The Market Impact and the Cost of Environmental Policy: Evidence from the Swedish Green Car Rebate*

Cristian Huse† Claudio Lucinda‡

December 2012

Abstract

This paper quantifies the effects of the Swedish green car rebate (GCR), a program to reduce oil dependence and greenhouse gas emissions in the automobile industry. We estimate the demand for automobiles in the Swedish market and simulate counterfactual policies to assess different dimensions of the program. Our most conservative estimates find the GCR to have increased the market shares of "green cars" by 5.5 percentage points and its cost to be about \$109/tonCO2 saved, thus 5 times the price of an emission permit. Since the main green cars in Sweden are FFVs (flexible-fuel vehicles), which can seamlessly switch between (high-CO2 emissions) gasoline and (low-CO2 emissions) ethanol, fuel choice is another dimension policymakers need to consider – once fuel arbitrage is accounted for, the cost of CO2 savings increases by over 16 percent if 50 percent of FFV owners drive on gasoline instead of ethanol. Moreover, the GCR design was detrimental to Swedish carmakers, which lost substantial market share due to the policy. As the GCR gives vehicles able to operate on alternative (renewable) fuels a favorable treatment as compared to those operating only on regular (fossil) ones, we also consider a counterfactual in which they are treated equally. Our findings suggest that consumers would have switched to the FFV technology even without the rebate.

JEL Classification: H23, H25, L11, L62, L71, L98, Q42, Q48.

Keywords: CO2 emissions; Ethanol; Environmental policy; Flexible-fuel vehicles; Fuel economy; Green Car; Governmental policy; Greenhouse gases; Renewable fuels.

---

[*] We thank Tobias Olsson for making data available, Alexandra Lindfors and Martin Roxland for research assistance, and participants at the SBE Meeting, the SSE Empirical Micro and REAP-MOITA workshops for feedback. We are also indebted to Nikita Koptyug, Henrique Pacini and Heleno Pioner (REAP-MOITA discussant) for comments. The usual disclaimer applies.

[†] Stockholm School of Economics. Email address: cristian.huse@sse.edu. Web: http://cristianhuse.webs.com. Correspondence address: Stockholm School of Economics, Box 6501, 113 83 Stockholm, Sweden. Phone: + 46 8736 9167.

[‡] University of São Paulo (FEA-RP). Email address: claudiolucinda@fearp.usp.br. Correspondence address: Av. Bandeirantes, 3900, Monte Alegre, 14040-900, Ribeirão Preto-SP, Brazil. Phone: + 55 16 3602 4971.

1 Introduction

Economists have been interested in the interplay between regulation and market outcomes since at least Ricardo (1817). One century later, following seminal contributions by Olson (1965) and Stigler (1971), a substantial body of literature studying regulation developed. In particular, regulation in the transportation sector has received increased attention in recent years due to a number of policies implemented in different countries, following the increasing concern about GHG (greenhouse gas) emissions, notably CO2.[1]

Road transport is responsible for 20 percent of the CO2 emissions generated by fuel consumption worldwide. With the growth of emerging economies, fuel demand for transportation needs is set to grow by 40 percent and the number of passenger cars worldwide is set to double to almost 1.7 billion by 2035 (IEA 2011a, 2011b). Within the European Union, passenger cars are responsible for about 12 percent of the overall emissions. This share is a much higher 19 percent in Sweden, thus close to the 20 percent estimated to hold for the US market, as the country has one of the most fuel-devouring car fleets on the continent (Commission of the European Communities 2007). Reducing emissions from passenger cars is thus essential for Sweden to meet EU-wide environmental goals.[2] In practice – especially when gasoline taxes are difficult to sustain on political grounds – this essentially involves increasing fuel economy standards of the means of transport and/or investing in alternative fuels and technologies for the transportation sector. (See Parry, Walls and Harrington 2007 for a discussion of the importance of alternative fuels.)

This paper examines the effect of regulation on the Swedish new passenger car market. Specifically, it evaluates the effect of the Swedish Green Car Rebate (GCR) on CO2 emissions savings, their costs as well as the market shares of the different brands operating in the market.

The Swedish automobile industry is responsible for substantial amounts of employment, investment, exports and R&D in the country.[3] As a result, one may argue that –on top of environmental concerns– a policy such as the GCR could have been tailored to benefit domestic producers, be it because of the economic importance of the industry or due to the fact that regulators are likely to be captured by businesses in the process of regulatory design (Laffont and Tirole 1991, Boyer and Laffont 1999). This view is corroborated by the literature on strategic trade policy (Dixit 1984, Brander and Lewis 1985), according to which benefiting domestic producers could even be welfare-enhancing. In what follows, this paper examines the effect of environmental policy on both environmental and economic variables, focusing on the cost-effectiveness of the program and on the extent to which domestic carmakers benefited from its design, if at all.

The Swedish Green Car Rebate The Swedish Green Car Rebate (GCR) is one among a number of policies designed to incentivize the purchase of fuel-efficient vehicles worldwide amid

---

[1] Subsidies were awarded to hybrid and electric vehicles in the US and Canada; China and Brazil reduced sales tax; scrappage programs were launched in the US and a number of European countries in 2008 and 2009. Given its design, the policy we study is closer in spirit to the US hybrid subsidy.

[2] The 1994 EEA Treaty which created the European Economic Area originally set a target of 120 gCO2/km by 2005 (later relaxed to 130 gCO2/km by 2012) and aimed at cutting carbon emissions by 20 percent by 2020 compared to the levels of 1990. For perspective, Sweden's fleet does lag behind most EU 25 countries when it comes to average CO2 emissions; these are lower only than those of Estonia and Latvia (EFTE 2009).

[3] Having originated in Sweden, Volvo and Saab were taken over by US carmakers, thus becoming brands within conglomerates Ford and GM, respectively. The change in corporate control did not change the fact that the bulk of activities such as design, engineering and manufacturing of the local brands was still performed in Sweden, so much so that both are still considered local brands by Swedish consumers. Out of a population of 9 million, some 120,000 are employed by the automobile industry, which is responsible for over 10 percent of Swedish exports (BIL Sweden 2010).

the ever growing concern with GHG and the quest for oil independence. The GCR, which consisted of a 10,000 SEK rebate paid to private individuals purchasing new environmentally friendly – or *green* – cars.[4] Two features distinguish the GCR from similar policies elsewhere. First, in contrast with related policies elsewhere which have typically not been applied widely enough to affect a large fraction of the new vehicle market (Sallee 2011a), the GCR was broad in that green cars commanded a 25 percent market share among newly-registered cars already in 2008, as compared to the 2.15 percent commanded by HEVs in the US after a similar policy (Beresteanu and Li 2011). On the supply side, the number of green car models available on the Swedish market increased from 73 to 120 already in 2008 – for perspective, Beresteanu and Li (2011) document 15 hybrid models available on the US market in 2007.[5]

Second, the GCR relies on *alternative* (renewable) fuels to achieve its aims. Anecdotal evidence suggests that the skew towards renewables was inspired by Brazil, whose CO2 emissions per unit of fuel consumption in road traffic are 20 percent below the world average due to the use of ethanol (IEA 2011a), although getting the support of the Green Party is sometimes also mentioned as an explanation for this feature of the policy.[6] The GCR defined a green car according to which fuels it is able to operate on and on how much CO2 it emits: while cars able to run only on *regular* (fossil) fuels (such as gasoline and diesel) were considered green cars provided they emitted no more than 120 gCO2/km, those able to run on alternative fuels (ethanol, electricity, and gas – which we call CNG hereafter) were given a more lenient treatment roughly equivalent to 220 gCO2/km. As a result, 54 among the 120 green cars marketed in 2008 were alternative ones and two-thirds of the new green cars registered in 2008 were able to operate using renewable fuels. Among these, the dominant ones are FFVs (flexible fuel vehicles), which seamlessly operate using any combination of ethanol and gasoline.[7]

While the first FFV dates back to the early 1900s – the Ford Model T was able to operate on gasoline, kerosene and ethanol– it was only in the 1980s that vehicles able to operate using renewable fuels took center stage, in the Brazilian market. However, since the technology was based on captive ethanol vehicles, consumers were effectively locked-in and suffered due to fuel shortages, which eventually resulted in the demise of the captive ethanol technology in the country.[8]

Empirical Strategy We quantify the impacts of the Swedish GCR by estimating a structural model for the Swedish car market and examining a number of counterfactuals to the actual policy. To do so we use a unique registration-based dataset for the Swedish car market with car models disaggregated at the fuel segment level which we combine with product characteristics, fuel and mileage data.

---

[4] The rebate corresponds to roughly 6 percent off of the price of a new VW Golf 1.6. With the SEK/$ exchange rate at 6.984 (7.650) at the inception (end) of the program, the rebate was in the range $1,300-1,500. In what follows we use a SEK/$ exchange rate of 7 unless mentioned otherwise.

[5] In the Swedish market, product introduction in the FFV and low-emission segments typically occurs via the introduction of new variants (versions) of existing models.

[6] While countries such as France and Germany established an emission ceiling in their programs, the US has put forth a scrappage scheme; Sweden combined an emission threshold with renewable fuel requirements. See http://ec.europa.eu/environment/air/transport/road.htm for an overview of the European framework. Note also that in the US the emission requirement is replaced with a (roughly equivalent) fuel economy one.

[7] According to the Swedish Environmental Protection Agency (2008), one liter of ethanol contains about 74 percent of the energy in one liter of gasoline.

[8] The New York Times (1989) reports in December 1989 how *"taxi fleets have started to glide to a halt, as many as two-thirds of Rio's service stations have closed their alcohol [ethanol] pumps, (...) a 400-car alcohol line blocked traffic on the Rio-Sao Paulo highway"* and mentions a 40 percent shortfall in ethanol supplies expected for January 1990.

In our analysis, we focus on both environmental and market effects of alternative policies. On the environmental side we quantify CO2 emission savings as well as their cost.

On the market side, we focus on market shares of different fuel segments and brand market shares, both overall and disaggregated by fuel segment.[9] This provides another dimension along which to evaluate the skew towards renewables and how the program affected different car manufacturers. In particular, we examine to which extent – if at all – local manufacturers Saab and Volvo benefited from the policy.

We consider three counterfactuals. First, we assess the overall impact of the GCR by considering a scenario with no environmental policy. Next, we address a key feature of the GCR, namely the asymmetric treatment of vehicles running on regular as compared to those running on alternative fuels. That is, we assess what would have happened had one treated regular and alternative fuels in a similar way by letting only vehicles emitting no more than 120 gCO2/km be classified as green cars and thus qualify for the rebate. Finally, we examine what would have happened had all carmakers decided to turn their captive gasoline cars into FFVs to benefit from the program. This is a scenario consistent with what has happened in the mid-2000s in the Brazilian market, where all major carmakers producing in the country decided to phase out captive gasoline vehicles in favor of FFVs. Since the FFV technology piggybacks on the gasoline one, and the estimated cost to turn a captive gasoline car into a FFV is \$100-200 (and decreasing, see Corts 2010, Anderson and Sallee 2011), this scenario is arguably less extreme than it looks at first glance.

Main Findings On the environmental front, the results indicate that the GCR resulted in a decrease in lifetime CO2 emissions of about 493.2 thousand tonCO2 for the vehicles sold during the period in which the policy was in place. This implies a cost of 760 SEK/tonCO2 (or \$109), thus lower than the \$177 obtained by Beresteanu and Li (2011) and at the lower end of results in the range \$91-288 obtained by Li, Linn and Spiller (2011) for the US market. The cost of CO2 savings can also be compared to the prices of emission rights and to the social cost of carbon (SCC) – at about five times the cost of CO2 emission permits or the value of the SCC, the estimates do not lend support to the view that the program was cost-effective.[10]

Accounting for the fact that a substantial share of FFV owners switches to the cheapest between gasoline and ethanol results in non-trivial cost increases. For instance, if gasoline usage among FFV owners is 50 percent, CO2 savings decrease by 14 percent and their costs by 16 percent as compared to the benchmark, reaching 883 SEK or \$126. That is, the FFV technology makes fuel choice an additional dimension regulators have to take into account when designing policy.

Removing the asymmetry of the GCR would result in lower CO2 savings but also a lower cost, in both absolute and relative terms. Importantly, a symmetric version of the GCR would have minor effects on the market shares of alternative vehicles, which suggests that favoring them was not even necessary, i.e. consumers would have purchased alternative vehicles – especially FFVs – due to the potentially lower operating costs they provide by allowing to switch fuels.

Finally, in a scenario where carmakers were to fully replace their captive gasoline models with FFVs, CO2 savings would increase substantially, but at a high total cost for the taxpayer:

---

[9] See Train and Winston (2007) for a related analysis for the US market.

[10] These figures can be compared to the cost of similar programs in the US, to the price of European emission permits and to the social cost of carbon. Emission rights were illiquid instruments during the period the GCR was in place. End-of-period spot prices were in the range 118-142 SEK/tonCO2 for each quarter in 2009 at the then prevailing SEK/EUR exchange rates. The SCC is estimated to be EUR 15 (about 150 SEK) per ton of CO2 (Interagency Working Group on Social Cost of Carbon 2010; Aldy, Krupnick, Newell, Parry and Pizer 2010). In Sweden, policymakers distinguish between traded and non-traded goods; thus, they price CO2 emissions from fuel at 1060 SEK/tonCO2, see Mandell (2011) for a discussion. (We thank Jan-Eric Nilsson for bringing up this point.)

this alternative policy would result in a roughly fivefold cost increase as compared to the GCR. However, the high share of FFVs compounded with fuel switching would easily make the program very expensive also in relative terms, e.g. if 50 percent of FFV owners arbitrage across fuels, the cost of the program would be 36 percent above those of the actual GCR.

On the market front, the first counterfactual highlights that high-emission vehicles, especially those running on gasoline, suffered an ever increasing competition from fuel segments benefiting from the GCR; these include low-emission regular vehicles and (high-emission) FFVs, all of which were eligible for the rebate and jointly experienced a 5.5 percentage point increase in market shares due to the policy. As a result, the main brands losing out from the policy were Swedish carmakers Volvo and Saab as well as (high-end) German carmakers Audi, BMW and Mercedes.[11]

A symmetric version of the GCR would make Saab and high-end German brands better off as compared to the actual policy.

The reason why Volvo would be at the losing end under such counterfactual is its focus on the high emission fuel segments, but such losses would be mild, amounting to less than 0.5 percentage point. Importantly, the market share of FFVs would decrease by less than 0.4 percentage point (from 14.1 to 13.7 percent) as compared to the GCR, which suggests that consumers would have purchased FFVs regardless of the policy. This finding is similar in spirit to those in Chandra, Gulati and Kandlikar (2010), who look at hybrid electric vehicles in the Canadian market, and Sallee (2011b), who finds evidence that consumers –rather than producers– capture most of the incentives offered when purchasing the Toyota Prius in the US market.

Finally, full conversion to the FFV technology would result in higher market shares for Swedish and high-end German brands as compared to the actual GCR, at least partially restoring market shares lost under the GCR. This finding once again shows how the FFV segment carved market share at the expense of high-emission gasoline vehicles.

Contribution and Related Literature We contribute to the burgeoning literature on the impact of policies targeted at the transportation sector, notably the automobile market, to promote the adoption of fuel-efficient technologies. To our knowledge, this is the first attempt to structurally investigate a green car policy with a broad impact on the automobile market and skewed towards renewables. The use of a structural model allows to assess different aspects of the policy by performing counterfactuals.

