed characteristics and independent across markets.

Demand is estimated using a utility function, where the consumer chooses to buy the car that maximizes that individual consumer's utility. The level of utility that the consumer derives from that car is a function of both individual and product characteristics. In Berry's model, the utility u of consumer i for product j is given by

$$u_{ijr} = x_{jr}\tilde{\beta}_{ijr} + \xi_{jr} + \varepsilon_{ijr}. \quad (1)$$

where ξ_{jr} can be thought of as the mean of consumers' valuations of unobserved product characteristics and ε_{ijr} represents the distribution of individual consumer preferences about this mean. If we assume the error term, ε_{ijr} , to be mean-zero, the mean utility level, δ , of product j in market r is

$$\delta_{jr} \equiv x_{jr}\beta + \xi_{jr}. \quad (2)$$

Equation (2) effectively allows us to estimate the market shares of each firm based solely on their respective mean utilities, where the unobserved characteristics alone constitute the error term. This is useful as we only have data on market level but not on individual level and cannot observe ξ .

5.3 Market definition and the outside good

Alternative to the “inside” goods $j = 1, \dots, J$ offered by the N firms, consumers might decide to buy an “outside” good, $j = 0$. The outside good can be interpreted as buying a used car or not to buy a car at all. In the absence of an outside good, consumers would have to buy one of the inside goods and a general increase in prices would not decrease aggregate output. However, the presence of the outside good means that observed output quantities of the N firms are not sufficient to calculate market shares of the $N+1$ alternatives. The total market can either be observed or estimated based on population. BLP (1995) set total market size equal to the number of households in the economy. However, we study the demand of individual consumers instead of households. 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 200,000 SEK or

more. We assume that these consumers buy a new car on average every fifth year, thereby dividing our numbers by 60 (5 years*12 months). 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 products in the market. Finally, the price of the outside good is assumed not to be correlated with the price of goods sold by the firms.

5.4 The logit model

The best-known special case of how to solve for mean utility levels as a function of observed market shares is with the logit model (Berry, 1994). Given the utility function defined in equation (1), the market share of product j is given by the multinomial logit formula

$$\zeta_j(\delta) = e^{\delta_j} / (\sum_{k=0}^N e^{\delta_k}). \quad (3)$$

With the mean utility of the outside good normalized to zero the mean utility of product j is

$$\ln(s_j) - \ln(s_0) = \delta_{jr} \equiv x_{jr}\beta + \zeta_{jr}, \quad (4)$$

which is equivalent to

$$\ln(s_j / s_0) = x_{jr}\beta + \zeta_{jr}, \quad (5)$$

where s_j is the observed market share of product j , s_0 is the observed market share of the outside good and $\ln(s_j/s_0)$ is an expression for consumer mean utility for product j , hereafter denoted *meanu*.

5.5 The regression equation

Armed with the estimated demand for the respective products ($j=1..J$) we can formulate our regression equation as

$$\begin{aligned} \text{meanu}_{jrt} = & \alpha + \beta_1 \text{EA}_{rt} * \text{FFV}_{jrt} + \beta_2 (\text{P}_e/\text{P}_g)_{rt} * \text{FFV}_{rt} + \beta_3 c_{jrt} + \beta_4 f_{rt} + \beta_5 f_{rt} * \text{FFV}_{jrt} + \beta_6 g_{jrt} \\ & + \beta_7 g_{jrt} * \text{FFV}_{jrt} + y_{jrt} + \varepsilon_{jrt}, \quad (6) \end{aligned}$$

where FFV is a dummy variable which takes the value 1 if the car is a FFV and 0 otherwise, EA is a measure of ethanol availability, c contains the various products specific controls, f contains the region specific controls, g contains the dummies for rebates and tax exemptions (incentives) and y contains various fixed effects. The effect of ethanol availability on market shares of FFVs, β_2 , is of primary interest. Note that we include interactions of the FFV-dummy and the regional controls and incentive dummies respectively. To improve

readability, the index r,t which refers to region r in month t is henceforth dropped as it applies to every factor in every equation.

5.6 Variables

5.6.1 Ethanol availability and FFV dummy

We use three different measures of ethanol availability. As using only total number of ethanol stations per region and month would mean disregarding the heterogeneity between regions, we construct the following three measures:

Name	Description	Syntax
Measure 1	Number of ethanol stations divided by total number of stations	percente85sta
Measure 2	Number of ethanol stations per 1000 cars in car fleet*	e85sta_per1000cars
Measure 3	Number of ethanol stations per 1000 people	e85sta_per1000cap

* Car fleet includes only privately owned vehicles, i.e. excludes vehicles owned by legal entities.

Each of the availability measures is interacted with the FFV dummy. This allows us to separate the effect of ethanol availability on the market share of FFVs in particular.

5.6.2 Fuel prices

As discussed above, research has shown that fuel prices impact consumer vehicle choice. In the case of FFVs, car owners have the option to at any point choose the cheapest of E85 and gasoline. Lower prices on E85 relative to gasoline increase the benefits of an FFV and therefore the market share of FFVs could arguably be positively correlated with a lower relative price of ethanol to gasoline. We include a fuel price ratio $(P_e/P_g)_{rt}$ which is the ratio of the median ethanol price over the median gasoline price in region r and month t . As with ethanol availability, the fuel price ratio must be interacted with the FFV dummy for us to estimate the effect on FFVs in particular. The price ratio is adjusted for the lower energy content of ethanol by multiplying ethanol price by a factor 1.3 during summer months (E85)

and 1.26 (E75) in winter months (BEST, 2010). The ratio is also adjusted for the fact that the E75 period differs in length across regions.³

5.6.3 Control variables

Car characteristics

We further include a number of car characteristics that we deem relevant to consumer vehicle choice. Based on BLP (1995) we include: recommended sales price, vehicle tax, CO₂ emission, kerb weight, number of doors, number of cylinders, engine size (cylinder volume), engine power (effect) and fuel economy. Fuel economy is calculated as $1/(\text{fuel consumption} * \text{recommended fuel price})$ km/SEK, which enables comparison between cars with different fuel types.

Population characteristics

Population characteristics are used to control for demographic differences across regions. These are mainly based on Corts (2009) and specifically include population, income, and population density. Interacting each of these variables with the FFV dummy allows us to control for the effect of each characteristic on the market shares of FFVs in particular. Our dataset also includes a number of other demographic variables such as various education measures and gender distribution, which have been excluded as they either dropped or proved insignificant in early regressions.

Incentives for green cars

A dummy for the green car rebate is 1 for all green cars from April 2007 and onwards, and 0 for all others. A dummy for the congestion tax exemption is 1 for all alternative fuel cars (not those green cars that are gasoline or diesel with max 120 g/km of CO₂ emission) in Stockholm for the period January 2006 to July 2006 and from August 2007 and onwards, else 0. To control for the effect that these incentives have had on FFVs in particular, we include interactions of each individual incentive dummy and the FFV dummy.

5.6.4 Fixed effects

We further use dummies to control for regional fixed effects and time fixed effects. Regional fixed effects could for example be that ethanol may be less appealing in colder regions given its higher freezing point. Similarly, for time fixed effect, consumers may be less inclined to

³ Winterblend (e75) is offered Nov 1 – Mar 15 in Götaland/Svealand and from Oct 16 – Mar 31 in Norrland. (OKQ8, 2010)

purchase FFVs in the cold months of the year. Brand and model dummies control for preferences for certain cars not related to the included car characteristics. Finally, fuel type fixed effects for all 8 fuel classes are included to capture differences between fuel types, e.g. systematic differences in market shares.

5.7 Instrumental variables

Unobserved characteristics can encompass everything that market participants can observe but the econometrician cannot, e.g. style, reliability, safety etc. If producers know the unobserved characteristics, then prices of cars are likely to be correlated with these characteristics (BLP, 1995). This results in endogeneity of prices and upwardly biased own-price elasticities. In homogenous markets this problem can be solved by using instrumental variables. In discrete-choice models though, both prices and unobserved characteristics enter demand equations in a nonlinear fashion, which disables the use of instruments. However, with demand estimated from the mean utility levels as in Berry's model, instrumental variables can again be applied (Berry, 1994).

An instrument is a variable that is correlated with the endogenous variable, in this case price, and uncorrelated with the error term, in this case the unobserved product characteristics. The method is applied in two regressions (called two-stage least squares, 2SLS). In the first stage, the instrument is an independent variable and the endogenous variable is the dependent, meanu:

$$p_j = \pi_0 + \pi_1 z + \pi_2 EA_j * FFV_j + \pi_3 (P_e/P_g) * FFV + \pi_4 c'_j + \pi_5 f + \pi_6 f * FFV + \pi_7 g_j + \pi_8 g_j * FFV + y_j + \varepsilon_j, (7)$$

where p is price, z is the instrument and c' are the controls as before except for price.