The papers most closely related to ours are Chandra, Gulati and Kandlikar (2010) and Beresteanu and Li (2011), which look at policies designed to promote the adoption of hybrid electric vehicles (HEVs) in Canada and the US, respectively, both of which are close in spirit to the GCR.[12] [13] Typically, the literature documents that although these programs tend to increase the market

---

[11] Although it would be far fetched to attribute the fate of Volvo and Saab solely to the GCR, reports in the Swedish media in Fall 2009 documented the extent of the financial distress both Saab and Volvo were undergoing in Fall 2008 i.e., before the US carmakers applied for financial rescue (see e.g. http://www.teknikensvarld.se/2009/10/12/8449/saab-och-volvo-var-nara-konkurs/). It is however fair to say that the fact that Volvo's two main markets were Sweden and the US did definitely not help the carmaker, which reported a nearly 20 percent decrease in its global sales from 2007 to 2008, followed by a further decrease in 2009 (see http://www.volvocars.com/intl/top/corporate/pages/this-is-volvo-car-corporation.aspx). In the Swedish consumer market, Huse and Koptyug (2012) document that the 2007-2008 market shares of Volvo and Saab decreased from 17.42 to 12.44 percent and from 4.11 to 3.74 percent, respectively, *despite* the GCR. Since the GCR is not statistically significant at explaining total sales in the Swedish market (see Appendix B), this suggests that both carmakers did lose ground in the Swedish market during the period.

[12] Two papers pursuing similar lines of research, but looking at policies not so closely resembling the GCR, are Knittel (2009) and Li, Linn, and Spiller (2011), which examine the US "Cash-for-Clunkers" program.

[13] While we focus on the car market as a whole, other studies have examined particular market segments or

share of the market segment they promote at the expense of other ones, the cost of the programs is substantial.[14] This finding is likely to hold due to the fact that these programs typically target a small share of the market. More generally, the paper relates to early work by Pakes and Berry (1993) and Berry, Kortum and Pakes (1996) quantifying the impact of policy and environmental changes on the US car market and to recent research by Adamou, Clerides and Zachariadis (2012), which simulate alternative feebate schemes in the German car market and their effects in variables such as car sales, firm profits and CO2 emissions.

The paper also relates to the literature focusing on the cost of (environmental) regulation. For instance, Gollop and Roberts (1983) estimate the economic costs of sulfur dioxide (SO2) regulation in the US utility sector during the 1970s. More recently, Ryan (2011) estimates the cost of the 1990 Clean Air Act Amendments in the Portland cement industry, whereas Greenstone, List and Syverson (2012) quantify the impact of the Clean Air Act of 1970 on the productivity of US manufacturing.

The paper also assesses the extent to which different carmakers benefited from the policy. In doing so, it relates to the literature on regulatory capture, according to which businesses with the greatest stake in regulatory activity are likely to attempt to influence regulators. Early contributions to this literature include Olson (1965) and Stigler (1971). Laffont and Tirole (1991) express the argument in terms of agency theory, Boyer and Laffont (1999) specifically focus on environmental regulation whereas Dixit (1984) and Brander and Spencer (1985) emphasize how trade policy can be used to benefit domestic producers.

The focus on alternative fuels connects the paper to the literature studying the interaction between fuel and car markets and to the one focusing on renewable fuels. In the case of the former, the evidence is that consumer reactions are surprisingly slow (Borenstein 1993). This finding can be attributed to the fact that the dominant automobile engine is typically captive and/or there is no fueling infrastructure available for alternative fuels. As opposed to what happens in markets such as the US, where Corts (2010) documents a low market penetration of ethanol due to the lack of fueling infrastructure, Sweden has a well-developed network of fueling stations where ethanol is readily available. Thus, the majority of FFV owners tends to react to fuel prices, effectively arbitraging across fuels (gasoline and ethanol). Thus, it is then important to account for the fact that a fraction of motorists might switch between fuels in the calculation of CO2 savings and their associated costs, i.e. fuel choice is another dimension to be accounted for in policy design.

2 Institutional Background

Despite being smaller than markets such as the French and German ones, the Swedish car market is comparable to larger European ones when looking at ownership on a *per capita* basis and ownership per household, as reported in Table 1.[15] At 9.5 years of age, the average Swedish car is however older and its engine larger than its French or German counterparts. What is more, among the EU 18 countries (the original EU 15 countries plus Hungary, Lithuania and Slovenia) Sweden

---

models. Gallagher and Muehlegger (2007) estimate the effect of state and local incentives, rising gasoline prices, and environmental ideology on hybrid vehicle sales; Kahn (2008) studies the effect of environmental preferences on the demand for green products; Sallee (2011b) studies the incidence of tax credits for the Toyota Prius.

[14] The most conservative estimate among the above papers, by Li et al (2011), is that the ton of CO2 saved cost \$91, roughly five times the price of the corresponding emission permit. At the other end of the spectrum, Metcalf (2008) estimates this cost to be \$1700 for the US ethanol program.

[15] The numbers presented in Table 1 include all registered passenger cars, thus also including those owned by businesses and government.

consistently appeared at the bottom of the CO2 emissions ranking for years 2006-2008 (EFTE 2009). In what can be attributed to an early result of the GCR, the market share commanded by cars able to run on renewable fuels as a fraction of the fleet is the largest in Europe at almost 4 percent as of 2008 (ANFAC 2010).

TABLE 1 ABOUT HERE

The Green Car Rebate The Swedish Green Car Rebate (GCR), which was passed in Parliament and announced to the public in March 2007, effectively starting in April 2007, consisted of a 10,000 SEK (about $1500 using the average SEK/$ exchange rate during the period) transfer to all private individuals purchasing a car classified as environmentally friendly, or *green.*

Carmakers were caught by surprise by the policy: product lines are typically launched once a year and require carmakers to plan their overall strategy well in advance. In the Swedish market, where this happens late in the fall, the product lines for model-year 2007 had been launched and were already in the middle of their production cycle. As a result, carmakers were only able to adjust their product lines to the rebate, i.e. re-engineer their vehicles, from model-year 2008.

To qualify as a green car and be eligible for the rebate, a car is to belong to the appropriate environmental class and comply with certain emission criteria (SFS 2007). Cars are divided into two categories: regular and alternative fueled cars. Cars running on fossil fuels (or *regular fuels*) qualify as green cars if their CO2 emissions are no greater than 120 g/km.[16][17] Cars able to run on fuels other than gasoline and diesel (or *alternative fuels*) qualify as green cars if their consumption is lower than the equivalent of 9.2 liters/100 km using gasoline or 9.7 m3/100 km using gas (typically CNG, compressed natural gas); electric cars are considered green if their consumption is no greater than 37 kWh/100 km. The difference in treatment dispensed to regular and alternative fuels becomes evident if these figures are converted to emission levels: the threshold for alternative vehicle to be considered a green car is equivalent to about 220 gCO2/km running on gasoline.[18]

The Swedish Passenger Car Market The overall number of brands and models on the Swedish market increased during the sample period, especially following the inception of the GCR. In particular, the changes in the number of low emission models (those emitting less than 120 gCO2/km) marketed were non-trivial, increasing from 46 in 2007 to 69 in 2008 and 89 in 2009, see Table 2. These numbers suggest carmakers did react swiftly due at least in part to the GCR.

TABLE 2 ABOUT HERE

---

[16] In contrast to the US market, emission thresholds in Sweden apply to individual cars rather than to a brand-level sales-weighted average. At the equivalent of about 193 gCO2/mile, this emission threshold is already more stringent than the 250 gCO2/mile CAFE standard to take effect from 2016 in the US.

[17] Emissions of 120 gCO2/km correspond to fuel consumption of about 5 liters of gasoline or 4.5 liters of diesel per 100 km (75.7 and 84.1 mpg, respectively). Diesel cars must also have particle emissions of less than 5 mg/km, meaning that they need to have a particle filter.

[18] Although expressed in different units (gCO2/km and l/100km) the CO2 emissions and fuel efficiency measures are nearly equivalent; for vehicles marketed in Sweden, the correlation between CO2 emissions and mpg is -0.90, and the threshold for alternative fuels is equivalent to about 220 gCO2/km (for perspective, the 2012 Porsche 911 Carrera emits 205 gCO2/km). See Anderson, Parry, Sallee and Fischer (2011) and Huse (2012) for details. In what follows we use mostly units based on the metric system. That is, one *kpl* amounts to approximately 2.35 *mpg* since 1 mile equals 1.609 *km* and 1 gallon equals 3.78 liters; 9.2 liters/100km corresponds to 10.87 *kpl* or 25.54 *mpg.*

The main alternative fuel in Sweden is ethanol (E85), a fuel available in over half of all fueling stations in the country. It is a mixture of 85 percent ethanol and 15 percent gasoline in which the gasoline works as a lubricant and helps start the engine. On the Swedish market, cars able to operate on ethanol also do so on gasoline, thus being called FFVs (flexible-fuel vehicles). The price of an FFV is slightly higher than that of a comparable gasoline model, with second-hand values being roughly equivalent. FFV engines essentially piggy-back on the standard (Otto cycle) gasoline technology and the possibility to seamlessly switch between gasoline and ethanol may explain the swift adoption of FFVs.

Table 2 also reports that, starting from 2 models marketed in 2004 (two versions of the Ford Focus), the number of FFVs increased to 18 in 2007, 44 in 2008 and 66 in 2009, typically via the introduction of variants of existing models. The number of brands offering FFVs also increased substantially, from 1 in 2004 to 3 in 2007, 10 in 2008 and 12 in 2009. Interestingly, no FFV emits less than 120 gCO2/km. The effect of the GCR on the number of brands and models offering gas- and electric-based vehicles (which we refer to as gasoline/CNG and gasoline/electric vehicles, respectively) was much less dramatic – in the case of the former, this can be explained by the limited CNG retail network, concentrated in the southern part of the country, whereas in the case of the latter, anecdotal evidence suggests that electric vehicles are considered poor value for money by Swedish consumers.

FIGURE 1 ABOUT HERE

FFVs were the main gainers following the GCR reaching about 15 percent of registrations in 2008, while CNG and electric vehicles never commanded more than 1 percent of the market, see Figure 1. The growth in the FFV share was in large at the expense of high-emission regular vehicles, which commanded a market share of 77.7 percent in 2008 down from a 94.7 percent in 2006. Although low-emission regular vehicles also gained market share, this was much lower than the gain experienced by FFVs.

Purchasing a Car The registration of a vehicle with The Swedish Transport Agency (Transportstyrelsen) must take place within ten working days of a change in vehicle ownership. Sweden being a small market, car dealers keep a very low inventory level, so much so that typically one has to order a car a few months in advance and make a deposit. This results in very few episodes of sales or rebates from the part of carmakers and/or dealers. This evidence is reassuring in light of the use of list prices when estimating demand.[19]

3 Data

We combine a number of datasets, from administrative-based registration data to car characteristics, mileage and fuel data. (See the Appendix for details.)

Car Registrations Car registration data is from *Vroom*, a consulting firm. The data on privately owned vehicles (i.e. those eligible for the rebate) is recorded at the monthly frequency from January 2004 to December 2009. An observation is a combination of month, brand, model and fuel type.

---

[19] List prices, sticker prices or MSRPs (manufacturer's suggested retail prices) are set by manufacturers and are typically constant across geographic markets within a model-year. Given the difficulty in obtaining transaction prices, MSRPs have commonly been used in the literature, e.g. Beresteanu and Li (2011) for a recent example.

Car Characteristics Product characteristics are obtained from the consumer guides "Nybilsguiden" (New Car Guide) issued yearly by The Swedish Consumer Agency (Konsumentverket). For every car model available on the Swedish market the information includes characteristics such as fuel type, engine power and size, number of cylinders, weight, fuel economy (city driving, highway driving and mixed driving, with testing made under EU-determined driving cycle), CO2 emissions (measured in gCO2/km under EU-determined driving conditions and mixed driving) and list prices. We deflate the vehicle tax, car and fuel prices using the Consumer Price Index from Statistics Sweden. For car prices and vehicle tax we use the yearly average with 2009 as the base year and for fuel prices the monthly average with December 2009 as the base month.

Fuel Data We use market level data for fuels recorded at the monthly frequency at the national level. Recommended retail fuel prices for gasoline, diesel and ethanol are obtained from the Swedish Petroleum and Biofuels Institute (SPBI).

Mileage Data We use administrative data from the Swedish Motor Vehicle Inspection Company (*Bilprövningen*) on yearly average distances covered by Swedish passenger cars. For every year, we observe average odometer readings for cars of 3, 5, 7, 8 and 10 years of age disaggregated by brand, model, fuel type and body type.[20]

Combining Datasets One important issue arising when merging characteristics and registration datasets is that the former is observed at a more disaggregated level than the latter. Despite being more aggregated than car characteristics, the level of aggregation in registrations is still more refined than standard market level datasets in that we observe sales for different versions at the fuel level. For each combination of year-brand-model-fuel we use characteristics from the baseline version, i.e. the lowest priced model. Importantly, given the relatively small number of green versions (typically one or two per model), aggregation issues for these models essentially vanish.

4 Estimation

4.1 Demand

Model Specification We estimate the demand for cars using discrete choice models for market level data, following Berry (1994) and Berry, Levinsohn and Pakes (1995, BLP). The starting point is a microeconomic model of rational behavior for individual consumers (or households) which is then aggregated to generate market demands. Consumers buy at most one of the products available on the market and, if so, the one yielding the highest utility among the available products. The econometrician does not observe individual choices, only market level data, i.e. prices, quantities and a set of characteristics for each of the J products available on the market for a number of periods (we suppress the index t below to avoid clutter). These "inside" products are indexed by $j = 1, ..., J$, and the outside good, the option to buy a used car or to not buy a car at all is represented by $j = 0$. Define the conditional indirect utility of individual i when consuming product j as

$$u_{ij} = \sum_{k=1}^{K} x_{jk}\beta_{ik} + \xi_j + \varepsilon_{ij},\ i = 1, ..., I;\ j = 1, ..., J$$

---

[20] That is, we do not observe micro level data on mileage. As a result, we are unable to estimate a joint model of vehicle choice and utilization as in, e.g., Goldberg (1998).

where x_{jk} are observed product characteristics such as horsepower and engine size while ξ_j are characteristics observed by the market participants but not the econometrician (such as quality, style etc). We decompose the individual coefficients as $\beta_{ik} = \overline{\beta}_k + \sigma_k v_{ki}$, where $\overline{\beta}_k$ is common across individuals, v_{ki} is an individual-specific random determinant of the taste for characteristic k, which we assume to be Normally distributed, $(v_{1i}, ..., v_{Ki})' \sim \mathcal{N}(0, \Sigma)$, and σ_k measures the impact of v on characteristic k. Finally, ε_{ij} is an individual and option-specific idiosyncratic component of preferences, assumed to be a mean zero Type I Extreme Value random variable independent of both consumer attributes and product characteristics. Since consumers may decide not to buy a new car, the specification of the demand system is completed with an outside good yielding conditional indirect utility $u_{i0} = \xi_0 + \sigma_0 v_i + \varepsilon_{i0}$, where ε_{i0} is a mean zero individual market and time specific idiosyncratic term and v_i is an individual specific component reflecting heterogeneity in tastes.

The above estimation strategy assumes away a number of important features in the car market. First, given the coexistence of primary and secondary car markets (new and used cars), consumer and firm expectations about car and fuel prices are important factors to be taken into account when considering the car market – see Bento et al (2009) and Schiraldi (2011) for the joint modeling of these markets. Cars are moreover durable products, so current ownership of a car is likely to affect the current demand for automobiles, see Hendel and Nevo (2006) and Gowrisankaran and Rysman (2011) for ways of modeling intertemporal substitution. Our estimation approach, which is akin to recent studies such as Klier and Linn (2010) and Beresteanu and Li (2011) thus clearly represents a pragmatic modeling approximation to actual consumer choice behavior in the industry.