In the second stage regression, the variables are the same as in the usual regression (6) except that the price variable is replaced by the fitted values from the first stage regression,

$$meanu_j = \alpha + \beta_1 EA * FFV_j + \beta_2 (P_e/P_g) * FFV + \beta_3 \hat{p}_j + \beta_4 c'_j + \beta_5 f + \beta_6 f * FFV + \beta_7 g_j + \beta_8 g_j * FFV + y_j + \varepsilon_j, (8)$$

BLP (1995) suggests three instruments for each exogenous car characteristic:

1. the car characteristic itself
2. the sum of the characteristic across all own-firm products
3. the sum of the characteristic across competitors' products

We run the above specification (equations 7 and 8) for all instruments suggested in points 1-3 to find optimal instruments. As a rule of thumb, one seeks to obtain price elasticities which are negative, as price and demand are negatively correlated, and larger than 1 in absolute terms. This can be understood through the equation $(p-c)/p = 1/|E|$, where p is price, c is cost and E is elasticity. If one assumes that the price must be larger than the cost, $p > c$, and that the margin must be smaller than the price, $p-c < p$, we get $E > 1$.

5.8 Nested logit

A limitation of the logit model is that it tends to produce unrealistic cross-price elasticities. This occurs as it fails to relate the cross-price elasticity between two products to their difference in attributes. We address this problem by introducing a nested logit model. All cars are then divided into classes, or nests, and the market share within the own nest is added to the model as an explanatory variable [lnsjg1]. We divide all cars into four classes (quartiles), based on engine power [effect]. For the nested logit to be regarded as an improvement over the logit, the nest coefficient must fall in the range 0 to 1 and be significantly different from both 0 and 1. The nested logit regression equation is an adaptation of the instrumental variables equations (7) and (8) but with the addition of the nest variable, or nest share, and a second instrument for the same. The specification used is:

$$p_j = \pi_0 + \pi_1 z_j + \pi_2 EA_j * FFV_j + \pi_3 (P_e/P_g) * FFV + \pi_4 c'_j + \pi_5 f_r + \pi_6 f_r * FFV + \pi_7 g_j + \pi_8 g_j * FFV + y_j + \varepsilon_j, (9)$$

$$n_j = \pi_0 + \pi_1 q_j + \pi_2 EA_j * FFV_j + \pi_3 (P_e/P_g) * FFV + \pi_4 c'_j + \pi_5 f_r + \pi_6 f_r * FFV + \pi_7 g_j + \pi_8 g_j * FFV + y_j + \varepsilon_j, (10)$$

$$meanu_j = \alpha + \beta_1 EA * FFV_j + \beta_2 (P_e/P_g) * FFV + \beta_3 \hat{p}_j + \beta_4 \hat{n}_j + \beta_5 c'_j + \beta_6 f_r + \beta_7 f_r * FFV + \beta_8 g_j + \beta_9 g_j * FFV + y_j + \varepsilon_j, (11)$$

Where n is the nest share and q is a second instrument for the nest share.

5.9 Effects on non-ethanol fueled vehicles

In addition to the above specifications, we also estimate the link between ethanol availability and market shares of non-ethanol fuelled vehicles. The specification is an adaptation of the instrumental variables regression, with the addition of six new variables, each representing one fuel class. Each such variable is ethanol availability interacted with a fuel type dummy. Formally, the model is (stage 2 of 2SLS):

$$\text{mean}_{ij} = \alpha + \beta_1 \text{EA} * \text{FFV}_j + \beta_2 (P_e/P_g) * \text{FFV} + \beta_3 \hat{p}_j + \beta_4 c'_j + \beta_5 f + \beta_6 f * \text{FFV} + \beta_7 g_j + \beta_8 g_j * \text{FFV} + \beta_9 g * \text{FT}_j + \beta_{10} \text{EA} * \text{FT}_j + y_j + \varepsilon_j, \quad (12)$$

where FT contains dummies for the fuel types: gasoline, low emission gasoline, diesel, low emission diesel, bi-fuel (natural gas) and electric hybrid. Also, as before, EA is a measure of ethanol availability, p is vehicle price, c contains the various products specific controls, f contains the region specific controls, g contains the dummies for rebates and tax exemptions (incentives) and y contains fixed effects.⁴

5.10 Testing the endogeneity of ethanol availability

As discussed in section 2.4, qualitative data support that the pump law was the root cause of the emergence of the Swedish ethanol fuelling network, i.e. that stations did not start offering ethanol voluntarily as a response to underlying demand. If instead stations had begun to offer ethanol voluntarily, our measures of ethanol availability could be endogenous to the true drivers of this demand, and our model would produce biased estimators. To formally test this on our data, we perform a Hausman test⁵ on the potential endogeneity of our E85 availability measures. The test compares a regression where the potentially endogenous variable is estimated using an instrument to a second regression in which the same variable is treated as exogenous. The test produces a Chi2-statistic that allows us to evaluate the null hypothesis that the two regressions are not significantly different. Under the null, instrumenting does not significantly improve the estimation and the variable in question can be treated as exogenous.

⁴ Low emission here refers to CO₂ emissions < 120g/km.

⁵ We use the Stata 9.2 command [ivendog]

6. Results

6.1 Ordinary Least Squares

Table 2 presents the preferred OLS logit specifications based on equation (6), using our three availability measures. A number of controls have been excluded due to multicollinearity or lack of significance. Apart from vehicle price, the included controls are effect, kerb weight, doors, vehicle tax and CO₂ emissions. For complete results please see Appendix A.2. All tables contain p-values in parenthesis ().

Table 2: OLS logit regression results

Dependent variable:	OLS logit 1 meanu	OLS logit 2 meanu	OLS logit 3 meanu	OLS logit 4 meanu
percente85sta_dFFV	0.658** (0.008)			
e85sta_per1000cars_dFFV		1.294*** (0.000)		
e85sta_per1000cap_dFFV			2.786*** (0.000)	2.010** (0.003)
pe_over_pg_month_dFFV	-1.062*** (0.000)	-1.041*** (0.000)	-1.033*** (0.000)	
pe_over_pg_month_L1_dFFV				-1.253*** (0.000)
vehicle price	-0.00610*** (0.000)	-0.00610*** (0.000)	-0.00610*** (0.000)	-0.00622*** (0.000)
vehicle tax	0.000188*** (0.000)	0.000188*** (0.000)	0.000188*** (0.000)	0.000189*** (0.000)
CO2 emission	-0.0152*** (0.000)	-0.0152*** (0.000)	-0.0152*** (0.000)	-0.0154*** (0.000)
kerb weight	0.000873*** (0.000)	0.000873*** (0.000)	0.000873*** (0.000)	0.000888*** (0.000)
effect	0.0118*** (0.000)	0.0118*** (0.000)	0.0118*** (0.000)	0.0118*** (0.000)
doors	0.0228*** (0.000)	0.0229*** (0.000)	0.0229*** (0.000)	0.0185** (0.002)
N	46174	46174	46174	43859
Price elasticities:				
Percentile 1	-2.33	-2.33	-2.37	-2.36
Percentile 5	-2.07	-2.07	-2.07	-2.11
Percentile 50	-1.13	-1.13	-1.13	-1.15
Percentile 95	-0.61	-0.61	-0.61	-0.63
Percentile 99	-0.51	-0.51	-0.51	-0.52
Fixed effects:				
Region	yes	yes	yes	yes
Fuel	yes	yes	yes	yes
Brand	yes	yes	yes	yes
Time (year and month)	yes	yes	yes	yes

All three availability measures show positive and significant coefficients.

As discussed in the data section, measure 1 uses interpolated values between 2007 and 2009 for total number of stations. Consequently, it is more likely to contain measurement errors than measure 2 and 3 and is therefore less reliable. Because of this, we henceforth concentrate on measures 2 and 3 which relate fuel availability to population and car fleet respectively.

The fuel price ratio is significant and negative at the less than 1% level in all regressions. In OLS logit 4, we lag the price ratio by one month.

The OLS logit regressions produce unrealistic price elasticities. This derives from the fact that quantities and prices are determined simultaneously, giving the price coefficient an upward bias when using OLS. To mitigate this effect, we move on to the instrumental variables logit regressions.

6.2 Instrumental variables and nests

Keeping measures 2 and 3 for ethanol availability and non-lagged fuel prices, we use instruments according to equations (7) and (8) to address the endogeneity of vehicle prices. In finding suitable instruments we follow the algorithm suggested by BLP (1995). We find the best and second best instruments to be BLP2(fuel economy) and engine size respectively. As can be seen in IV logit 1-IV logit 4, instrumenting vehicle price improves the price elasticities relative to OLS. In particular, IV logit 2 and IV logit 4 produce the most reasonable elasticities suggesting that BLP2(fuel economy) should be the preferred instrument.

Table 3: IV logit and Nested IV logit regression results

Dependent variable:	IV logit 1 meanu	IV logit 2 meanu	IV logit 3 meanu	IV logit 4 meanu	Nested IV logit 1 meanu	Nested IV logit 2 meanu
endogenous variables:	price	price	price	price	price nest share	price nest share
Instruments:	engine size	BLP2(Fuelecon)	engine size	BLP2(Fuelecon)	BLP2(Fuelecon) Engine size	BLP2(Fuelecon) Engine size
e85sta_per1000cars_dFFV	1.425*** (0.000)	1.491*** (0.000)			1.175* (0.037)	
e85sta_per1000cap_dFFV			3.037*** (0.000)	3.164*** (0.000)		2.531* (0.024)
pe_over_pg_month_dFFV	-0.957*** (0.000)	-0.915*** (0.000)	-0.947*** (0.000)	-0.904*** (0.000)	-0.950*** (0.000)	-0.942*** (0.000)
vehicle price	-0.0237*** (0.000)	-0.0325 (0.094)	-0.0237*** (0.000)	-0.0326 (0.094)	-0.0205* (0.033)	-0.0205* (0.033)
vehicle tax	0.000369*** (0.000)	0.000460* (0.021)	0.000369*** (0.000)	0.000461* (0.022)	0.000322** (0.008)	0.000322** (0.008)
CO2 emission	-0.0178*** (0.000)	-0.0191*** (0.000)	-0.0178*** (0.000)	-0.0191*** (0.000)	-0.0153** (0.002)	-0.0153** (0.002)
kerb weight	0.00293*** (0.000)	0.00397 (0.081)	0.00294*** (0.000)	0.00398 (0.081)	0.00251* (0.041)	0.00250* (0.040)
effect	0.0276*** (0.000)	0.0355* (0.042)	0.0276*** (0.000)	0.0356* (0.042)	0.0235* (0.027)	0.0234* (0.027)
doors	0.0170* (0.012)	0.0140 (0.141)	0.0170* (0.012)	0.0139 (0.143)	0.0141 (0.054)	0.0141 (0.053)
nest share					0.136 (0.593)	0.137 (0.589)
N	46174	46174	46174	46174	46174	46174
Price elasticities:						
Percentile 1	-9.06	-12.43	-9.06	-12.47	-7.85	-7.84
Percentile 5	-8.06	-11.06	-8.06	-11.10	-7.00	-6.98
Percentile 50	-4.39	-6.03	-4.39	-6.05	-3.81	-3.80
Percentile 95	-2.39	-3.28	-2.39	-3.30	-2.07	-2.07
Percentile 99	-1.97	-2.71	-1.97	-2.71	-1.71	-1.71
Fixed effects:						
Region	yes	yes	yes	yes	yes	yes
Fuel	yes	yes	yes	yes	yes	yes
Brand	yes	yes	yes	yes	yes	yes

Having obtained realistic own-price elasticities, the cross-price elasticities remain problematic. To address this, we introduce nests in Nested IV logit 1 and Nested IV logit 2, based on equations (9)-(11), (Table 3). Here we instrument both for vehicle price, using

BLP2(fuel economy), and for the nest variable, “nest share”, using engine size. Somewhat surprisingly, the nest coefficient is insignificant in both Nested IV logit 1 and Nested IV logit 2 and we thus cannot conclude that it is statistically different from 0 or 1. Consequently, IV logit 2 and IV logit 4 remain our preferred specifications.

6.3 Testing the endogeneity of ethanol availability

To test the endogeneity of ethanol availability we need to find suitable instruments. These instruments should be factors that can reasonably be expected to drive demand for ethanol and thereby cause a station to open an ethanol pump. The factors that we believe meet this criteria and that we have available are population, population density and income levels, which are arguably generic drivers of demand. We also test whether the percentage of the population earning annual salary higher than 600,000 SEK and the percentage of those with a college degree can be used as instruments. We do not use population as an instrument as one of our two preferred measures of availability, measure 3, directly includes population. Also, any instrument used must be excluded from the second stage of a 2SLS equation. This is unfortunate as both population, population density and average income have been found to be relevant controls in IV logit 1-IV logit 4. Table 4 shows coefficients and p-values from first-stage regressions using each of our four potential instruments.

<i>Table 4: first stage results for potential instruments</i>		
Dependent Variable	e85sta_per1000cap_dFFV	e85sta_per1000cars_dFFV
Potential instrument (below):		
averageincome_dFFV	0.1636 (0.000)	0.3718 (0.000)
popdens_dFFV	-0.0003 (0.000)	-0.0007 (0.000)
Percentsalaryover600K_dFFV	-2.8778 (0.000)	-3.2887 (0.000)
percentcollegedegree_dFFV	-0.3778 (0.006)	-0.6783 (0.013)

All instruments are significantly correlated with availability on the less than 1% level. However, interpreting this correlation is not entirely straight forward. Since population and

car fleet enter both our preferred availability measures respectively through the denominator, we cannot conclude that the correlation of the instruments is actually related to the number of ethanol stations rather than to the denominator. Indeed, both income, population density, percentage of high income earners and percentage of college graduates could be correlated with both population and number of cars. Consequently, we do not believe we have managed to find strong instruments. Nonetheless, Table 4 presents the results of the Hausman-tests using the above instruments respectively:

Table 5: Hausman test for endogeneity

Endogenous variable:		
e85sta_per1000_	cap_dFFV	cars_dFFV
Instrument (below):	Chi2 (p-value)	Chi2 (p-value)
averageincome_dFFV	5.15981 (0.076)	5.37248 (0.068)
popdens_dFFV	6.89748 (0.032)	6.46219 (0.040)
percentsalaryover600K_dFFV	2.81637 (0.245)	3.98798 (0.136)
percentcollegedegree_dFFV	15.36062 (0.000)	16.66063 (0.000)

Notably, when using percentcollegedegree_dFFV as instrument, we can reject the null that availability is exogenous at the less than 1% level. However, when using popdens_dFFV, we can reject it only at the 5% level, only at the 10% level when using averageincome_dFFV and not at all when using percentsalaryover600K_dFFV. Again, the accuracy of this test is dependent on having identified strong instruments, which we argued is not the case. Thus, we are hesitant to take these results as proof of endogeneity, especially when considering the qualitative data suggesting that selling ethanol is not something oil companies would have done voluntarily. However, as a safety precaution, in Table 5 we present new versions of our preferred regressions IV logit 2 and IV logit 4 using percentcollegedegree_dFFV as instrument for availability.

Table 6: Results from instrumenting availability

	IV logit 5	IV logit 6
Dependent variable:	meanu	meanu
endogenous variables:	e85sta_per1000cars_dFFV vehicle price	e85sta_per1000cap_dFFV vehicle price
Instruments:	percentcollegedegree_dFFV BLP2(Fuelecon)	percentcollegedegree_dFFV BLP2(Fuelecon)
First stage F-stat (vehicle price)	8248.05	8248.05
First stage F-stat (e85sta_per1000cars_dFFV)	12753.72	
First stage F-stat (e85sta_per1000cap_dFFV)		12108.3
e85sta_per1000cars_dFFV	6.182*** (0.000)	
e85sta_per1000cap_dFFV		11.17*** (0.000)
vehicle price	-0.0219 (0.215)	-0.0243 (0.176)
pe_over_pg_month_dFFV	-1.175*** (0.000)	-1.086*** (0.000)
vehicletax	0.000348 (0.056)	0.000373* (0.044)
CO2	-0.0177*** (0.000)	-0.0180*** (0.000)
kerb weight	0.00273 (0.187)	0.00302 (0.153)
effect	0.0261 (0.099)	0.0283 (0.080)
doors	0.0184* (0.032)	0.0175* (0.045)
N	46174	46174
Fixed effects:		
Region	yes	yes
Fuel	yes	yes
Brand	yes	yes
Time (year and month)	yes	yes

Availability coefficients remain positive and significant when treated as endogenous. In fact, the coefficients are larger in IV logit 5 and IV logit 6 compared to IV logit 2 and IV logit 4. We note again that we do not believe that we have found conclusive proof of endogeneity. Rather, IV logit 7 and IV logit 8 reassures us that if availability were endogenous, the fundamental positive relationship between ethanol availability and FFV sales still remains.

6.4. The impact on demand for non-ethanol vehicles

By interacting ethanol availability with dummies for the seven different fuel categories⁶, as per equation (12), we estimate the effect of ethanol availability on non-ethanol fuelled cars in Table 7:1. In Table 7:2, we show the coefficients for the interacted green car rebate dummies from the same regressions. Note that IV logit 7 and IV logit 8 treats ethanol availability as exogenous and price as endogenous, similar to IV logit 2 and IV logit 4. This has three motivations: (i) as discussed in 7.3 we have not found reliable instruments for availability, (ii) qualitative data supports exogeneity and (iii) 2SLS requires at least one instrument for each endogenous variable; as IV logit 7 and IV logit 8 each contain 7 different availability interactions (one for each fuel type) we would need to have at least 7 different instruments, which we don't find feasible.