Identification Besides the exogenous characteristics, we use the set of "BST instruments", following Bresnahan, Stern and Trajtenberg (1997). That is, we use a set of polynomial basis functions of exogenous variables within a market segment. For a given market segment, we calculate the number of other products of the same firm and the number of firms in the same group, and the number of other products of the same producer in the same group. BST instruments implicitly assume a form of localized competition among products, and this seems consistent with anecdotal evidence for the automobile industry, characterized by a number of market niches and highly differentiated products.

Estimates We consider demand specifications with the following characteristics: engine power (measured in horsepower, HP), engine size (measured in cubic centimeters, CC), fuel economy (liters/100km, under mixed driving), vehicle tax and price. We also include time (month), brand, market segment, fuel segment (gasoline with emissions above and below 120 gCO2/km, diesel with emissions above and below 120 gCO2/km, FFV, gasoline/electric and gasoline/CNG) fixed-effects and interactions of fuel economy and fuel segment fixed-effects.[21] Consumer heterogeneity is introduced into price coefficients via 500 antithetic pairs of random draws of the standard Normal distribution. (The Appendix reports a number of alternative specifications also experimented with.)

TABLE 3 ABOUT HERE

We first compare alternative demand estimates in Table 3. Specification 1 ("OLS") reports the estimates obtained when price is assumed to be exogenous, i.e. it is a standard OLS logit regression

---

[21] We have also experimented with product fixed-effects, with unsatisfactory results. This is likely to be due to the use of a relatively short sample period, frequent name changes in products and moderate product entry and exit.

with market level data. Columns 2 and 3 report IV logit and RC logit estimates, respectively, using the instruments suggested by BST (1997).

Specification 1 features a negative and significant price coefficient of -0.0026. Own-price elasticities are however typically less than one in absolute value, which is inconsistent with the assumption of profit-maximizing firms.

Accounting for price endogeneity as in Specification 2 results in a steeper demand curve, in that the estimated price coefficient increases a fivefold as compared to its OLS counterpart. An immediate result from controlling for price endogeneity is the improved estimates of own-price elasticities, now in the range 1.4-4.2.

Introducing heterogeneity in the form of a random coefficient for price renders a price coefficient of -0.0220, thus about eight times the magnitude of its uninstrumented counterpart. More importantly, it improves own-price elasticities: the 10th and 90th percentiles are given by 5.3 and 2.5, respectively, with a median value of 3.9. These values are in line with standard estimates for European markets using market level data. For instance, Goldberg and Verboven (2001) report elasticities in the range 3-6 in their Table 6. The remaining estimates are in line with economic theory and the literature, e.g. consumers prefer higher engine power and engine size.[22]

4.2 Supply

We consider a standard differentiated product Bertrand-Nash pricing game on the supply side of the market. There are J products (indexed by $j = 1, ..., J$) which are produced by F firms (indexed by $f = 1, ..., F$), each of which produces a subset of products $\Im_f \subset \{1, ..., J\}$.[23] Firm f chooses the prices of its products to maximize its profits according to the profit maximization problem

$$\max_{\{p_j | j \in \Im_f\}} \sum_{j \in \Im_f} (p_j - c_j) D_j(p)$$

$$\begin{aligned} s.t.\ D_j(p) &\geqslant 0,\ j \in \Im_f \\ p_j &\geqslant 0,\ j \in \Im_f \end{aligned}$$

where c_j is the marginal cost of product j, assumed constant. Provided equilibrium prices of all products on the market are positive and all goods are sold in positive quantities (and so the constraints for this program do not bind in equilibrium, as is typically assumed in the empirical literature), the first-order conditions are given by

$$D_k(p) + \sum_{j \in \Im_f} \frac{\partial D_j(p)}{\partial p_k} (p_j - c_j) = 0$$

---

[22] The highest brand fixed-effect is that of Mercedes Benz (3.3), followed by Volvo and Porsche (3.1), Saab (2.8) and Audi (2.4), suggesting consumers prefer Swedish and high-end German brands. French brands Renault, Peugeot and Citroen have intermediate estimates whereas brands Daewoo, Dodge and Rover have the lowest estimates.

[23] Although one could argue that the decision-makers are the conglomerates rather than the firms/brands, i.e., Ford and GM instead of Volvo and Saab, anecdotal evidence for the Swedish market suggests that the local brands enjoyed a substantial degree of independence, performing R&D and product design in Sweden. One event corroborating this view is that since Saab and Volvo were not keen on launching FFVs in the late 1990s, the Swedish government approached Ford with the guarantee to purchase a given number of FFVs per year if they were produced. This is precisely how the FFV version of the Ford Focus was introduced in the Swedish market.

Product ownership is represented by the "ownership matrix" which, to each product in the market, assigns the firm producing it. Define the matrix Δ of dimension J by J and typical element

$$\Delta_{jk} = 1\{\text{both } j \text{ and } k \text{ produced by the same firm, } j, k = 1, ..., J\}$$

where $1\{.\}$ is the indicator function. Using the ownership indicators, the firm's first order condition may be rewritten as:

$$D_k(p) + \sum_{j=1}^{J} \Delta_{jk} \frac{\partial D_j(p)}{\partial p_k}(p_j - c_j) = 0, k = 1, ..., J$$

The (implicit) solution to this set of equations, $p^{NE} = (p_1^{NE}, ..., p_J^{NE})$, provides the prices at which each firm is maximizing its profits given the prices of others, and hence is the Nash equilibrium price to the game. Notice that there is one of these first-order conditions from firm f's objective function for every $k \in \Im_f$. Thus, we obtain a total of J first-order conditions, one for each product.

5 Policy Experiments

5.1 Overview

We assess the effect of three counterfactuals on both environmental and market dimensions, namely (i) CO2 emission savings and their associated costs; (ii) Market shares by fuel segment; (iii) Brand market shares disaggregated up to fuel segment. Following the literature, we allow carmakers to compete in prices *à la* Bertrand-Nash throughout the analysis. Moreover, our analysis is essentially short run in that we do not account for endogenous changes in product characteristics (see, e.g. Klier and Linn 2010, for a study in this direction). The three counterfactuals we consider are as follows. Counterfactual I ("No GCR") compares the actual GCR and the counterfactual of no policy. This allows to quantify the overall effects of the program on the environment and the Swedish car market.

Counterfactual II ("Symmetric GCR") considers the effects of a common threshold of 120 gCO2/km applied to regular and alternative fuels. One immediate effect of such a symmetric policy is that since no single FFV emits less than 120 gCO2/km (see Table 2), no FFV qualifies as a green car.[24]

Counterfactual III ("Full Adoption of FFV Technology") assesses what would have happened had all carmakers immediately decided to turn their captive gasoline cars into FFVs. Although arguably extreme, this scenario is consistent with what has happened in the Brazilian market in the mid-2000s, where all major carmakers decided to phase out gasoline vehicles in favor of FFVs. That is, conditional on buying e.g. any Volkswagen car model produced in Brazil as of 2006, a driver would acquire an FFV (Salvo and Huse 2011). In the US, carmakers have also begun equipping models with flexible fuel engines. With the ever decreasing price of electronics, the cost of turning a captive gasoline car into a FFV is \$100-200 (thus less significant than those in e.g. Berry, Kortum and Pakes 1996; see Corts 2010, Anderson and Sallee 2011 for details). This

---

[24] Although in this scenario one would expect carmakers to eventually bring to market a number of low-emission FFV models, we follow the bulk of the literature since at least Pakes, Berry and Levinsohn (1993) and focus on short-run effects – a thorough long-run analysis would involve setting up a dynamic model of the industry (as in e.g. Ryan 2011) and is left for future research.

scenario thus stresses a potentially perverse effect of the program whereby “too many FFVs” would qualify for the rebate and increase the total cost of the program, without necessarily using ethanol.

To calculate CO2 emission savings, we combine mileage estimates and fuel economy data with car sales in every scenario considered, see Section 3 for details. The resulting CO2 emissions are then divided by the total cost of the GCR to obtain the cost of CO2 savings.

While the baseline specification in each experiment considers a situation in which FFV owners do not drive using gasoline, we do also allow for the fact that FFVs enable their owners to arbitrage across fuels. Since a non-negligible share of FFV owners in Sweden takes advantage of fuel arbitrage and gasoline emits more CO2 than ethanol, fuel switching increases the cost of CO2 savings and fuel choice is an additional margin policymakers have to take into account in considering the design of policies.[25] Thus, besides the baseline case (i.e., no gasoline usage) we also report results for 25, 50 and 75 percent of gasoline usage to gauge the cost-effectiveness of the program.

5.2 Environmental Effects

CO2 Savings and their Costs Table 4 reports estimated CO2 savings and the associated costs of the experiments considered.[26] The first column reports the results for Counterfactual I, which compares the GCR with the no-policy counterfactual. Assuming all FFV owners fuel only using ethanol, the CO2 emission savings induced by the GCR are of 493.2 thousand tonCO2, as reported in Panel A. Note, however, that the savings decrease once fuel switching is accounted for, i.e. CO2 savings reduce by 14 and 18 percent to 424.6 and 406.7 thousand tonCO2 if gasoline usage increases to 50 and 75 percent, respectively.

Lower CO2 savings imply an increased cost per tonCO2 saved, and this is what Panel B in Table 4 reports for Counterfactual I. While lack of fuel switching results in a cost of 760 SEK/tonCO2, or $109, accounting for fuel arbitrage results in a sizable increase in the cost of CO2 savings, even though FFVs command a relatively small share of the market: while an increase from zero to 25 percent in the use of gasoline results in an increase of about 12 percent (about $13) to 850 SEK/tonCO2, the cost can increase by 21 percent to 921 SEK (about $132) if gasoline usage increases to 75 percent.

TABLE 4 ABOUT HERE

Counterfactual II computes CO2 savings and cost estimates obtained from a symmetric version of the GCR. By not contemplating FFVs, in this counterfactual fuel arbitrage does not play a role, i.e. cost and savings are flat across different levels of gasoline usage. Note also that CO2 savings are lower than those in the actual GCR: in the absence of fuel switching, these savings are 193.8 thousand tonCO2, whereas 50 percent of gasoline usage induces savings of 192.1 thousand tonCO2. Not making FFVs eligible for the rebate results in a total cost of just 24 percent of the actual GCR.

Due to the strong presence of FFVs, Counterfactual III results in substantial CO2 emission savings when compared to the other experiments. On the other hand, fuel arbitrage becomes a

---

[25] In what follows, we are mostly agnostic about what share of FFV owners actually arbitrages across fuels, simply reporting figures for shares of 25, 50 and 75 percent. Huse (2012) documents how the drop in oil prices following the 2008 recession, which was quickly passed through to domestic fuel prices, effectively making gasoline cheaper than ethanol in energy-adjusted terms, led to a drop of 73 percent in the monthly sales of ethanol and proposes a stylized structural model whereby the share of fuel switchers (arbitrageurs) among FFV owners is in the range 46-77 percent.

[26] While the results in Table 4 are obtained under the maintained assumption of a 15-year vehicle lifetime to make easier to compare to the literature, e.g. Beresteanu and Li (2011), the results in Appendix B show that these results are qualitatively unchanged under an assumption of 25-year vehicle lifetime.

key margin to be taken into consideration. In the absence of fuel switching, the emission savings amount to 3,159.8 thousand tonCO2, whereas a 50 percent of gasoline usage results in savings of a still sizable 1,474 thousand tonCO2. Although at 470.9 percent of the cost of the actual GCR the total cost of the program is substantial, at 558 SEK/tonCO2 its cost relative to emission savings is comparable to the GCR in the case of no fuel switching. However, the substantial presence of FFVs in the new car fleet induces a non-trivial cost increase once fuel arbitrage is accounted for: this cost increases to 1197 and 1704 SEK under 50 and 75 percent of gasoline usage, respectively.

The results in Table 4 show that, without accounting for fuel arbitrage, at about $109 the cost estimates of the program are comparable to the lower end of the estimates of Li, Linn and Spiller (2011) for the US, which are in the range $91-288, and roughly 40 percent lower than those of Beresteanu and Li (2011) for the US HEV program. However, these costs increase to about $126 and $132 if 50 and 75 percent of FFV owners arbitrage across fuels, respectively. A symmetric version of the GCR results in both lower CO2 savings and lower costs per tonCO2 saved. The extent to which such a program would be preferred to the actual GCR depends on the objective function of the regulator. Finally, full adoption of the FFV technology by carmakers would induce substantial CO2 savings as compared to the GCR benchmark, but also substantial cost increases per tonCO2 saved once fuel arbitrage is accounted for – due to the substantial share of FFVs that would have been purchased –, and especially in what concerns the absolute costs of the program.

5.3 Market Effects

Fuel Segment Market Shares Figure 2a reports market shares of the different fuel segments under the GCR i.e. the actual policy. High emission gasoline vehicles command 50.7 percent of the market, well ahead of high emission diesel ones, with 24.7 percent.[27] Among the fuel segments benefiting from the GCR, the leading one is the FFV, which commands 14.1 percent, followed by low emission gasoline and diesel, with 6.68 and 3.61 percent, respectively. Gasoline/electric and gasoline/CNG vehicles command less than 1 percent of the market and face negligible changes across counterfactuals.

Figure 2b examines the effect of abolishing the GCR on the different fuel segments. Doing so benefits mostly high emission vehicles, with the market share commanded by gasoline and diesel ones increasing by 4.89 and 0.603 percentage points (pp hereafter), respectively. The marked difference in the change in market shares comes from the fact that FFVs are close competitors to high-emission gasoline than high-emission diesel vehicles: the FFV technology essentially piggybacks on the Otto cycle technology used by gasoline vehicles. On the other hand, abolishing the GCR would adversely affect the market shares of FFVs and low-emission vehicles (both gasoline and diesel), with decreases of 1.95, 1.91 and 1.64pp, respectively. Equivalently, the GCR shifted demand from high emission vehicles – especially gasoline ones – to FFVs and low emission ones, precisely the segments favored by the GCR.

FIGURE 2 ABOUT HERE

Figure 2c examines what would have happened had the GCR treated regular and alternative fuels symmetrically. Low emission vehicles are the main gainers in that they experienced an increase of 1.57 and 0.589pp for gasoline and diesel vehicles, respectively. The main take-away from Figure

---

[27] In what follows, we report "inside shares", i.e. market shares sum to one, ignoring the role of the outside good for the sake of comparability across scenarios. Appendix B provides supporting evidence that the share of the outside good was unaffected by the GCR.

2c is however the low impact of a symmetric version of the GCR on the share of FFVs. This finding suggests that a substantial share of consumers would have purchased FFVs regardless of the GCR, likely due to the potentially lower operating costs provided by such technology (see Huse and Koptyug 2012b for such an analysis at the micro level). As for high emission gasoline and diesel, their market shares decreased by 1.3 and 0.521pp, respectively.

Had carmakers decided to replace all their captive gasoline models with FFV versions, the dominant fuel segment would be high emission FFVs, which would command a 65.1 percent market share, as shown in Figure 2d.[28] High emission diesel vehicles would lose 6pp and command a 18.7 percent market share, followed by low emission FFVs, with 13.6 percent, and low emission diesel vehicles, with 2.4 percent. While high emission FFVs would essentially absorb the market shares of high emission gasoline and FFV vehicles (all of which are high emission) under the GCR, the main gainers according to this experiment would be low emission FFVs, which would command 7pp above the market share of low emission gasoline vehicles under the GCR. On the other hand, and as expected, diesel vehicles would lose substantial market share, especially in the high emission segment.

The results in Figure 2 suggest that the actual GCR has shifted demand from high emission vehicles to both FFVs and low emission vehicles. A symmetric version of the GCR would have further increased the presence of low emission vehicles and hardly affected the one of FFVs, suggesting that the skew towards renewables – which was an essential part of the GCR – would not have been necessary, i.e. consumers would have purchased FFVs regardless. However, had carmakers adopted the FFV technology *en masse*, the main gainers would have been low emission FFVs, which would make substantial ground at the expense of diesel vehicles, both low and high emission.