⁶ FFV, BFV, HEV, Gasoline (Co2<120), Diesel (Co2<120), Gasoline (Co2>120), Diesel (Co2>120)

Table 7.1: Effect of ethanol availability on other fuel classes

Dependent variable:	IV logit 7 meanu	IV logit 8 meanu
endogenous variables:	price	price
firs-stage F-stat	7464.510	7465.12
vehicle price	-0.0264 (0.106)	-0.0244 (0.113)
pe_over_pg_month_dFFV	-0.911*** (0.000)	-0.908*** (0.000)
Ethanol availability measure:	Measure 2	Measure 3
e85sta_per1000_:	cars	capita
Availability interactions (below)		
FFV	2.659*** (0.000)	5.241*** (0.000)
HEV	-1.794 (0.154)	-4.819* (0.043)
BFV	8.726** (0.006)	14.52** (0.005)
Gasoline (Co2<120)	4.389*** (0.000)	5.424*** (0.000)
Diesel (Co2<120)	1.498** (0.007)	1.950 (0.073)
Gasoline (Co2>120)	0.0568 (0.920)	-0.0993 (0.926)
Diesel (Co2>120)	3.022*** (0.000)	6.230*** (0.000)
Fixed effects:		
Region	yes	yes
Fuel	yes	yes
Brand	yes	yes
Time (year and month)	yes	yes
N	46174	46174

Table 7.2: Effect of ethanol availability on other fuel classes

Dependent variable:	IV logit 7 meanu	IV logit 8 meanu
endogenous variables:	price	price
firs-stage F-stat	7464.510	7465.12
vehicle price	-0.0264 (0.106)	-0.0244 (0.113)
pe_over_pg_month_dFFV	-0.911*** (0.000)	-0.908*** (0.000)
Ethanol availability measure:	Measure 2	Measure 3
e85sta_per1000_:	cars	capita
Rebate interactions (below)		
FFV	0.208 (0.071)	0.211 (0.065)
HEV	0 (.)	0 (.)
BFV	0 (.)	0.133 (0.584)
Gasoline (Co2<120)	-0.0774 (0.590)	0.102 (0.481)
Diesel (Co2<120)	0.519*** (0.000)	0.564*** (0.000)
Fixed effects:		
Region	yes	yes
Fuel	yes	yes
Brand	yes	yes
Time (year and month)	yes	yes
N	46174	46174

The effect of availability on FFVs remains strongly significant and positive while the fuel price ratio coefficient remains strongly significant and negative. Notably, the effects on both green gasoline cars, green diesel cars, non-green diesel cars and bi-fuel vehicles is significant and positive, suggesting that increased ethanol availability does not cause customers to substitute from these vehicles to FFVs. However, the effect on HEVs is negative in both regressions and significant at the 5% level in IV logit 8.

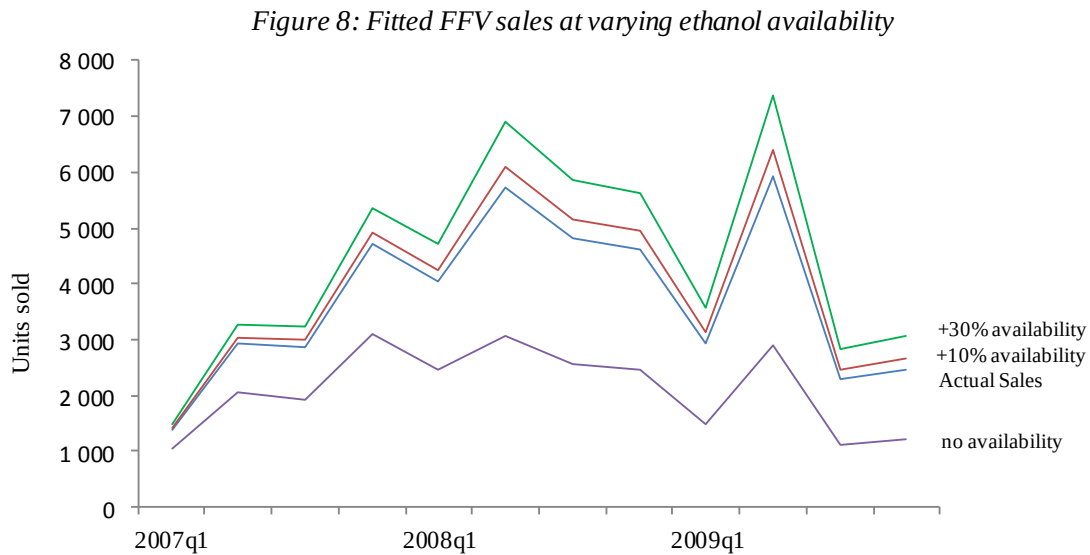
6.5 Counterfactuals

Using the results from IV logit 8, which is our preferred specification, we can calculate fitted, or counterfactual sales of FFVs for a given percentage change in availability. We obtain the fitted sales figure by first calculating a fitted value of our dependent variable, $meanu_j$, using the formula:

$$meanu_{j,fitted} = meanu_{j,actual} + \% \text{ change} * availability_j * \beta_{availability}^7 \quad (13)$$

$$sales_j = \exp(meanu_{j,fitted}) * s0_j * \text{market size} \quad (14)$$

Counterfactual sales and market shares are summarized in Tables 8, 9, 10 and Figures 8, 9 10.⁸



⁷ Note that this is consistent with the formula $y_1 = y_0 + \Delta x * (dx/dy)$, where $(\% \text{ change} * availability_j)$ is Δx and $\beta_{availability}$ is dx/dy .

⁸ Note that unit sales of Gasoline (CO2>120) is constant in Table 9. This is because the coefficient for said fuel class could not be proved significantly different from zero in IV logit 8. As other fuel classes increase their sales with availability, the market share of Gasoline (CO2>120) is decreasing in ethanol availability in Table 8.

Figure 9: FFV unit sales at varying availability

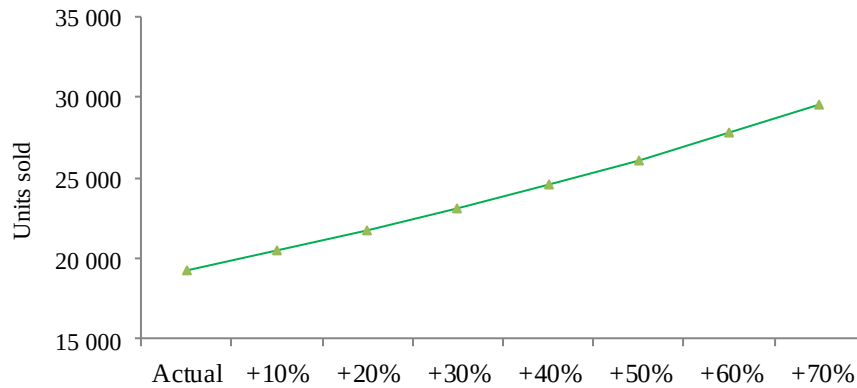


Figure 10: FFV market share at varying availability

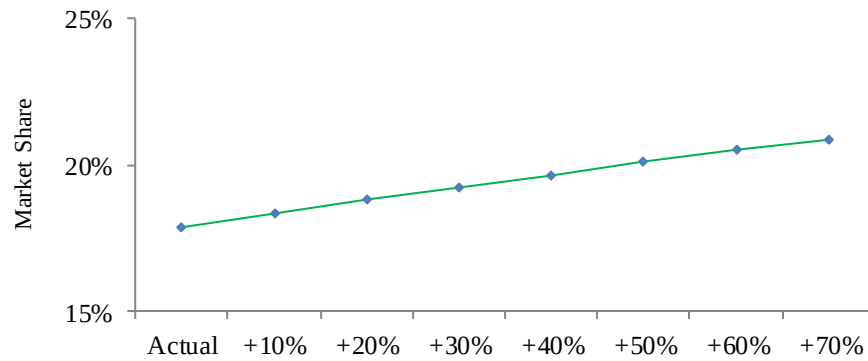


Table 8: 2008 Market Shares of new car sales by fuel

Ethanol availability:	Actual 	+10% 	+30%	No availability
FFV	17.86%	18.33%	19.23%	13.09%
HEV	0.08%	0.07%	0.06%	0.17%
BFV	0.09%	0.10%	0.12%	0.03%
Gasoline (Co2<120)	8.58%	8.83%	9.34%	6.05%
Diesel (Co2<120)	5.38%	5.31%	5.17%	5.69%
Gasoline (Co2>120)	45.23%	43.67%	40.54%	60.32%
Diesel (Co2>120)	22.79%	23.69%	25.54%	14.65%
Total	100%	100%	100%	100%

<i>Table 9: 2008 New car sales by fuel</i>				
Ethanol availability:	Actual	+10%	+30%	No availability
FFV	19,225	20,431	23,086	10,565
HEV	84	80	73	136
BFV	92	106	143	23
Gasoline (Co2<120)	9,233	9,850	11,216	4,884
Diesel (Co2<120)	5,787	5,923	6,204	4,596
Gasoline (Co2>120)	48,684	48,684	48,684	48,684
Diesel (Co2>120)	24,525	26,416	30,670	11,824
Total	107,630	111,490	120,075	80,711

<i>Table 10: percentage change in car sales by fuel in 2008</i>				
Ethanol availability:	Actual	+10%	+30%	No availability
FFV	0.0%	6.3%	20.1%	-45.0%
HEV	0.0%	-4.6%	-13.2%	62.1%
BFV	0.0%	15.7%	55.4%	-75.2%
Gasoline (Co2<120)	0.0%	6.7%	21.5%	-47.1%
Diesel (Co2<120)	0.0%	2.3%	7.2%	-20.6%
Gasoline (Co2>120)	0.0%	0.0%	0.0%	0.0%
Diesel (Co2>120)	0.0%	7.7%	25.1%	-51.8%
Total volume change	-	3.6%	11.6%	-25.0%

7. Analysis

7.1 Effects of increased ethanol availability on FFVs

Our results indicate a significant positive relationship between the availability of ethanol and sales of new FFVs. These results are robust to controlling for both the congestion tax exemption and the green car rebate. As can be seen in Tables 7.1 and 7.2, the rebate dummy for FFVs is in fact only weakly significant (10%) when controlling for ethanol availability. This could indicate that demand for FFVs is more responsive to improved fuel availability than to the 10,000 SEK rebate. If true, this may be a factor for policy makers to consider before implementation of the planned super-green car rebate of 40,000 SEK. Considering that poor profitability seems to have been the main reason for station owners not to offer ethanol before the pump law, subsidizing the investment cost of installing ethanol tanks and pumps may be an alternative to renewing the rebate scheme.