Brand Market Shares Figure 3a reports the effect of the GCR on brand-level market shares.[29] The main players operating in the Swedish market are Volvo (15.9 percent market share), Toyota (10.1 percent), Peugeot (8.34 percent) and Volkswagen (VW, 6.5 percent), with brands Ford, Hyundai, Skoda, Citroen and Audi also commanding market shares above 3 percent. Despite being more of a niche player, for having a narrow range of models, Swedish brand Saab has historically been placed among the top 10 brands in the sample period (see Huse and Koptyug 2012 for details).

Figure 3b, which reports the results of the counterfactual of no GCR, shows that both Swedish and high-end German brands are at the losing end of the policy. The main gainer under such counterfactual would be Mercedes, with a 2.5pp increase in market shares, followed by Volvo (2.28pp), Audi (1.62pp), BMW (1.26pp) and Saab (1.24pp). Swedish and high-end German brands are close competitors in the Swedish market, having a marked presence in the high-end gasoline segment. It then comes as no surprise the fact that they share the burden of the GCR. On the other hand, lower-end (or value) brands Peugeot, Kia and Skoda decrease their market shares by amounts in the range 1-2.19pp under the counterfactual of no GCR. As we detail below, these are brands typically offering the low-end models within the high-emission (gasoline or diesel) fuel segments.

---

[28] Note that Figure 2d displays market shares instead of changes thereof. The reason for reporting this result in a different way is the introduction of the high- and low- emission FFVs fuel segments.

[29] Another way of examining market effects would be to examine firm profits, as in e.g. Adamou et al (2012). Here, however, in the interest of space we follow the literature, e.g. Train and Winston (2007), and report only market shares – given their different magnitudes across carmakers, profits are somewhat more difficult to compare than market shares, but the qualitative results are similar.

Figure 3c shows the effect of the symmetric GCR on the overall market shares of car manufacturers. The main brands benefiting from such a policy would be Toyota, Citroen and Peugeot, all of which have a marked presence in low emission segments, whereas the main loser would be Volvo, which has a substantial presence in the FFV and the high-emission segments, precisely the ones losing out from a symmetric policy.

FIGURE 3 ABOUT HERE

Figure 3d shows the effects of the full conversion to the FFV technology by all carmakers. The main gainer is Toyota (2.57pp), which is followed by high-end German brands Mercedes, Audi and BMW (1.92, 0.957 and 0.821pp, respectively), and Swedish brand Saab (1.15pp). Except for Toyota, these are among the brands most affected by the GCR, whose high emission gasoline vehicles would become FFVs and recover market share. Importantly, Volvo would experience a mild increase of less than 0.5pp in market shares. On the other hand, the main losers from Counterfactual III are brands such as VW, Skoda, Kia and Opel, with decreases in the range 1.1-1.6pp. Again, these are mostly brands which have benefited from the GCR and would lose out once all larger cars are turned into FFVs.

The findings in Figure 3 thus highlight three main features. First, the main losers following the GCR were local brands Saab and Volvo, together with high-end German brands Audi, BMW and Mercedes. Second, for most of these brands, the actual GCR is the worst scenario among the counterfactuals considered (the exception is Volvo under Counterfactual II). Finally, one way how these brands could have recovered market share would be to fully convert their gasoline models to the FFV technology.

Brand Market Shares within Fuel Segments In what follows, we decompose the changes in market shares within each of the five fuel segments for the three counterfactuals considered, so as to allow discerning gainers from losers at a more disaggregated level.

(i) High Emission Gasoline Segment Leading brands in the high emission gasoline segment under the GCR are Toyota, Volvo, VW, Peugeot and Skoda, each commanding market shares of at least 3.5 percent of the total market, see Figure 4a.

As already suggested in Figure 2b, the high emission gasoline fuel segment was hit hard by the GCR. The changes in market shares for Counterfactual I, reported in Figure 4b, show that this is the fuel segment where Swedish and high-end German brands saw their biggest losses whereas value brands saw substantial gains: abolishing the GCR would have resulted in increases of over 2pp in the market shares of Volvo and Mercedes, over 1pp for BMW and Audi and nearly 1pp for Saab, as well as decreases of at least 1pp for brands such as Skoda, Peugeot and Toyota.

FIGURE 4 ABOUT HERE

Figure 4c shows how the losses within the high emission gasoline segment, first detected in Figure 2c, were shared across brands in the case of a symmetric GCR. Overall, such losses were small and evenly spread, with only Volvo and Toyota facing decreases of over 0.1pp.

All in all, comparing the effects reported in Figures 3b and 4b lends further support to the view that Swedish and high-end German brands were at the losing end of the GCR: these losses come mostly from the high emission gasoline segment, of which FFV models (all of which are high emission vehicles in our data) are close substitutes.

(ii) High Emission Diesel Segment Volvo is the leading brand within the high emission diesel segment, commanding a 6.24 percent market share, and followed by Peugeot and VW, both of which command just over 2 percent, and far ahead of the remaining brands, see Figure 5a.

Figure 5b shows that under no policy, the main gainer would be Toyota (1.49pp), well ahead of brands Audi and Saab, both of which command about 0.4pp. The main losers are value brands Peugeot, Fiat, Hyundai and Kia, all of which would have lost about half a percentage point from the abolition of the program.

FIGURE 5 ABOUT HERE

Figure 5c shows that the high emission diesel segment is hardly affected by the symmetric GCR counterfactual: the only brand losing over 0.1pp is Volvo. Finally, Figure 5d shows how the losses in the high emission diesel segment from the counterfactual of full conversion to the FFV technology reflected on the different brands. The main loser is Volvo with a loss of 1.88pp, followed by Peugeot (0.966pp); brands Kia, Hyundai, VW and Fiat also witness a loss of at least 0.6pp in this scenario.

(iii) Low Emission Gasoline Segment The main players in this segment are Toyota, Peugeot, Hyundai and Citroen, with market shares in the range 0.9-2.82 percent of the market. Figure 6b shows that under the counterfactual of no policy, Asian manufacturers Toyota and Hyundai are the main losers in this segment, , with a decrease of roughly 0.8pp in market shares.

FIGURE 6 ABOUT HERE

As already reported in Figure 2c, the low emission gasoline segment witnessed an increase in market share under Counterfactual II. Figure 6c shows that the main gainer was Toyota (0.649pp), followed by Peugeot (0.312pp) and Citroen (0.231pp).

(iv) Low Emission Diesel Segment The main player in the low emission diesel segment under the GCR is Citroen, which commands a market share of 1.44, well ahead of VW and Opel, both of which command about 0.5 percent, see Figure 7a. Figure 7b shows that the leadership of Citroen results essentially from the GCR – abolishing it results in a decrease of roughly 1pp for the French brand.

FIGURE 7 ABOUT HERE

Figure 7c shows that the symmetric GCR has a mild effect across brands whereas Figure 7d shows that full conversion to the FFV technology of the existing gasoline models would again have mostly hurt Citroen, which would have lost nearly 0.9pp.

(v) FFV Segment The main players in the FFV segment are Swedish brands Volvo and Saab (5.08 and 2.83 percent, respectively), followed by Ford (which introduced FFVs in Sweden), Peugeot, VW and Renault (with 2.31, 1.15, 0.911 and 0.877 percent, respectively), see Figure 8a. The counterfactual of no policy in Figure 8b shows that these brands benefited by the GCR. Next, Figure 8c shows that a symmetric version of the GCR would have mild effects across brands – only Volvo would lose more than 0.1pp. Figure 8c thus shows not only that consumers would have purchased FFVs even without the GCR –as already pointed out in Figure 2c–, but also that the brands operating within this segment would hardly be affected.

FIGURE 8 ABOUT HERE

Finally, Figure 8d shows that in a scenario of full conversion to the FFV technology, the main gainers in the high emission FFV segment would essentially be the Swedish and high-end German brands, i.e. the ones losing out from the GCR due to their strong presence in the high emission gasoline segment. On the other hand, the main losers would have been value brands such as Skoda and Peugeot, besides Toyota. These value brands would however be the main gainers in the low emission FFV segment, as reported in Figure 8e. For instance, Toyota and Peugeot would command market shares of 3.31 and 1.82 percent, respectively, compared to 2.82 and 1.17 percent in the low-emission gasoline segment under the GCR.

Conclusion

This paper estimates a structural model of the Swedish car market to examine environmental and market effects of the Swedish green car rebate (GCR). Our findings can be summarized as follows. First, the cost of the program was comparable to those of recent US counterparts. We estimate the cost of CO2 emission savings over the lifetime of vehicles purchased via the GCR to be in the range $109-132/ton CO2, thus five to six times the price of an EU emission permit and at the lower end of estimates for the US, even if the policy affected the market more widely than elsewhere.

Second, Swedish and high-end German brands, all of which have a marked presence in the high emission gasoline segment, lose substantial market share as a result of the GCR. This result is at odds with the view that regulators are captured by (local) businesses.

Third, the finding that a symmetric version of the GCR has mild effects on the market share of FFVs suggests that the potentially lower operating costs provided by this technology would have been enough to attract consumers to this fuel segment, rendering the GCR unnecessary to shift demand towards vehicles able to operate on alternative fuels. Put in another way, the FFV technology would not need to be subsidized to attract consumers.

Fourth, within a context of new, hybrid, technologies such as the FFV, fuel choice is another margin policymakers should take into account. While one upside of flexible-fuel (or hybrid) technologies is the avoidance of technological lock-in, an immediate downside is that additional costs are incurred when consumers arbitrage across fuels.

Finally, full conversion to the FFV technology would have resulted in extremely high costs for the program and amplify the perverse effects of fuel arbitrage, yet allowing carmakers most severely affected by the actual policy to recover market share via the adoption of the FFV technology. Had carmakers decided to switch their captive gasoline cars to the FFV technology, the cost of the GCR would have increased by a fivefold, but without obvious improvements in terms of CO2 savings or costs thereof.

The paper assesses a unique policy skewed toward renewables and which affected a substantial share of the new car market. The findings highlight that policymakers ought to take into account the technologies in use in the markets they are regulating. This issue is to become ever more important as more and more alternative technologies, e.g. hybrid, multifuel, are brought to market in the coming years.

References

[1] ACEA (2008). The automobile industry pocket guide, Retrieved from http://www.acea.be/

[2] Adamou, A., S. Clerides and T. Zachariadis (2011). Designing Carbon Taxation Schemes for Automobiles: A Simulation Exercise for Germany, Working paper.

[3] Environmental and Economic Effects of CO2-based Automobile Taxes in Germany. Working paper.

[4] Aldy, J., A. J. Krupnick, R. Newell, W. H. Parry and W. A. Pizer (2010). "Designing Climate Mitigation Policy", *Journal of Economic Literature* 48 (4), 903-934.

[5] Anderson, S. T. (2012). "The Demand for Ethanol as a Gasoline Substitute", *Journal of Environmental Economics and Management* 63 (2), 151-168.

[6] Anderson, S., I. Parry, J. M. Sallee, and C. Fischer (2011). "Automobile Fuel Economy Standards: Impacts, Efficiency, and Alternatives", forthcoming *Review of Environmental Economics.*

[7] Austin, D. and T. Dinan (2005). "Clearing the Air: The Costs and Consequences of Higher CAFE Standards and Increased Gasoline Taxes", *Journal of Environmental Economics and Management*, 562-582.

[8] Bastard L. (2010). "The Impact of Economic Instruments on the auto Industry and the Consequences of Fragmenting Markets - Focus on the EU Case", Discussion Paper No. 2010-08, International Transportation Forum. http://www.internationaltransport forum.org/jtrc/DiscussionPapers/DP201008.pdf

[9] Bento, A., L. Goulder, M. Jacobsen, and R. von Haefen (2009). "Distributional and efficiency impacts of increased U.S. gasoline taxes", *American Economic Review* 99, 667-699.

[10] Beresteanu, A. and S. Li (2011). "Gasoline Prices, Government Support, and the Demand for Hybrid Vehicles". *International Economic Review* 52(1): 161-182.

[11] Berry, S. (1994). "Estimating Discrete-Choice Models of Product Differentiation", *The RAND Journal of Economics* 25 (2), 242-262.

[12] Berry, S., S. Kortum and A. Pakes (1996). "Environmental Change and Hedonic Cost Functions for Automobiles". *Proceedings of the National Academy of Sciences*, 12731-12738.

[13] Berry, S., J. Levinsohn and A. Pakes (1995). "Automobile prices in Market Equilibrium", *Econometrica* 63, 841-890.

[14] Berry, S., J. Levinsohn and A. Pakes (1999). "Voluntary Export Restraints on Automobiles: Evaluating a Strategic Trade Policy", *American Economic Review* 89(3), 400-430.

[15] BEST (2009). Promoting clean cars, Project title: BioEthanol for Sustainable Transport, Project report, Retrieved from: http://www.best-europe.org/

[16] BIL Sweden (2010). Svensk Fordonsindustri Faktablad.

[17] Boyer, M. and J-J Laffont (1999). "Toward a Political Theory of the emergence of Environmental Incentive Regulation". *The RAND Journal of Economics* 30 (1): 137-157.

[18] Brander, J. and B. Spencer (1985). "Export subsidies and international market share rivalry", *Journal of International Economics* 18, 83-100.

[19] Bresnahan, T. F., S. Stern and M. Trajtenberg (1997). "Market Segmentation and the sources of Rents from Innovation: Personal Computers in the Late 1980s", *RAND Journal of Economics* 28 (0), S17-44.

[20] Busse, M., C. Knittel and F. Zettelmeyer (2009). "Pain at the Pump: The Differential Effect of Gasoline Prices on New and Used Automobile Markets", NBER Working Paper No. 15590.

[21] Chandra, A., S. Gulati and M. Kandlikar (2010). "Green Drivers or Free Riders? An Analysis of Tax Rebates for Hybrid Vehicles", *Journal of Environmental Economics and Management* 60(2), 78-93.

[22] Corts, K. S. (2010). "Building Out Alternative Fuel Retail Infrastructure: Government Fleet Spillovers in E85", *Journal of Environmental Economics and Management* 59 (3), 2010, 219-234.

[23] Davis, L. W. (2008). "The Effect of Driving Restrictions on Air Quality in Mexico City", *Journal of Political Economy* 116(1), 38-81.

[24] Dixit, A. (1984). "International trade policy for oligopolistic industries", *Economic Journal* 94 (supplement), 1–16.

[25] Dube, J. P. Fox, J. T. and Su, C-L (2012). "Improving the Numerical Performance of BLP Static and Dynamic Discrete Choice Random Coefficients Demand Estimation", *Econometrica,* 80 (5), 2231-2267.

[26] EFTE (2009). Reducing CO2 Emissions from New Cars: A Study of Major Car Manufacturers' Progress in 2008. Brussels, Belgium. European Federation for Transport and Environment

[27] European Energy Exchange (2009). Retrieved from: http://www.eex.com/

[28] Fershtman, C., N. Gandal and S. Markovich (1999). "Estimating the Effect of Tax Reform in Differentiated Product Oligopolistic Markets". *Journal of Public Economics* 74, 151-170.

[29] Gallagher, K. S. and E. Muehlegger (2011). "Giving Green to get Green? Incentives and Consumer Adoption of Hybrid Vehicle Technology", *Journal of Environmental Economics and Management* 61, 1-15.

[30] Goldberg, P.K. and F. Verboven (2001). "The Evolution of Price Dispersion in the European car market", *Review of Economic Studies*, 68, 811-848.

[31] Gollop, F. M. and M. J. Roberts (1983). "Environmental Regulations and Productivity Growth: The Case of Fossil-Fueled Electric Power Generation". *Journal of Political Economy* 91(4), 654-674.

[32] Gowrisankaran, G. and M. Rysman (2011). "Dynamics of Consumer Demand for New Durable Goods". Working paper.