Having said that, the efficiency of a supply-side strategy is not clear. While Figure 9 suggests that FFV sales has slightly increasing returns to availability, Table 10 shows that this effect is not translated into FFV market share, which actually has slightly decreasing returns to availability. Table 8 tells us that even a 30% increase in availability (measured as stations per 1000 people) would only increase the market shares of FFVs with around 1.4 percentage points. If we think that population is relatively stable over time, we can interpret a 30% increase in availability as a 30% increase in the number of stations offering ethanol. To understand the magnitude of such an increase, one can compare it to the increase in ethanol stations during the last three years, 2008-2010, which has been 26%, 15% and 9% respectively. To us, the small impact on FFV market share from a relatively large increase in ethanol availability suggests that there are several other factors, aside from fuel supply, that affect demand for FFVs. Therefore, increasing supply will not in itself be sufficient in making FFVs a widely accepted substitute for regular gasoline and diesel cars.

In sum, it seems that on the one hand, increased availability of ethanol does indeed increase FFV market share. But on the other hand, the actual magnitude of the increase appears to be small.

7.2 Effects of increased ethanol availability on non-FFVs

According to our results, FFVs are far from the only fuel class affected by an increase in ethanol availability. This may have several possible explanations.

Both green gasoline and green diesel cars increase with ethanol availability in terms of sales (Table 9 and 10). The effect is largest for green gasoline cars, while green diesels actually lose market share due to the stronger growth of other fuel classes. The positive correlation suggests that more FFV sales does not come at the expense of other green cars. However, the actual economic link between green gasoline and diesel cars and ethanol availability is not clear. One possible albeit far-fetched story is that increased supply of ethanol spurs ‘green trends’ among vehicle consumers, making them more likely to buy any green car relative to non-greens and that this in turn would benefit all green fuel classes.

Also the effect on bi-fuel vehicles (BFVs), i.e. cars that can run on gasoline as well as natural gas, is strongly significant and positive. In fact, the sales of BFVs vary more with ethanol availability than do FFVs. On the one hand, this may seem puzzling given that the pump law required stations to offer at least *one* biofuel and that the vast majority of stations chose ethanol over natural gas. Therefore, one could expect the availability of gas and ethanol to be negatively correlated. However, as we saw in figure 7 in section 2.4, the pump law did bring an increase also in the number of natural gas stations. Therefore it’s possible that E85 availability is in fact positively correlated with natural gas availability and that this effect is what is giving us the positive correlation. If true, this represents a weakness in our model that could have been addressed by including the availability of natural gas.

The effect on HEVs is negative and significant in IV logit 8, resulting in HEV market share decreasing from already low levels as ethanol availability increases. This could suggest that the increased attractiveness of FFVs from better availability causes consumers looking for alternative-fuel cars to substitute from HEVs to FFVs. We note however that the negative effect is only significant at the 5% level in IV logit 8 and not even at the 10% level in IV logit 7.

We find no evidence of any connection between ethanol availability and sales of regular gasoline cars. The fact that there is no apparent negative correlation indicates that improved

availability of ethanol does not cause consumers to substitute from gasoline cars to FFVs. On the other hand, if such substitution was the case, the effect may be too small to pick up in our estimates given the large size of the gasoline cars' market share. The significant positive effect on regular diesels is more puzzling. We fail to think of any plausible economic explanation for this result and suspect that it is caused by some pattern in the data unknown to us.

Finally, we note that while the effect on HEV sales is negative, the effects on all other fuel classes except for regular gasoline are positive. As the decrease in HEV's does not nearly cover the increase in other classes, increased ethanol availability seems to increase total car sales – even after controlling for the green car rebate. This would mean that the increase in sales of FFVs and other cars come at the expense of the outside good, i.e. the option of not buying a car or buying a used car. Let us first consider the option of more people buying new cars instead of used ones. This could be the case if the fuel classes that increase with ethanol availability are scarcer in the second-hand market than in the new market. Suppose with higher availability consumers are more inclined to buy an FFV, and if used FFVs are hard to come by, consumers may choose a new car instead of a used one. This explanation is possible, but unlikely the whole story. Alternatively, the increase in total cars can mean that more people choose to buy cars as opposed to not buying. In the case of FFVs, this effect would imply the existence of consumers who, given that ethanol availability is below a certain level, will abstain from buying a car rather than buying a non-FFV. Then, as availability passes the critical level, said customers will choose to purchase an FFV rather than abstaining from car purchase. If such consumers exist, they are probably more likely to live in densely populated regions where a greater access to local infrastructure eases the dependence on personal driving for transportation. Unfortunately, our results do not allow us to draw any conclusions on regional effects.

7.3 Effects of the relative price of ethanol to gasoline

Our results show a significant and negative correlation between the relative price of ethanol to gasoline and the sales and market share of FFVs. This indicates that consumer do indeed consider the economic benefit of being able to choose between two fuels when purchasing a vehicle. This is in line with the results of the 2009 survey mentioned in section 4.2 (BEST,

2010) in which owners of alternative-fuel vehicles stated that the expectations of avoiding high gasoline or diesel prices was the third most important factor influencing their vehicle purchase decision.

From an environmental perspective, the ultimate objective should not be to increase FFV market share, but rather to reduce the use of fossil fuels such as gasoline and diesel. Again, recall that FFV owners can choose to drive solely on gasoline. Thus, policies aimed at increasing the availability of ethanol may affect the use of FFVs but, theoretically, may not significantly impact the use of ethanol vis-à-vis fossil fuels. Suppose instead policies could be targeted at ensuring an attractive relative price of ethanol. Given our findings, this has the potential of affecting *both* the market share of FFVs and the actual consumption of fossil fuels. Such policies may therefore in fact be more efficient compared to supply-policies such as the pump law in stimulating a shift from fossil fuels to ethanol.

8. Limitations

A limitation of our study is that it does not allow conclusions about whether the pump law has truly solved the chicken-and-egg problem of biofuels. That is, we cannot say whether the increase in ethanol availability created large enough fleet of FFVs to make the selling of ethanol profitable to filling stations. If that had been the case, the FFV market could have been said to have passed the threshold that the chicken-and-egg problem constitutes.

We have no data on the social costs associated with the forced increase in ethanol supply. While these costs are not as easily measurable as for example the 10,000 SEK green car rebate, it would have been relevant to compare the potential environmental gains to the total costs. In the case of the pump law, the costs were borne by the private companies required to install ethanol pumps. Moreover, we have not estimated the actual environmental impact of increased FFV market share. This is however difficult to assess as any environmental gain is conditional on FFV owners actually fuelling ethanol.

Another limitation lies in our model specification. As discussed in section 6.8, the logit model fails to relate the cross-price elasticity for two given products to the similarity in attributes. In fact, products will be differentiated only by their mean utility. This means that

the market shares of a very exclusive car like a Ferrari, and a much cheaper car like a Kia, would react identically to a change in the price of a Porsche, if Kia and Ferrari had the same market shares. We addressed this issue using nested logit regressions, but the nest coefficient was found insignificant.

The risk of having omitted factors that affect vehicle choice is another limitation of our study. In particular, it may have been relevant to include some control of environmental engagement as this is a potential driver of FFV market share. Possibly, we could have used local parliament election results for the green party, Miljöpartiet, as proxy for this.

Lastly, there may be limitations in the quality of certain parts of our data. Our fuel price data comes from a user generated data base and cannot be guaranteed to be absolutely accurate. The number of price observations and thereby the statistical reliability differs substantially across both months and regions. Regarding ethanol availability, our data does not capture any ethanol stations not connected to oil companies. As described in section 2.4, independent stations tend to have low sales volumes and are therefore less likely to be affected by the pump law, i.e. less likely to offer ethanol. Nonetheless, it is possible that true ethanol availability is marginally higher than what is shown in our data.