[33] Greenstone, M., J. A. List, and C. Syverson (2012). "The Effects of Environmental Regulation on the Competitiveness of U.S. Manufacturing". Working paper.

[34] Harrington, W., I. Parry and M. Walls (2007). "Automobile Externalities and Policies", *Journal of Economic Literature* 45, 374-400.

[35] Hendel, I. and A. Nevo (2006). "Measuring the Implications of Sales and Consumer Inventory Behavior", *Econometrica* 74 (6), 1637-1673.

[36] Huse, C. (2012). "Fast and Furious (and Dirty): How Asymmetric Regulation May Hinder Environmental Policy". Working paper.

[37] Huse, C. and N. Koptyug (2012). "Bailing On The Car That Wasn't Bailed Out: Explaining Consumer Reactions to Financial Distress". Working paper.

[38] Huse, C. and N. Koptyug (2012b). "Cars as Options? Quantifying the Value of Multifuel Technologies", presented at the Annual Meeting of the Brazilian Econometric Society.

[39] IEA (2011a). CO2 Emissions from Fuel Combustion. Paris, France. International Energy Agency.

[40] IEA (2011b). World Economic Outlook. Paris, France. International Energy Agency.

[41] Interagency Working Group on Social Cost of Carbon (2010). Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866. Washington, DC.

[42] Jacobsen, M. (2010). "Evaluating U.S. Fuel Economy Standards in a Model with Producer and Household Heterogeneity", UCSD Working paper.

[43] Jacobson, M. S. (2007). "Effects of ethanol (E85) versus gasoline on cancer and mortality in the United States", *Environmental Science & Technology* 41, 4150-4157.

[44] Kahn, Matthew (2007). "Do greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice", *Journal of Environmental Economics and Management* 54, 129-145.

[45] Klier, T. and J. Linn (2010). "New Vehicle Characteristics and the Cost of the Corporate Average Fuel Economy Standard", forthcoming at the *RAND Journal of Economics*.

[46] Laffont, J-J. and J. Tirole (1991). "The Politics of Government Decision-Making: A Theory of Regulatory Capture", *The Quarterly Journal of Economics* 106(4), 1089-1127.

[47] Li, S., J. Linn, and E. Spiller (2011). "Evaluating "Cash-for-Clunkers": Program Effects on Auto Sales and the Environment", RFF Discussion Paper 10-39-Rev.

[48] Li, S., C. Timmins, and R. von Haefen (2009). "How Do Gasoline Prices Affect Fleet Fuel Economy?", *American Economic Journal: Economic Policy* 1, 113-137.

[49] Klier, T., and J. Linn (2010). "The Price of Gasoline and New Vehicle Fuel Economy: Evidence from Monthly Sales Data", *American Economic Journal: Economic Policy* 2 (3), 134-153.

[50] Knittel, C. R. (2009). "The Implied Cost of Carbon Dioxide under the Cash-for-Clunkers Program", Working paper UC Davis.

[51] Mandell, S. (2008). "Carbon Emission Values in Cost Benefit Analyses", *Transport Policy* 18(6) 888-892.

[52] Metcalf, G. (2008). "Using Tax Expenditures to Achieve Energy Policy Goals", *American Economic Review Papers and Proceedings* 98, 90-94.

[53] Miljöfordon.se (2009). Retrieved from: http://www.miljofordon.se

[54] Ministry of the Environment (2007). Press release: The Government introduces a green car rebate, Retrieved from: http://www.regeringen.se/sb/d/586/a/79866

[55] Ministry of the Environment (2008a). Press release: Regeringen avsätter mer pengar till miljöbilspremien, Retrieved from: http://www.regeringen.se/sb/d/119/a/101932

[56] Ministry of the Environment (2008b). Press release: Klimat- och energisatsningar i budgetpropositionen 2009, Retrieved from: http://www.regeringen.se/sb/d/119/a/110590

[57] Ministry of the Environment (2009). Press release: New green cars to be exempted from vehicle tax, Retrieved from: http://www.regeringen.se/sb/d/11760/a/122175

[58] Miravete, E. J., and M.J. Moral (2009). "Qualitative Effects of Cash-For-Clunkers Programs". Working paper UT Austin.

[59] Olson, M. (1965). *The Logic of Collective Action: Public Goods and the Theory of Groups*. Harvard University Press.

[60] Pakes, A., S. T. Berry, and J. A. Levinsohn (1993). "Applications and Limitations of Some Recent Advances in Empirical Industrial Organization: Price Indexes and the Analysis of Environmental Change". *American Economic Review Papers and Proceedings* 83, 240-246.

[61] Parry, I. W. H., M. Walls, and W. Harrington (2007). "Automobile Externalities and Policies", *Journal of Economic Literature* 45 (2), 373–399.

[62] Petrin, A (2002) "Quantifying the benefits of new products: The case of the Minivan", *Journal of Political Economy* 11, 705-729

[63] Reiss, P. and Wolak, F. (2005). "Structural Econometric Modeling: Rationales and examples from Industrial Organization", *Handbook of Econometrics*, Vol. 6.

[64] Ricardo, D. (1817). On the Principles of Political Economy and Taxation. In *The Works and Correspondence of David Ricardo*, ed. P. Sraffa. Cambridge: Cambridge University Press, 1951.

[65] Ryan, S. P. (2011). "The Costs of Environmental Regulation in a Concentrated Industry", forthcoming *Econometrica.*

[66] Sallee, J. (2011a). "The Taxation of Fuel Economy", in *Tax Policy and the Economy* v. 25, Editor Jeffrey R. Brown, NBER: University of Chicago Press, 1-38.

[67] Sallee, J. (2011b). "The Surprising Incidence of Tax Credits for the Toyota Prius". *American Economic Journal: Economic Policy* 3, 189-219.

[68] Salvo, A., and C. Huse (2011). "Is Arbitrage Tying the Price of Ethanol to that of Gasoline? Evidence from the Uptake of the Flexible-Fuel Technology", *Energy Journal* 32 (3), 119-148.

[69] Salvo, A., and C. Huse (2012). "Build it, but will they come? Evidence from consumer choice between gasoline and sugarcane ethanol". Working paper.

[70] SFS (2005). Lag (2005:1248) om skyldighet att tillhandahålla förnybara drivmedel, Retrieved from: http://www.riksdagen.se/Webbnav/index.aspx?nid=3911&bet=2005:1248

[71] SFS (2007). Förordning (2007:380) om miljöbilspremie, Retrieved from: http://www.riksdagen.se/Webbnav/index.aspx?nid=3911&bet=2007%3A380

[72] Stigler, G. J. (1971). The Theory of Economic Regulation. *Bell Journal of Economics* 2, 3-21.

[73] The New York Times (1989). "Autos Cry for Alcohol; France Will Do Its Part". Edition of 30 December 1989.

[74] The Swedish Consumer Agency (2004-2009). Nybildguiden (The New Car Guide).

[75] The Swedish Environmental Protection Agency (2008a). Index över nya bilars miljöpåverkan 2007, Retrieved from: http://www.naturvardsverket.se/

[76] The Swedish Environmental Protection Agency (2008b). Allmänhetens kunskaper och attityder till klimatförändringen (tidigare växthuseffekten), Retrieved from: http://www.naturvardsverket.se/

[77] The Swedish Petroleum Institute (2009a). Försäljningsställen av motorbränslen, Retrieved from: http://www.spi.se/fsg.asp?cboFromYr=2009&cboToYr=2009&cboCompany=<Alla>&cboCa

[78] The Swedish Petroleum Institute (2009b). Leveranser bränslen per månad, Retrieved on May 18, 2009 from: http://www.spi.se/statistik.asp?art=99

[79] The Swedish Tax Agency (2009). FAQ on vehicle tax, Retrieved from: http://www.skatteverket.se/funktioner/svarpavanligafragor/privat/fordonsskatt/allafragorochsvar.4.5cbc

[80] Trafikverket (2011). Uppdaterade reduktionsvärden för etanol- och gasfordon till bilindex. Retrieved from http://www.trafikverket.se/PageFiles/25435/nov10/04-2011_PM%20uppdaterade%20reduktionsv%C3%A4rden110308.pdf

[81] Train, K. and Winston, S. (2007). "Vehicle Choice Behavior And The Declining Market Share Of U.S. Automakers", *International Economic Review* 48(4), 1469-1496.

[82] Yanowitz, J., and R. L. McCormick (2009). "Effect of E85 on Tailpipe Emissions from Light-Duty Vehicles", *Journal of the Air & Waste Management Association* 59, 172-182.

A Data (Not for publication)

Sales data *Vroom* has adjusted new car registration data to better represent the cars that are actually used by an individual and that do not serve as demonstration units or alike. For a registration to be included in the data set, the vehicle has to be acquired by an individual within 30 days of the registration. The sales data is aggregated at the base model level for each fuel type, i.e. the item Audi A3 gasoline contains all versions of the A3 that are primarily driven on gasoline. We consider seven different fuel segments: high- and low-emission gasoline; high- and low-emission diesel; gasoline/ethanol (FFVs); gasoline/gas (CNG); and electric hybrids.

Vehicle characteristics The characteristics data is on a more disaggregated level than the sales data, e.g. there are 18 different Audi A3 gasoline versions. To be able to combine characteristics and sales data, we have aggregated the characteristics over sub-models based on the baseline model, thus following the literature, e.g. BLP (1995). Following the Swedish Consumer Agency definition, we define market segments according to vehicle weight, with the five segments defined by the thresholds 1100, 1250, 1400 and 1600 kg.

Combining sales data and characteristics When combining the sales data and the characteristics data, a small fraction of the observations did not have a match. We thus expanded our search as follows, checking the following manually. First, we checked for the same brand, model and fuel type for the following year, since models for a given year are released late in the prior fall. Second, we checked for the same brand and fuel type for the same year. Third, for the same brand and fuel type for the following year. Finally, for the same fuel type and same year (the standard deviation is lower within a population consisting of cars of the same fuel type but different brands than within a population of a certain brand but with different fuel types).

Fuel economy and CO2 emissions In the consumer guides, the emission data for FFVs is solely based on gasoline driving. According to The Swedish Consumer Agency (2008), there are no official values for ethanol driving. However, in their report on the climate effects of new cars, the Swedish Environmental Protection Agency (2008a) develops a way to calculate emission reductions. First, due to its lower energy content, E85 consumption is approximately 35 percent higher than gasoline consumption. Second, carbon dioxide emissions for E85 are 688.3 g/l, regardless of whether it made of sugar cane ethanol or sulphite pulp ethanol. Using this and the data on gasoline consumption from the guides, we can calculate ethanol consumption in l/100km (gasoline consumption*1.35) and carbon dioxide emissions in g/km (ethanol consumption*688.3/100). Thus, carbon dioxide emissions for E85 could be calculated by multiplying the gasoline consumption in l/100km by 9.29205 ($\frac{1.35\times 688.3}{100}$). For winter months, the ethanol blend used is E75, which has a higher consumption (approximately 42% higher). For these months, the carbon dioxide emissions are multiplied by $\left(\frac{1.42\times 688.3}{100}\right)$.

To estimate CO2 emissions, we estimate yearly mileage driven (in km), together with a measure of CO2 emissions (in g/km). For captive cars, mileage estimates are based on the results reported in Appendix C whereas for FFVs they also depend on the fraction of vehicle owners using each fuel. We consider four cases, namely 0, 25, 50 and 75 percent gasoline usage. Although we do not take a stand on which level looks more appropriate, Huse (2012) documents a 73 percent reduction in monthly ethanol sales following the 2008 oil price drop, which suggest that fuel switchers correspond to a non-negligible share of FFV owners.

The emission data for gas (CNG) is based on what is called certification gas, which is the same as fossil gas (Din Bil Stockholm/Hammarby, 2008). Carbon dioxide emissions from fossil gas are evaluated to be 2120 g/m3 whereas for biogas these are evaluated to 390 g/m3. The supply of vehicle gas in Sweden consists of both fossil gas and biogas, as well as a mixture of the two. According to Din Bil, the supply is evenly split, which is consistent with the report by the Swedish Environmental Protection Agency (2008a) which states that, in 2007, 53 percent of the vehicle gas sold was biogas and 47 percent was fossil gas. The emission data for gas cars is hence not correct since it assumes all cars are driven on fossil gas, thus the general emission levels for gas cars are exaggerated. We therefore re-estimate these to be equal to gas consumption per km*(2120*0.47 + 390*0.53), based on the numbers above.

Potential market To go from observed quantities to observed market shares we need to define the size of the potential market for each time period. One way to obtain the potential market variables would be by estimating them, as suggested in Reiss and Wolak (2005). Alternatively, one could follow the criterion used in BLP (1995), where the total number of households constitutes the potential market. According to Reiss and Wolak (2005), this definition has some shortcomings. First, not all households can afford a new car and other entities than households can purchase cars. Since we only examine car sales to individuals, only the former poses a possible problem. It is not realistic that all households can afford to purchase a new car, therefore this would overestimate the potential market. Therefore we define the market as the number of individuals (instead of households, as Sweden has a high number of single person households) above the age of 20 with a yearly income of 200,000 SEK (about $27,500) or more. These are the potential purchasers of a new car. It is however unlikely that they can consider buying a new car each month. We therefore assume that consumers generally consider buying a new car every fifth year, thereby dividing the numbers by 60.

B Counterfactuals (Not for publication)

Impact of the rebate on aggregate sales When calculating the counterfactuals, we need an estimate of the share of the outside good. In order for us to be able to use the market shares for the outside good from the actual scenario, i.e. with the rebate, we must ensure that there is no correlation between the rebate and total sales. We follow Chandra et al (2010) and examine the effect of the rebate on aggregate sales by estimating the following equation

$$\ln(total\_sales_t) = \alpha + \phi 1\{GCR_t\} + z_t'\beta + v$$

where $1\{GCR_t\}$ represents the rebate dummy, z_t contains potential market characteristics such as the CPI and the Industrial production index by Statistics Sweden. The results are reported in Table B1. There is no evidence of an effect of the rebate on aggregate sales. Thus we use the actual market shares for the outside good when computing the counterfactuals.

TABLE B1 ABOUT HERE

Impact of the assumption of vehicle lifetime on costs and CO2 savings Following the literature, see e.g. Beresteanu and Li (2011), in the main text we performed our calculations under the assumption that vehicle lifetime is 15 years. To gauge the effect of this assumptions, we re-did our calculations under the assumptions of a 25-year lifetime – the results are reported in Table B2.

TABLE B2 ABOUT HERE

Although the results do change in quantitative terms, they are similar in qualitative terms. The alternative estimates for Counterfactuals I and II reported in Panel A are not surprising in that they show an increase in CO2 savings due to the increased lifetime of the fleet. For instance, increasing lifetime by 67 percent (25/15 years) results in an 18 percent increase in CO2 savings. The reason why the increase in savings is less than proportional than the one in lifetime is the decreasing yearly mileage of older vehicles (see Table C2 for the case up to 15 years). However, when it comes to Counterfactual III, notice that CO2 savings increase only if all FFV owners are assumed to drive on gasoline (0% gasoline usage) – fuel arbitrage is such that CO2 savings may indeed decrease under an extended vehicle lifetime. On the cost side, the results mirror those described above, in that the cost of CO2 savings decreases under Counterfactuals I and II and typically increases for Counterfactual III.

A comparison of the estimates above with those in the literature shows that the findings in the text are robust to changes in the lifetime assumption. In particular, notice that at 642 SEK (or $91.7), the cost of the program in the benchmark case (CF I with 0% gasoline usage) is almost identical to those in Beresteanu and Li (2011), with fuel arbitrage increasing such cost by up to 20 percent if gasoline usage reaches 75%.

Finally, the relative costs of Counterfactuals II and II as compared to those of Counterfactual I are also quite similar, being hardly affected by the lifetime assumption.

C Mileage Regressions (Not for publication)

We use data from the Swedish Motor Vehicle Inspection Company to estimate the average yearly mileage of a vehicle (measured in kilometers, km). Each observation (a combination of brand-model-segment-fuel-vintage) is weighted according to the number of subjects inspected. Our preferred specification is reported under Column 5 in table C1 and has controls for age, fuel fixed-effects, age-fuel interactions, fuel-year interactions (which captures fuel price levels at the yearly frequency) and fixed-effects for brand-model-segment, and year. Based on this specification, we then estimate the lifetime mileage of cars disaggregated by fuel.

TABLE C1 ABOUT HERE

Associated mileage estimates for Column 5 assuming a vehicle lifetime of 15 years are reported in Table C2 and are consistent with some stylized facts.[30] First, yearly mileage decreases with age. Second, diesel vehicles are the most heavily used vehicles whereas gasoline ones are the least heavily used. Gasoline/CNG vehicles are slightly less used than diesel ones, but more than FFVs and gasoline/electric vehicles.

TABLE C2 ABOUT HERE

---

[30] While Table C2 reports estimates based on a 15-year vehicle lifetime, Appendix B carries out the same analysis as in the text with a 25-year vehicle lifetime. The lifespan of a car can arguably be substantially longer, but anecdotal evidence for Sweden suggests that older cars are kept in the (affordable and widespread) country houses of the average Swedish household. Being based on the "Summer house" essentially implies that these cars will run for few weeks during summer every year.

D Alternative Demand Specifications (Not for publication)

We have conducted two sets of robustness checks. First, we compared our estimates based on the nested fixed-point algorithm (NFP) with alternative ones based on the MPEC algorithm (Dubé, Fox and Su 2011).[31] The results are similar to those reported in Table 3.

Second, we considered alternative specifications of the conditional indirect utility function used to estimate demand. For instance, we considered the following alternatives for the price and/or engine size coefficients:

1. $\beta_P = \bar{\beta}_P + \sigma_y y_i + \sigma_{AGE} AGE_i$. Both y_i and AGE_i were draws from the income and age distributions of the Swedish population

2. $\beta_P = \bar{\beta}_P + \sigma_y y_i$ and $\beta_{CC} = \bar{\beta}_{CC} + \sigma_{AGE} AGE_i$. In this alternative, we experimented with heterogeneity based in income for the price coefficient and heterogeneity based on age for the engine size coefficient.

3. $\beta_P = \frac{\bar{\beta}_P}{y_i}$ and $\beta_{CC} = \bar{\beta}_{CC} + \sigma v_i$. Here, v_i are draws from the Standard Normal distribution whereas y_i are draws from the income distribution (this is inspired in Berry, Levinsohn and Pakes 1999 and Beresteanu and Li 2011).

4. $\beta_p = \frac{\bar{\beta}_P}{y_i} + \sigma v_i$. This is another alternative specification inspired by Berry, Levinsohn and Pakes (1999) and Beresteanu and Li (2011).

No specification was able to deliver results better than those of the ones reported in Table 3. More specifically, they were not able to capture enough heterogeneity to ensure the markups to be not monotonically decreasing with product prices. Since our market shares are quite small, given the large number of models in each time period, low heterogeneity implied not only lower percentage markups for higher priced cars, but also lower absolute markups for such automobiles, clearly at odds with what one would expect in this market.

---

[31] NFP settings included a convergence tolerance of 1e-13 for the contraction and 1e-6 for the optimization using the KNITRO optimizer.

Tables and Figures for
“The Market Impact and Costs of the Swedish `Green Car’ Rebate”
by Cristian Huse & Claudio Lucinda

TABLE 1 – Descriptive Statistics of Selected European Passenger Car Markets

	Sweden	**France**	**Germany**
Passenger car fleet, millions (2008)	4.3	30.9	41.3
Passenger cars per 100 inhabitants (2008)	46.3	49.5	50.4
% Households with a vehicle (2006)	84.5	82	NA
Average car age, years (2008)	9.5	8.3	8.2
Average engine of new cars, in cc (2007)	1,964	1,680	1,863
Average power of new cars, in kw (2007)	105	80	96
% Passenger cars able to run on fuels other than gasoline and diesel (2008)	3.8	0	0.9
Share of cars ≤ 5 years (2008)	29.0%	33.4%	34.3%
Share of cars 5-10 years (2008)	31.9%	33.0%	33.0%
Share of cars > 10 years (2008)	39.1%	33.6%	33.6%

Note: This table is constructed using data from ANFAC (2010). Engine sizes are reported in cc (cubic centimeters).

TABLE 2 – Descriptive Statistics of Models Available on the Swedish Market, by Fuel Segment

		CO2 Emissions (gCO2/km)					
Fuel		**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Total	Mean	210.8	210.4	205.5	197.7	198.8	191.4
	se(mean)	1.2	1.2	1.2	1.4	1.3	1.2
	Median	205	205	197	185	188	181
	1Q-3Q	175-239	172-239	167-233	159-223	161-225	155-217
	#brands	37	40	40	45	44	40
	#models	1854	1920	2101	1624	1946	2026
Total ≤ 120g	Mean	107.1	106.8	113.6	114.4	113.6	114.1
	se(mean)	3.1	2.9	0.9	1.1	0.9	0.7
	median	114.5	113	116	118	116	118
	1Q-3Q	90-118	90-116	109-119	109-119	109-116	109-119
	#brands	8	8	10	13	17	22
	#models	20	21	40	46	69	89
Gasoline	mean	218.0	218.4	215.4	210.5	212.4	205.9
	se(mean)	1.3	1.4	1.4	1.8	1.7	1.7
	median	213	211	207	194	198	193
	1Q-3Q	184-246	182-249	180-244	169-238	173-238	167-232
	#brands	37	40	40	45	43	39
	#models	1398	1417	1473	1081	1225	1195
Gasoline ≤ 120g	mean	116.3	115.3	112.1	111.1	112.1	113.1
	se(mean)	0.8	0.8	0.9	1.0	0.9	1.0
	median	116	116	111	109	109	112
	1Q-3Q	113-119	113-116	109-116	109-113	109-116	109-119
	#brands	3	2	4	5	7	12
	#models	10	8	14	10	18	36
Diesel	mean	188.8	188.1	183.0	172.3	174.8	168.4
	se(mean)	2.1	2.0	1.8	1.8	1.6	1.3
	median	185.5	187	174	162	169	160.5
	1Q-3Q	153-215	153-216	154-210	145-189	148-193	146-184
	#brands	28	28	31	32	34	35
	#models	442	491	596	513	667	748
Diesel ≤ 120g	mean	97.1	101.3	114.8	115.8	114.4	115.2
	se(mean)	1.0	1.2	1.4	1.4	4.5	5.2
	median	90	100	118	119	119	119
	1Q-3Q	90-116	90-116	115-119	116-119	114.5-119	112-119
	#brands	5	6	6	11	14	19
	#models	9	12	23	33	48	51
FFV	mean	165.0	198.0	185.4	184.4	194.2	195.1
	se(mean)	0.0	12.2	6.8	4.6	3.7	3.1
	median	165	215	172	175.5	184.5	191.5
	1Q-3Q	165-165	150-228	169-179	169-206	174-213	177-214
	#brands	1	3	3	3	10	12
	#models	2	11	17	18	44	66
FFV ≤ 120g	#models	0	0	0	0	0	0
Gasoline/CNG	mean	199.5	198.0	164.4	150.4	147.6	156.9
	se(mean)	12.4	12.2	7.9	6.3	9.7	4.5
	median	213	228	164	157	155	157
	1Q-3Q	150-231	150-215	148-183	136.5-164	138-160	144-167
	#brands	5	5	5	5	4	3
	#models	11	11	11	8	5	11
Gasoline/Electric	mean	104.0	104.0	147.8	147.8	161.8	171.3
	se(mean)	.	.	23.9	23.9	23.3	21.3
	median	104	104	147.5	147.5	185	188.5
	1Q-3Q	104-104	104-104	106.5-189	106.5-189	109-192	109-219
	#brands	1	1	3	3	3	3
	#models	1	1	4	4	5	6

Note: This table reports sample statistics of the distribution of engine CO2 emissions (measured in gCO2/km, running on gasoline or diesel) disaggregated by fuel and the number of brands and car models present in each fuel segment.

TABLE 3 – Demand Estimates

	(1) **OLS**		**(2)** **IV**		**(3)** **RC Logit**	
Price	-0.0026	***	-0.0114	***	-0.0220	***
	(0.00)		(0.00)		(0.00)	
HP	0.00717	***	0.0204	***	0.024	***
	(0.00)		(0.00)		(0.00)	
CC	0.0000876		0.000254	***	0.000	*
	(0.00)		(0.00)		(0.03)	
Road tax	-0.000348	***	-0.000355	***	0.000	***
	(0.00)		(0.00)		(0.00)	
Fuel economy	-0.203	***	-0.143	***	-0.056	
	(0.02)		(0.02)		(0.10)	
Sigma_price					0.006	***
					(0.00)	
Brand FEs	Yes		Yes		Yes	
Time FEs	Yes		Yes		Yes	
Market Segment FEs	Yes		Yes		Yes	
Fuel segment FEs	Yes		Yes		Yes	
Fuel economy-fuel segment interactions	Yes		Yes		Yes	
N	13962		13962		13962	
	Own-price elasticities - percentiles					
p10	-1.0		-4.2		-5.3	
p25	-0.7		-3.1		-4.6	
p50	-0.6		-2.4		-3.9	
p75	-0.4		-1.8		-3.1	
p90	-0.3		-1.4		-2.5	

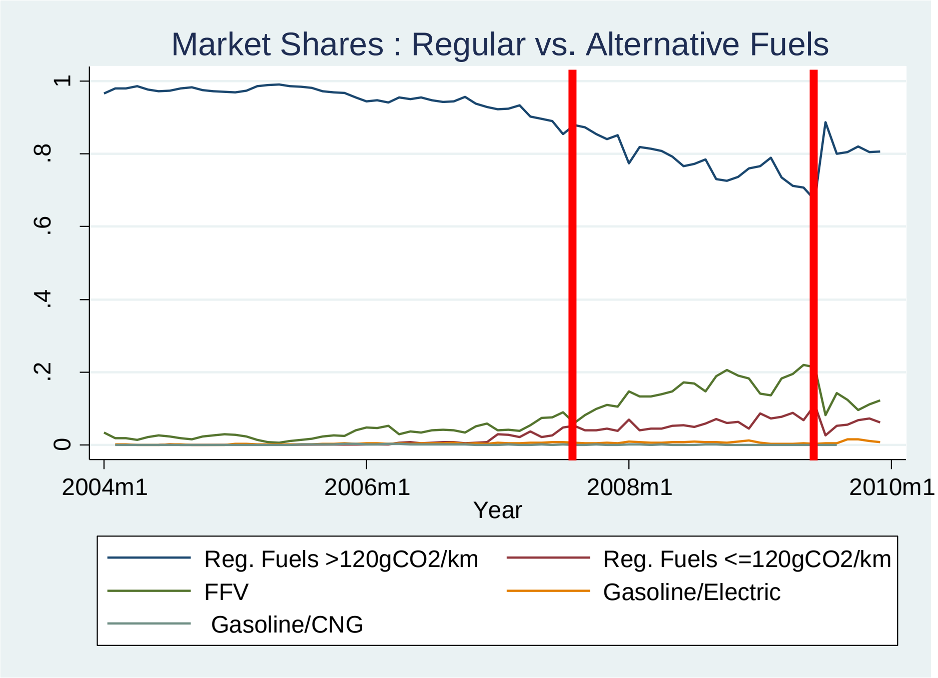
Note: Standard errors clustered by brand. * $p<0.05$, ** $p<0.01$, *** $p<0.001$. The value of the F-statistics of the first-stage regression is 31.48.

TABLE 4 – CO2 Savings and Costs of Alternative Policies

	CF I "No GCR"	CF II "Symmetric GCR"	CF III "Full FFV Adoption"
Panel A: CO2 Savings (thousands tonCO2)			
Gasoline usage			
0%	493.2	193.8	3,159.8
25%	441.0	192.5	1,878.6
50%	424.6	192.1	1,474.0
75%	406.7	191.6	1,035.6
Panel B: Cost of CO2 Savings (SEK/tonCO2 saved)			
Gasoline usage			
0%	760	465	558
25%	850	468	939
50%	883	469	1197
75%	921	470	1704
		Total Cost of Program as a Percentage of the GCR	
Percentage	--	24.0	470.9

Note: This table reports the total cost of the program in each scenario in Panel A, lifetime savings in tons of CO2 emissions induced by the different counterfactuals in Panel B and their associated costs in SEK/tonCO2 in Panel C. Results are reported for the assumption of Bertrand-Nash pricing as well as different levels of gasoline usage among FFV owners to illustrate the impact of fuel arbitrage on the program. All computations assume the lifetime of a vehicle to be 15 years. See Appendix A for details on the assumptions on gasoline usage, Appendix B for a robustness check using a 25-year lifetime assumption, and Appendix C for mileage regression results.

FIGURE 1 – Market Shares by Fuel Segment



Note: This figure depicts market shares of passenger cars sold to private individuals in the Swedish car market at the monthly frequency disaggregated by fuel segments. Vehicles running on regular fuels are split into two groups, namely high- and low-emission regular vehicles depending on whether they emit more or less than 120 gCO2/km. Vehicles able to run on alternative fuels are split into FFVs (gasoline/ethanol, or FFVs), gasoline/CNG and gasoline/electric. The figure shows the decrease in the market shares of high-emission regular vehicles and the increase in those of low-emission regular vehicles and FFVs, the leading alternative vehicle, while showing that the market shares of gasoline/CNG and gasoline/electric vehicles were essentially flat during the GCR period. The figure also suggests the existence of anticipatory effects at the (publicly announced) and of the GCR in June 2009, but no compelling evidence thereof at its start in April 2007.