9. Conclusion

This thesis has studied the effects on sales and market shares of new FFVs from increased availability of ethanol to consumers. We began by suggesting an analogy between the FFV and a real fuel option. Based on this analogy, we argued that the demand for FFVs should be positively correlated to the availability of ethanol and negatively correlated to the relative price of ethanol to gasoline. We have found significant results indicating that increased availability of ethanol, measured as total ethanol stations per 1000 people and per 1000 cars, leads to increases in sales and market shares of FFVs. Also, we find equally significant results indicating that sales and market shares of FFVs are negatively correlated to the relative price of ethanol to gasoline. While our results show that forcing supply does indeed have the potential of spurring demand for FFVs, we cannot say with certainty that this can solve the chicken-and-egg problem of biofuels. Using counterfactuals to compute the effects of an increase in ethanol availability on the sales of FFVs, HEVs, BFVs, low emission

gasoline and diesel cars and on regular gasoline and diesels cars, we find that a 30% increase in availability would increase FFV unit sales by 20%, but only increase FFV market share by approximately 1.4 percentage points.

10. Suggestions for further research

Our thesis does not directly address the link between fuel availability, demand for FFVs and ultimate demand for ethanol. If one could obtain data on ethanol consumption disaggregated by region and month, this could be combined with our data to study the link between fuel availability and fuel demand. Perhaps even more interesting is the actual link between FFV fleet and ethanol demand. For example, one could argue that using legislation to increase availability of biofuel has little value if the resulting increase in FFV market share is not translated into increased demand for ethanol or, perhaps more importantly, reduced demand for fossil fuels. Therefore, we encourage studies that investigate what factors influence the ultimate fuel choice of FFV owners.

Alternatively, suppose one could obtain quantitative financial data on the profitability of selling ethanol. Suppose also that such data could be used to determine a critical level of ethanol demand, below which the marketing of ethanol would not be profitable and therefore not undertaken voluntarily by filling stations. Further suppose one could estimate the link between FFV fleet size and ethanol demand and combine this with our findings regarding the link between ethanol availability and FFV sales. Taken together, this could allow one to estimate what increase in the level of ethanol availability is required to generate sufficient ethanol demand to make supply of ethanol economically profitable. This could ultimately lead to insights on the potential for solving the chicken-and-egg problem through increased ethanol supply.

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11.3 Data

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11.4 Other

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Appendix

A.1 Data adjustments

In our real fuel prices data set, we drop those combinations of region and month with less than three real price observations, since three observations are considered a minimum to use for the median fuel price ratio variable.

The characteristics data contains information on each brand, model, *sub model* and fuel type, i.e. on a more detailed level than the sales data. To enable merging the two data sets, we keep only one set of characteristics for each car of a certain brand, *model* and fuel type. We choose to keep the version with the lowest recommended car price, i.e. the base model. Furthermore, we use the later of the two vehicle tax rates for cars sold in 2006 given in *Nybilsguiden*. Finally, car prices are divided by 1 000 to get more convenient coefficients. We exclude cars with a deflated recommended price of more than 400,000 SEK.

The car characteristics are merged with the car sales data by matching brand, model, fuel type and year. For those observations still not matched, we lag the car characteristics data one year and match the remaining again. The reason is that most year models are released during the prior autumn, i.e. some models sold in late 2008 are actually the models of 2009.

A.2 Estimation results

Please see below a list of descriptions of our variables followed by more detailed results of our estimates.

<i>Table A.1: Variable list</i>	
meanu	$\ln(sj/s0)$
percente85sta_dFFV	percentage of E85 stations of total stations, interacted with FFV dummy
e85sta_per1000cars_dFFV	number of E85 stations per 1000 cars, interacted with FFV dummy
e85sta_per1000cap_dFFV	number of E85 stations per 1000 capita, interacted with FFV dummy
pe_over_pg_month_dFFV	ratio of median E85 price over median petrol price, interacted with FFV dummy
pe_over_pg_month_L1_dFFV	ratio of median E85 price over median petrol price, lagged one month, interacted with FFV dummy
inflpk	vehicle price
ch1	vehicle tax
ch2	CO2 emission
ch3	curb weight
ch4	effect
ch5	doors
rch1	population
rch2	population density
rch4	average income
rch1_dFFV	population, interacted with FFV dummy
rch2_dFFV	population density, interacted with FFV dummy
rch4_dFFV	average income, interacted with FFV dummy
rebate_dFFV	dummy for green car rebate, interacted with FFV dummy
congestiontax_dFFV	dummy for congestion tax exemption, interacted with FFV dummy
lnsjg1	market share within the own nest

<i>Table A.1: Variable list cont.</i>	
e85sta_per1000cap_dHEV	number of E85 stations per 1000 capita, interacted with HEV dummy
e85sta_per1000cap_dBFV	number of E85 stations per 1000 capita, interacted with BFV dummy
e85sta_per1000cap_dGREENGAS	number of E85 stations per 1000 capita, interacted with dummy for gasoline car with CO2 emissions of less than 120 g/km
e85sta_per1000cap_dGREENDIESEL	number of E85 stations per 1000 capita, interacted with dummy for diesel car with CO2 emissions of less than 120 g/km
e85sta_per1000cap_dGASNONGREEN	number of E85 stations per 1000 capita, interacted with dummy for gasoline car with CO2 emissions of not less than 120 g/km
e85sta_per1000cap_dDIESEL	number of E85 stations per 1000 capita, interacted with dummy for diesel car with CO2 emissions of not less than 120 g/km
e85sta_per1000cars_dHEV	number of E85 stations per 1000 cars, interacted with HEV dummy
e85sta_per1000cars_dBFV	number of E85 stations per 1000 cars, interacted with BFV dummy
e85sta_per1000cars_dGREENGAS	number of E85 stations per 1000 cars, interacted with dummy for gasoline car with CO2 emissions of less than 120 g/km
e85sta_per1000cars_dGREENDIESEL	number of E85 stations per 1000 cars, interacted with dummy for diesel car with CO2 emissions of less than 120 g/km
e85sta_per1000cars_dGASNONGREEN	number of E85 stations per 1000 cars, interacted with dummy for gasoline car with CO2 emissions of not less than 120 g/km
e85sta_per1000cars_dDIESEL	number of E85 stations per 1000 cars, interacted with dummy for diesel car with CO2 emissions of not less than 120 g/km
rebate_dHEV	dummy for green car rebate, interacted with HEV dummy
rebate_dBFV	dummy for green car rebate, interacted with BFV dummy
rebate_GREENGAS	dummy for green car rebate, interacted with dummy for gasoline car with CO2 emissions of less than 120 g/km
rebate_GREENDIESEL	dummy for green car rebate, interacted with dummy for diesel car with CO2 emissions of less than 120 g/km
congestiontax_dHEV	dummy for congestion tax exemption, interacted with HEV dummy
congestiontax_dBFV	dummy for congestion tax exemption, interacted with BFV dummy

Table A.2: OLS1

Dependent variable: meanu

	Coefficient	P-values
percente85sta_dFFV	0.658**	(0.008)
pe_over_pg_month_dFFV	-1.062***	(0.000)
inflpk	-0.00608***	(0.000)
rch4_dFFV	-0.281	(0.310)
rch2_dFFV	0.000495	(0.515)
rch1_dFFV	0.000000377***	(0.000)
ch1	0.000188***	(0.000)
ch2	-0.0152***	(0.000)
ch3	0.000873***	(0.000)
ch4	0.0118***	(0.000)
ch5	0.0228***	(0.000)
rch4	-0.977	(0.358)
rch2	0.0802***	(0.000)
rch1	-0.0000146***	(0.000)
rebate_dFFV	0.256*	(0.023)
congestiontax_dFFV	-0.00166	(0.992)
N	46174	

Table A.3: OLS2

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cars_dFFV	1.294***	(0.000)
pe_over_pg_month_dFFV	-1.041***	(0.000)
inflpk	-0.00608***	(0.000)
rch4_dFFV	-0.402	(0.135)
rch2_dFFV	0.00123	(0.115)
rch1_dFFV	0.000000370***	(0.000)
ch1	0.000188***	(0.000)
ch2	-0.0152***	(0.000)
ch3	0.000873***	(0.000)
ch4	0.0118***	(0.000)
ch5	0.0229***	(0.000)
rch4	-0.906	(0.394)
rch2	0.0791***	(0.000)
rch1	-0.0000144***	(0.000)
rebate_dFFV	0.213	(0.061)
congestiontax_dFFV	0.0539	(0.758)
N	46174	

Table A.4: OLS3

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cap_dFFV	2.786***	(0.000)
pe_over_pg_month_dFFV	-1.033***	(0.000)
inflpk	-0.00608***	(0.000)
rch4_dFFV	-0.377	(0.149)
rch2_dFFV	0.00129	(0.099)
rch1_dFFV	0.000000384***	(0.000)
ch1	0.000188***	(0.000)
ch2	-0.0152***	(0.000)
ch3	0.000873***	(0.000)
ch4	0.0118***	(0.000)
ch5	0.0229***	(0.000)
rch4	-0.885	(0.405)
rch2	0.0784***	(0.001)
rch1	-0.0000142***	(0.000)
rebate_dFFV	0.212	(0.061)
congestiontax_dFFV	0.0500	(0.773)
N	46174	

Table A.5: OLS4

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cap_dFFV	2.010**	(0.003)
pe_over_pg_month_L1_dFFV	-1.253***	(0.000)
inflpk	-0.00620***	(0.000)
rch4_dFFV	-0.359	(0.169)
rch2_dFFV	0.00146	(0.059)
rch1_dFFV	0.000000386***	(0.000)
ch1	0.000189***	(0.000)
ch2	-0.0154***	(0.000)
ch3	0.000888***	(0.000)
ch4	0.0118***	(0.000)
ch5	0.0185**	(0.002)
rch4	-0.351	(0.748)
rch2	0.0766***	(0.001)
rch1	-0.0000139***	(0.000)
rebate_dFFV	0.178	(0.138)
congestiontax_dFFV	-0.0327	(0.847)
N	43859	

Table A.6: IV1

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cars_dFFV	1.425***	(0.000)
pe_over_pg_month_dFFV	-0.957***	(0.000)
inflpk	-0.0237***	(0.000)
ch1	0.000369***	(0.000)
ch2	-0.0178***	(0.000)
ch3	0.00293***	(0.000)
ch4	0.0276***	(0.000)
ch5	0.0170*	(0.012)
rch4	-0.869	(0.441)
rch4_dFFV	-0.387	(0.153)
rch2	0.0766**	(0.001)
rch2_dFFV	0.00111	(0.154)
rch1	-0.0000136***	(0.000)
rch1_dFFV	0.000000368***	(0.000)
rebate_dFFV	0.198	(0.082)
congestiontax_dFFV	0.0845	(0.631)
N	46174	

Table A.7: IV2

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cars_dFFV	1.491***	(0.000)
pe_over_pg_month_dFFV	-0.915***	(0.000)
inflpk	-0.0325	(0.094)
ch1	0.000460*	(0.021)
ch2	-0.0191***	(0.000)
ch3	0.00397	(0.081)
ch4	0.0355*	(0.042)
ch5	0.0140	(0.141)
rch4	-0.851	(0.481)
rch4_dFFV	-0.380	(0.167)
rch2	0.0753**	(0.003)
rch2_dFFV	0.00105	(0.183)
rch1	-0.0000133***	(0.000)
rch1_dFFV	0.000000367***	(0.000)
rebate_dFFV	0.191	(0.098)
congestiontax_dFFV	0.0999	(0.579)
N	46174	

Table A.8: IV3

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cap_dFFV	3.037***	(0.000)
pe_over_pg_month_dFFV	-0.947***	(0.000)
inflpk	-0.0237***	(0.000)
ch1	0.000369***	(0.000)
ch2	-0.0178***	(0.000)
ch3	0.00294***	(0.000)
ch4	0.0276***	(0.000)
ch5	0.0170*	(0.012)
rch4	-0.849	(0.452)
rch4_dFFV	-0.354	(0.178)
rch2	0.0758**	(0.001)
rch2_dFFV	0.00117	(0.135)
rch1	-0.0000135***	(0.000)
rch1_dFFV	0.000000384***	(0.000)
rebate_dFFV	0.199	(0.080)
congestiontax_dFFV	0.0792	(0.651)
N	46174	

Table A.9: IV4

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cap_dFFV	3.164***	(0.000)
pe_over_pg_month_dFFV	-0.904***	(0.000)
inflpk	-0.0326	(0.094)
ch1	0.000461*	(0.022)
ch2	-0.0191***	(0.000)
ch3	0.00398	(0.081)
ch4	0.0356*	(0.042)
ch5	0.0139	(0.143)
rch4	-0.831	(0.492)
rch4_dFFV	-0.343	(0.200)
rch2	0.0745**	(0.003)
rch2_dFFV	0.00111	(0.163)
rch1	-0.0000131***	(0.000)
rch1_dFFV	0.000000384***	(0.000)
rebate_dFFV	0.192	(0.094)
congestiontax_dFFV	0.0940	(0.599)
N	46174	

Table A.10: Nested IV1

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cars_dFFV	1.175*	(0.037)
pe_over_pg_month_dFFV	-0.950***	(0.000)
inflpk	-0.0205*	(0.033)
lnsjg1	0.136	(0.593)
ch1	0.000322**	(0.008)
ch2	-0.0153**	(0.002)
ch3	0.00251*	(0.041)
ch4	0.0235*	(0.027)
ch5	0.0141	(0.054)
rch4	-1.112	(0.303)
rch4_dFFV	-0.335	(0.187)
rch2	0.0739***	(0.001)
rch2_dFFV	0.000815	(0.343)
rch1	-0.0000128***	(0.000)
rch1_dFFV	0.000000316**	(0.004)
rebate_dFFV	0.178	(0.091)
congestiontax_dFFV	0.115	(0.477)
N	46174	

Table A.11: Nested IV2

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cap_dFFV	2.531*	(0.024)
pe_over_pg_month_dFFV	-0.942***	(0.000)
inflpk	-0.0205*	(0.033)
lnsjg1	0.137	(0.589)
ch1	0.000322**	(0.008)
ch2	-0.0153**	(0.002)
ch3	0.00250*	(0.040)
ch4	0.0234*	(0.027)
ch5	0.0141	(0.053)
rch4	-1.094	(0.310)
rch4_dFFV	-0.312	(0.193)
rch2	0.0732***	(0.001)
rch2_dFFV	0.000874	(0.311)
rch1	-0.0000127***	(0.000)
rch1_dFFV	0.000000329**	(0.004)
rebate_dFFV	0.177	(0.095)
congestiontax_dFFV	0.112	(0.491)
N	46174	

Table A.12: Hausman1

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0347	(0.075)
e85sta_per1000cap_dFFV	1.114	(0.453)
pe_over_pg_month_dFFV	-0.857***	(0.000)
ch1	0.000483*	(0.016)
ch2	-0.0194***	(0.000)
ch3	0.00423	(0.064)
ch4	0.0374*	(0.032)
ch5	0.0130	(0.164)
rch1	-0.0000134***	(0.000)
rch2	0.0766***	(0.001)
rch4	-0.998	(0.422)
rch1_dFFV	0.000000391***	(0.000)
rch2_dFFV	0.000407	(0.536)
rebate_dFFV	0.298*	(0.020)
congestiontax_dFFV	0.0329	(0.811)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cap_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 2.57511 F(246083) P-value = 0.07616

Durbin-Wu-Hausman chi-sq test: 5.15981 Chi-sq(2) P-value = 0.07578

Table A.13: Hausman2

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0359	(0.065)
e85sta_per1000cap_dFFV	-0.0662	(0.975)
pe_over_pg_month_dFFV	-0.831***	(0.000)
ch1	0.000496*	(0.013)
ch2	-0.0196***	(0.000)
ch3	0.00437	(0.056)
ch4	0.0385*	(0.028)
ch5	0.0125	(0.183)
rch1	-0.0000136***	(0.000)
rch2	0.0777***	(0.001)
rch4	-1.093	(0.385)
rch1_dFFV	0.000000395***	(0.000)
rch4_dFFV	0.198	(0.541)
rebate_dFFV	0.359*	(0.020)
congestiontax_dFFV	-0.00238	(0.990)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cap_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 3.44246 F(246083) P-value = 0.03199

Durbin-Wu-Hausman chi-sq test: 6.89748 Chi-sq(2) P-value = 0.03179

Table A.14: Hausman3

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0318	(0.102)
e85sta_per1000cap_dFFV	3.900	(0.080)
pe_over_pg_month_dFFV	-0.921***	(0.000)
ch1	0.000453*	(0.024)
ch2	-0.0190***	(0.000)
ch3	0.00389	(0.088)
ch4	0.0349*	(0.046)
ch5	0.0143	(0.124)
rch1	-0.0000130***	(0.000)
rch2	0.0738***	(0.001)
rch4	-0.771	(0.530)
rch1_dFFV	0.000000382***	(0.000)
rch4_dFFV	-0.466	(0.294)
rch2_dFFV	0.00137	(0.185)
rebate_dFFV	0.154	(0.307)
congestiontax_dFFV	0.116	(0.455)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cap_dFFV

H0: Regressors are exogenous

Wu-Hausman F test:	1.40547 F(246082) P-value = 0.24526
Durbin-Wu-Hausman chi-sq test:	2.81637 Chi-sq(2) P-value = 0.24459

Table A.15: Hausman4

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0243	(0.176)
e85sta_per1000cap_dFFV	11.17***	(0.000)
pe_over_pg_month_dFFV	-1.086***	(0.000)
ch1	0.000373*	(0.044)
ch2	-0.0180***	(0.000)
ch3	0.00302	(0.153)
ch4	0.0283	(0.080)
ch5	0.0175*	(0.043)
rch1	-0.0000121***	(0.000)
rch2	0.0666**	(0.002)
rch4	-0.180	(0.877)
rch1_dFFV	0.000000358***	(0.000)
rch4_dFFV	-1.683***	(0.000)
rch2_dFFV	0.00387***	(0.000)
rebate_dFFV	-0.220	(0.157)
congestiontax_dFFV	0.333*	(0.030)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cap_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 7.66756 F(246082) P-value = 0.00047