FIGURE 2 – Effect of Alternative Policies on Fuel Segment Market Shares

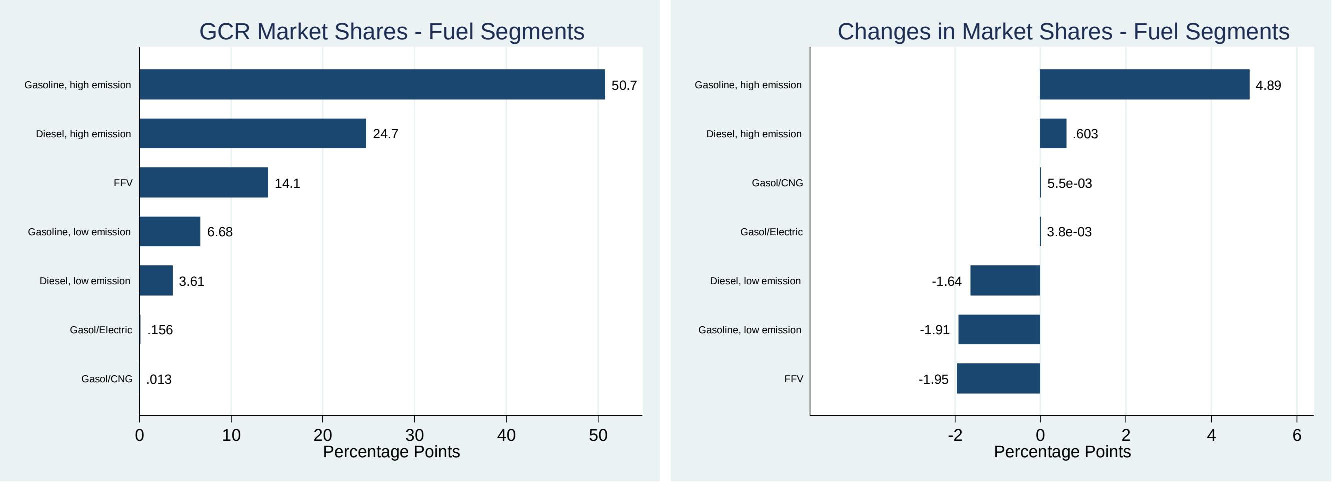


Figure 2a – GCR market shares

Figure 2b – Counterfactual I: No GCR vs. GCR

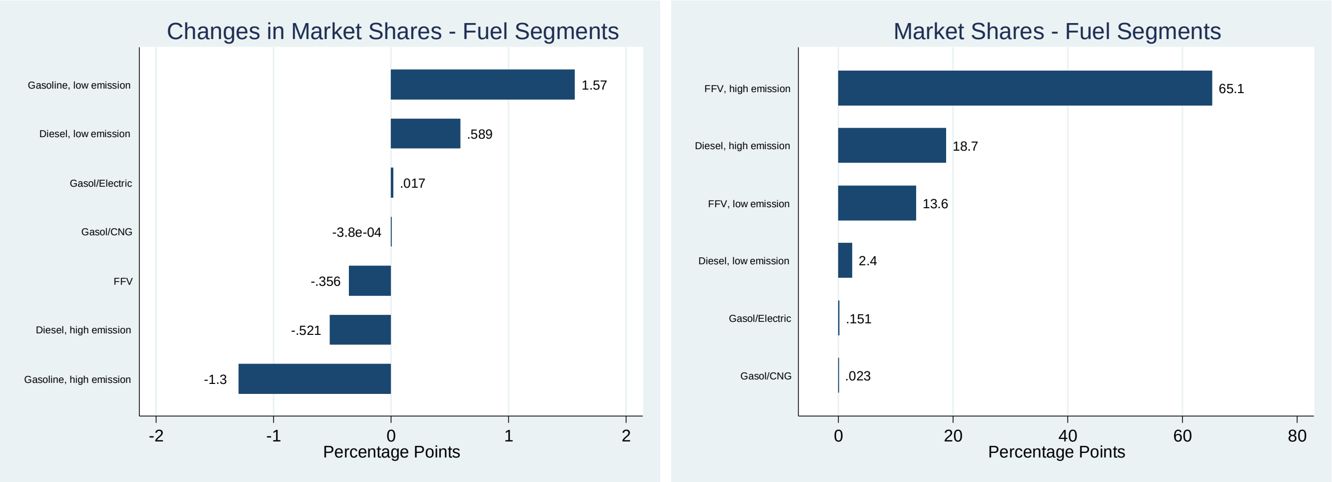


Figure 2c – Counterfactual II: Symmetric GCR vs. GCR

Figure 2d – Counterfactual III: Full Conversion to FFV vs. GCR

Note: This figure displays market shares under the GCR and changes in market shares at the fuel segment induced by alternative policies. Figure 2a displays market shares under the GCR (actual policy); Figure 2b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 2c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR; Figure 2d displays market shares (instead of changes thereof) had all carmakers replaced their captive gasoline vehicles with FFVs (Note also the distinction between high- and low-emission FFVs when examining Counterfactual III). For the sake of clarity, the figure omits some brands for which (changes in) market shares were negligible.

FIGURE 3 – Effect of Alternative Policies on Brand Market Shares

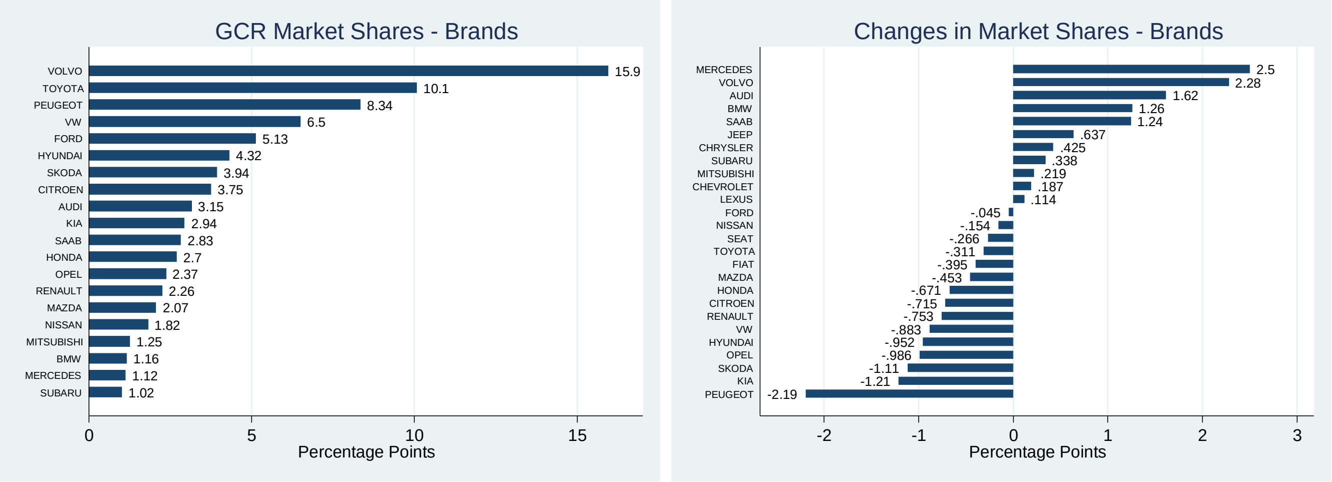


Figure 3a – GCR market shares

Figure 3b – Counterfactual I: No GCR vs. GCR

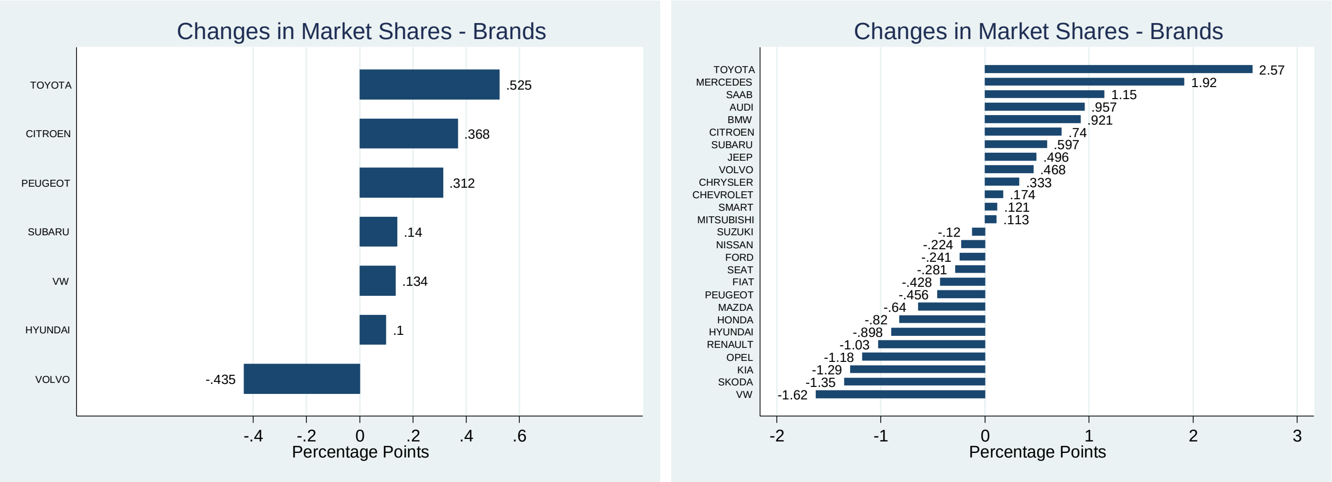


Figure 3c– Counterfactual II: Symmetric GCR vs GCR

Figure 3d – Counterfactual III: Full Conversion to FFV vs GCR

Note: This figure displays brand market shares under the GCR and changes in market shares induced by alternative policies. Figure 3a displays market shares under the GCR (actual policy); Figure 3b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 3c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR; Figure 3d displays *changes* in market shares had all carmakers replaced their captive gasoline vehicles with FFVs as compared to the GCR. For the sake of clarity, the figure omits some brands for which changes in market shares were negligible.

FIGURE 4 – Effect of Alternative Policies on Brand Market Shares within High Emission Gasoline Vehicles

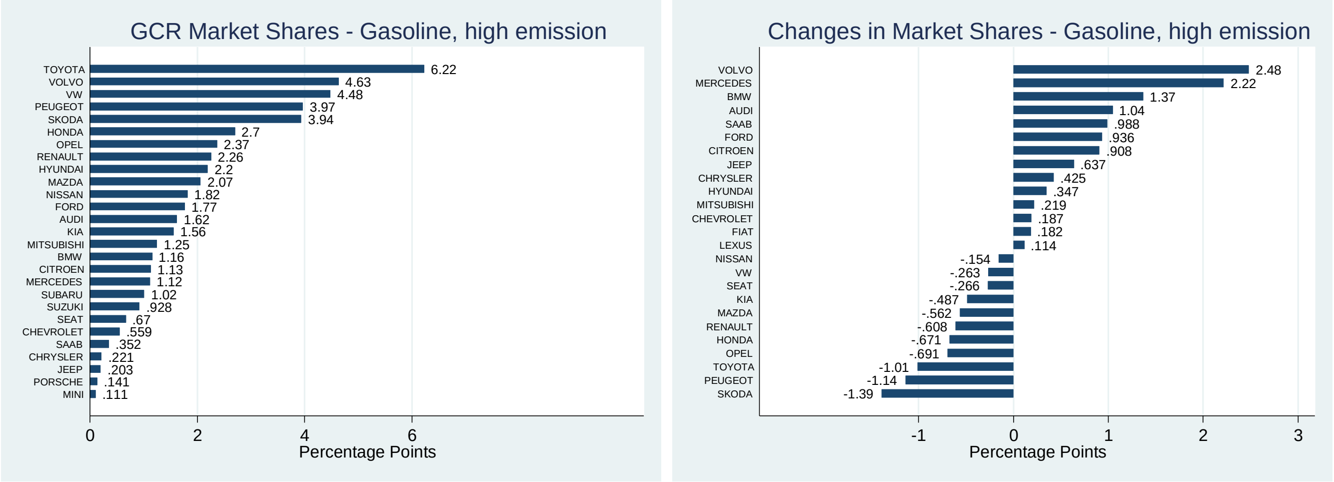


Figure 4a – GCR market shares

Figure 4b – Counterfactual I: No GCR vs. GCR

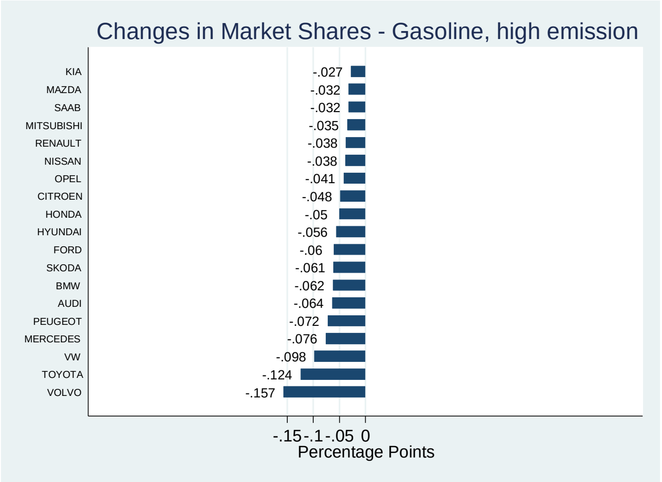


Figure 4c– Counterfactual II: Symmetric GCR vs GCR

Note: This figure displays brand market shares within the high emission gasoline segment under the GCR and changes in market shares induced by alternative policies. Figure 4a displays market shares under the GCR (actual policy); Figure 4b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 4c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR. For the sake of clarity, the figure omits some brands for which changes in market shares were negligible.

FIGURE 5 – Effect of Alternative Policies on Brand Market Shares within High Emission Diesel Vehicles

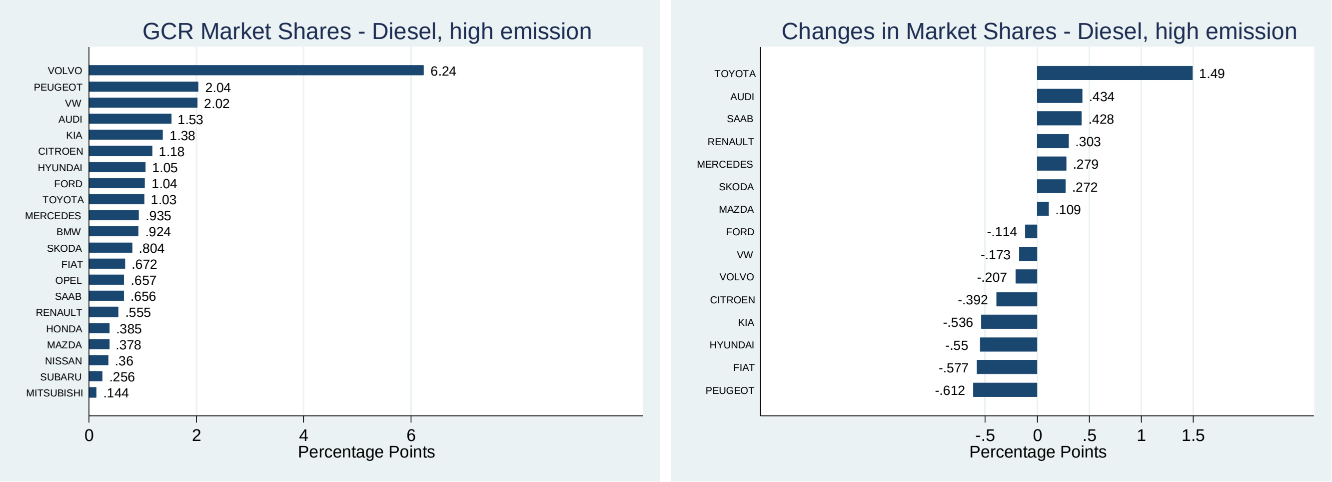


Figure 5a – GCR market shares

Figure 5b – Counterfactual I: No GCR vs. GCR

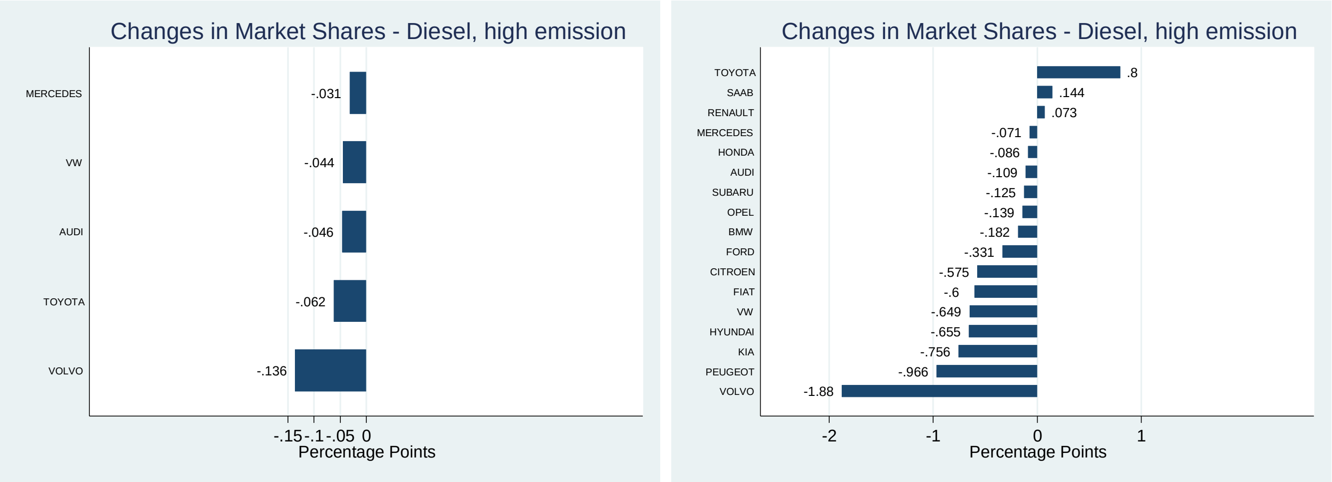


Figure 5c– Counterfactual II: Symmetric GCR vs GCR

Figure 5d – Counterfactual III: Full Conversion to FFV vs GCR

Note: This figure displays brand market shares under the GCR and changes in market shares induced by alternative policies. Figure 5a displays market shares under the GCR (actual policy); Figure 5b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 5c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR; Figure 5d displays *changes* in market shares had all carmakers replaced their captive gasoline vehicles with FFVs as compared to the GCR. For the sake of clarity, the figure omits some brands for which changes in market shares were negligible.