Durbin-Wu-Hausman chi-sq test: 15.36062 Chi-sq(2) P-value = 0.00046

Table A.16: Hausman5

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0347	(0.075)
e85sta_per1000cars_dFFV	0.491	(0.453)
pe_over_pg_month_dFFV	-0.859***	(0.000)
ch1	0.000484*	(0.016)
ch2	-0.0194***	(0.000)
ch3	0.00423	(0.064)
ch4	0.0375*	(0.032)
ch5	0.0130	(0.165)
rch1	-0.0000135***	(0.000)
rch2	0.0769***	(0.001)
rch4	-1.010	(0.416)
rch1_dFFV	0.000000385***	(0.000)
rch2_dFFV	0.000362	(0.573)
rebate_dFFV	0.301*	(0.016)
congestiontax_dFFV	0.0326	(0.813)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cars_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 2.68126 F(246083) P-value = 0.06849

Durbin-Wu-Hausman chi-sq test: 5.37248 Chi-sq(2) P-value = 0.06814

Table A.17: Hausman6

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0359	(0.065)
e85sta_per1000cars_dFFV	-0.0330	(0.975)
pe_over_pg_month_dFFV	-0.830***	(0.000)
ch1	0.000496*	(0.013)
ch2	-0.0196***	(0.000)
ch3	0.00437	(0.055)
ch4	0.0385*	(0.027)
ch5	0.0125	(0.183)
rch1	-0.0000136***	(0.000)
rch2	0.0777***	(0.001)
rch4	-1.093	(0.385)
rch1_dFFV	0.000000395***	(0.000)
rch4_dFFV	0.199	(0.577)
rebate_dFFV	0.359*	(0.025)
congestiontax_dFFV	-0.00263	(0.989)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cars_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 3.22518 F(246083) P-value = 0.03976

Durbin-Wu-Hausman chi-sq test: 6.46219 Chi-sq(2) P-value = 0.03951

Table A.18: Hausman7

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0282	(0.144)
e85sta_per1000cars_dFFV	3.407	(0.072)
pe_over_pg_month_dFFV	-1.021***	(0.000)
ch1	0.000414*	(0.037)
ch2	-0.0185***	(0.000)
ch3	0.00346	(0.125)
ch4	0.0316	(0.067)
ch5	0.0158	(0.085)
rch1	-0.0000129***	(0.000)
rch2	0.0722***	(0.001)
rch4	-0.546	(0.653)
rch1_dFFV	0.000000331***	(0.000)
rch4_dFFV	-1.108	(0.143)
rch2_dFFV	0.00238	(0.105)
rebate_dFFV	-0.0199	(0.931)
congestiontax_dFFV	0.229	(0.220)
_cons	-6.874**	(0.002)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cars_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 1.99019 F(246082) P-value = 0.13668
Durbin-Wu-Hausman chi-sq test: 3.98798 Chi-sq(2) P-value = 0.13615

Table A.19: Hausman8

Dependent variable: meanu

	Coefficient	P-values
inflpk	-0.0219	(0.216)
e85sta_per1000cars_dFFV	6.182***	(0.000)
pe_over_pg_month_dFFV	-1.175***	(0.000)
ch1	0.000348	(0.056)
ch2	-0.0177***	(0.000)
ch3	0.00273	(0.188)
ch4	0.0261	(0.100)
ch5	0.0184*	(0.031)
rch1	-0.0000124***	(0.000)
rch2	0.0678**	(0.001)
rch4	-0.105	(0.927)
rch1_dFFV	0.000000279***	(0.000)
rch4_dFFV	-2.162***	(0.000)
rch2_dFFV	0.00430***	(0.000)
rebate_dFFV	-0.325	(0.059)
congestiontax_dFFV	0.415**	(0.010)
N	46174	

Tests of endogeneity of: inflpk e85sta_per1000cars_dFFV

H0: Regressors are exogenous

Wu-Hausman F test: 8.31672 F(246082) P-value = 0.00024

Durbin-Wu-Hausman chi-sq test: 16.66063 Chi-sq(2) P-value = 0.00024

Table A.20: IV5

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cars_dFFV	6.182***	(0.000)
pe_over_pg_month_dFFV	-1.175***	(0.000)
inflpk	-0.0219	(0.215)
ch1	0.000348	(0.056)
ch2	-0.0177***	(0.000)
ch3	0.00273	(0.187)
ch4	0.0261	(0.099)
ch5	0.0184*	(0.032)
rch4	-0.105	(0.926)
rch4_dFFV	-2.162***	(0.000)
rch2	0.0678**	(0.004)
rch2_dFFV	0.00430***	(0.000)
rch1	-0.0000124***	(0.000)
rch1_dFFV	0.000000279***	(0.000)
rebate_dFFV	-0.325	(0.078)
congestiontax_dFFV	0.415*	(0.049)
N	46174	

Table A.21: IV6

Dependent variable: meanu

	Coefficient	P-values
e85sta_per1000cap_dFFV	11.17***	(0.000)
pe_over_pg_month_dFFV	-1.086***	(0.000)
inflpk	-0.0243	(0.176)
ch1	0.000373*	(0.044)
ch2	-0.0180***	(0.000)
ch3	0.00302	(0.153)
ch4	0.0283	(0.080)
ch5	0.0175*	(0.045)
rch4	-0.180	(0.876)
rch4_dFFV	-1.683***	(0.000)
rch2	0.0666**	(0.006)
rch2_dFFV	0.00387***	(0.000)
rch1	-0.0000121***	(0.000)
rch1_dFFV	0.000000358***	(0.000)
rebate_dFFV	-0.220	(0.185)
congestiontax_dFFV	0.333	(0.094)
N	46174	

Table A.22: IV7

Dependent variable: meanu

	Coefficient	P-values
pe_over_pg_month_dFFV	-0.911***	(0.000)
inflpk	-0.0264	(0.106)
e85sta_per1000cars_dFFV	2.659***	(0.000)
e85sta_per1000cars_dHEV	-1.794	(0.154)
e85sta_per1000cars_dBFV	8.726**	(0.006)
e85sta_per1000cars_dGREENGAS	4.389***	(0.000)
e85sta_per1000cars_dGREENDIESEL	1.498**	(0.007)
e85sta_per1000cars_dGASNONGREEN	0.0568	(0.920)
e85sta_per1000cars_dDIESEL	3.022***	(0.000)
rebate_dFFV	0.208	(0.071)
rebate_dHEV	0	(.)
rebate_dBFV	0	(.)
rebate_GREENGAS	-0.0774	(0.590)
rebate_GREENDIESEL	0.519***	(0.000)
ch1	0.000438*	(0.014)
ch2	-0.0193***	(0.000)
ch3	0.00323	(0.091)
ch4	0.0304*	(0.039)
ch5	0.0158	(0.059)
rch4	-1.567	(0.171)
rch4_dFFV	-0.324	(0.235)
rch2	0.104***	(0.000)
rch2_dFFV	0.000988	(0.209)
rch1	-0.0000156***	(0.000)
rch1_dFFV	0.000000369***	(0.000)
congestiontax_dFFV	0.0774	(0.665)
congestiontax_dHEV	1.124***	(0.000)
congestiontax_dBFV	-0.0193	(0.941)
N	46174	

Table A.23: IV8

Dependent variable: meanu

	Coefficient	P-values
pe_over_pg_month_dFFV	-0.908***	(0.000)
inflpk	-0.0244	(0.113)
e85sta_per1000cap_dFFV	5.241***	(0.000)
e85sta_per1000cap_dHEV	-4.819*	(0.043)
e85sta_per1000cap_dBFV	14.52**	(0.005)
e85sta_per1000cap_dGREENGAS	5.424***	(0.000)
e85sta_per1000cap_dGREENDIESEL	1.950	(0.073)
e85sta_per1000cap_dGASNONGREEN	-0.0993	(0.926)
e85sta_per1000cap_dDIESEL	6.230***	(0.000)
rebate_dFFV	0.211	(0.065)
rebate_dHEV	0	(.)
rebate_dBFV	0.133	(0.584)
rebate_GREENGAS	0.102	(0.481)
rebate_GREENDIESEL	0.564***	(0.000)
ch1	0.000419*	(0.013)
ch2	-0.0191***	(0.000)
ch3	0.00300	(0.097)
ch4	0.0286*	(0.040)
ch5	0.0170*	(0.035)
rch4	-1.456	(0.199)
rch4_dFFV	-0.295	(0.265)
rch2	0.0966***	(0.000)
rch2_dFFV	0.00104	(0.189)
rch1	-0.0000141***	(0.000)
rch1_dFFV	0.000000386***	(0.000)
congestiontax_dFFV	0.0738	(0.677)
congestiontax_dHEV	1.154***	(0.000)
congestiontax_dBFV	0	(.)
N	46174	