FIGURE 6 – Effect of Alternative Policies on Brand Market Shares within Low Emission Gasoline Vehicles

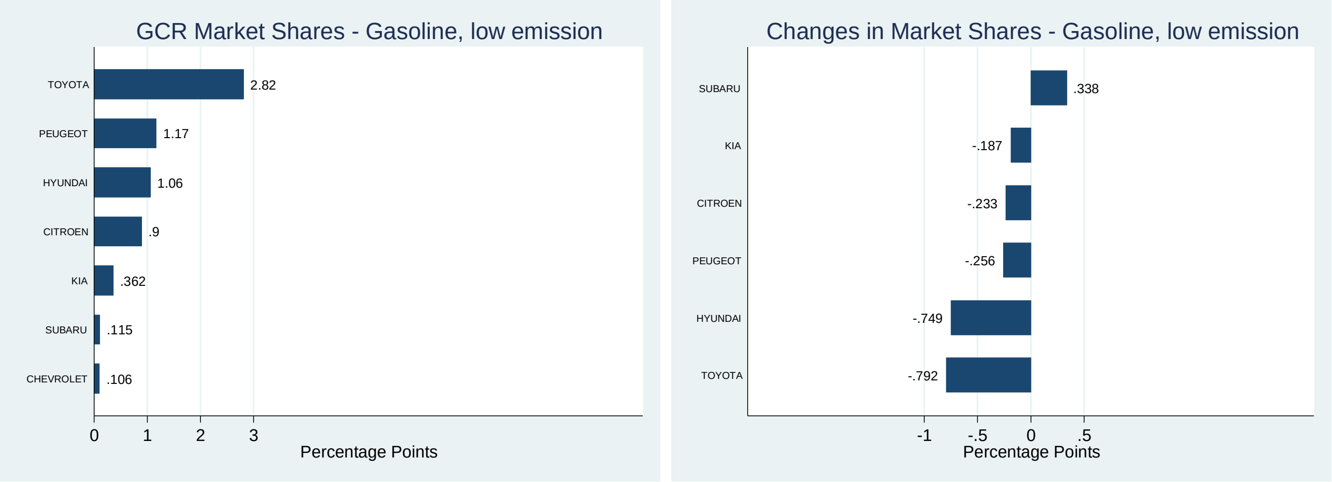


Figure 6a – GCR market shares

Figure 6b – Counterfactual I: No GCR vs. GCR

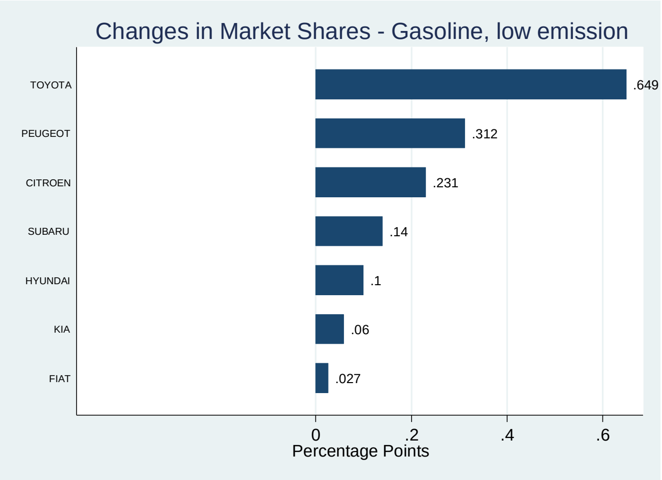


Figure 6c– Counterfactual II: Symmetric GCR vs GCR

Note: This figure displays brand market shares under the GCR and changes in market shares induced by alternative policies. Figure 6a displays market shares under the GCR (actual policy); Figure 6b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 6c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR. For the sake of clarity, the figure omits some brands for which changes in market shares were negligible.

FIGURE 7 – Effect of Alternative Policies on Brand Market Shares within Low Emission Diesel Vehicles

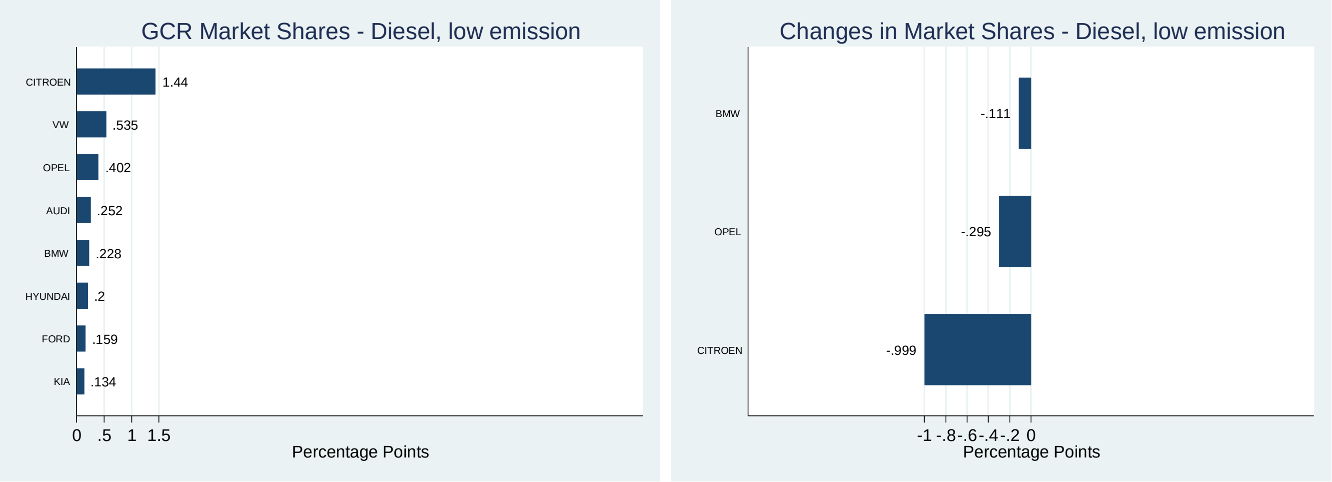


Figure 7a – GCR market shares

Figure 7b – Counterfactual I: No GCR vs. GCR

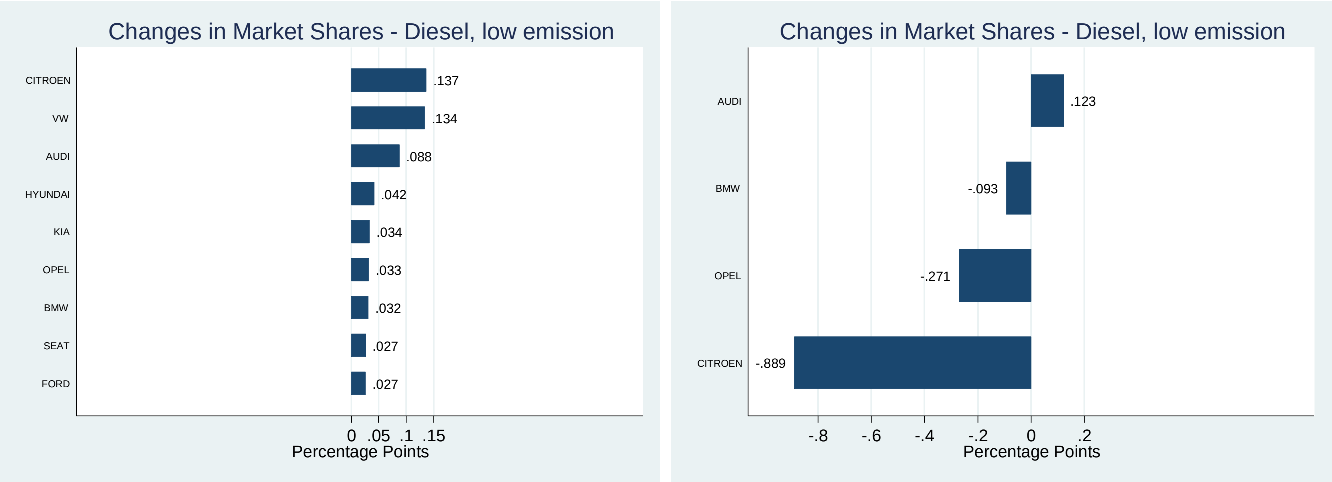


Figure 7c– Counterfactual II: Symmetric GCR vs GCR

Figure 7d – Counterfactual III: Full Conversion to FFV vs GCR

Note: This figure displays brand market shares under the GCR and changes in market shares induced by alternative policies. Figure 5a displays market shares under the GCR (actual policy); Figure 5b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 5c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR; Figure 5d displays *changes* in market shares had all carmakers replaced their captive gasoline vehicles with FFVs as compared to the GCR. For the sake of clarity, the figure omits some brands for which changes in market shares were negligible.

FIGURE 8 – Effect of Alternative Policies on Brand Market Shares within FFV Vehicles

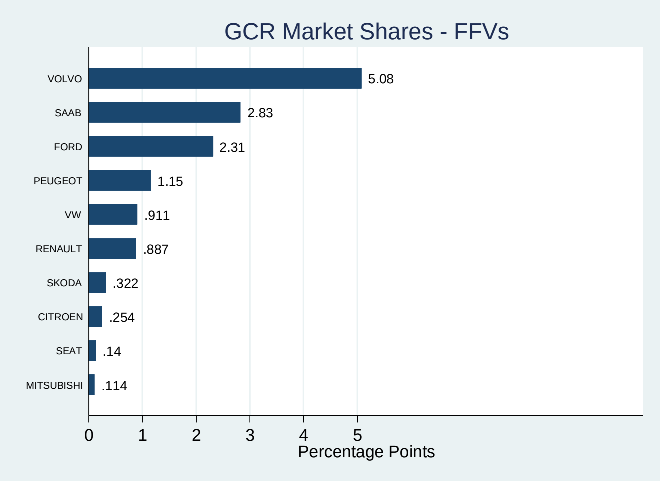


Figure 8a – GCR market shares

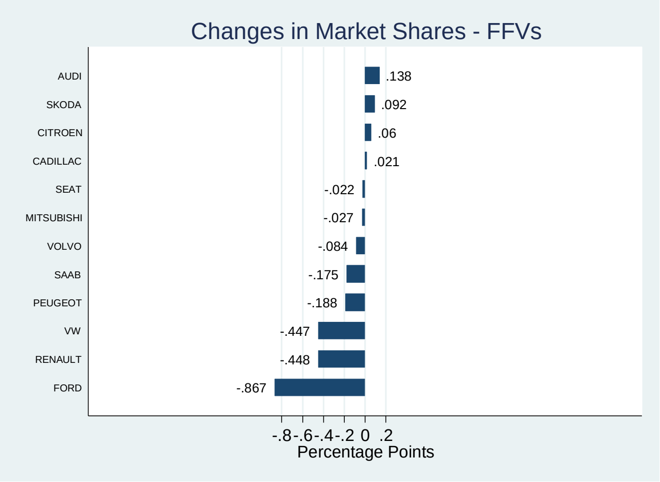


Figure 8b – Counterfactual I: No GCR vs. GCR

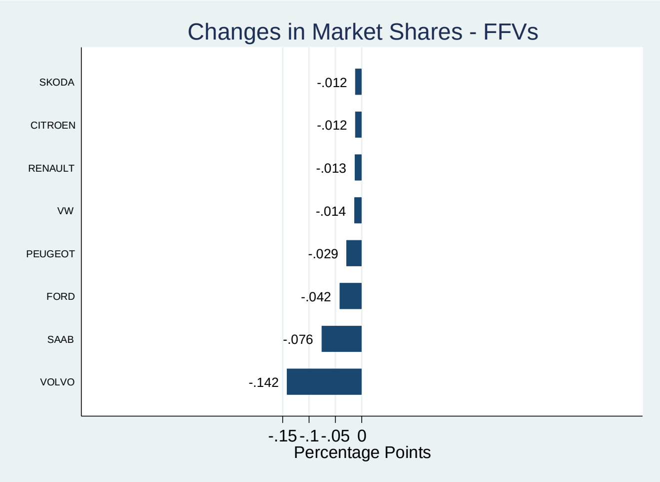


Figure 8c– Counterfactual II: Symmetric GCR vs GCR

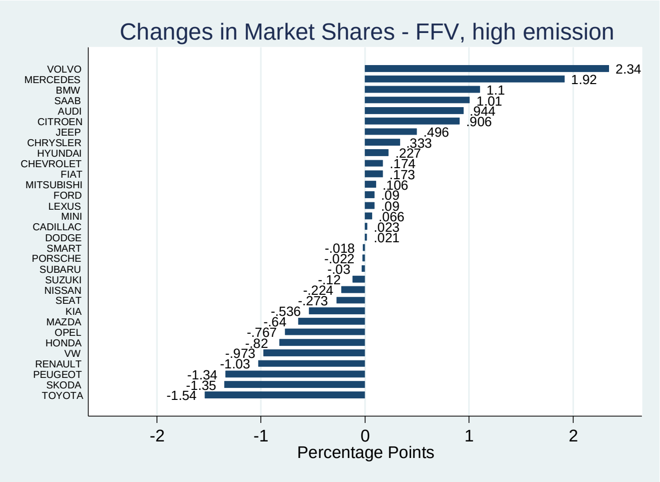


Figure 8d – Counterfactual III (a): Full Conversion to FFV vs GCR

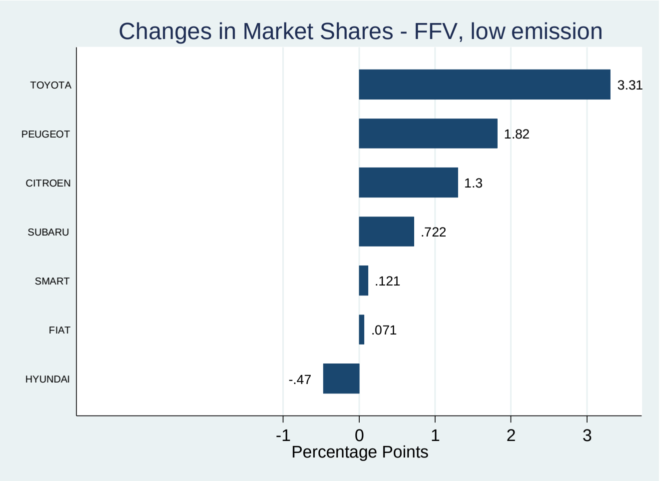


Figure 8e – Counterfactual III (b): Full Conversion to FFV vs GCR

Note: This figure displays brand market shares under the GCR and changes in market shares induced by alternative policies. Figure 8a displays market shares under the GCR (actual policy); Figure 8b displays *changes* in market shares under the counterfactual of no policy (i.e., no GCR) as compared to the GCR; Figure 8c displays *changes* in market shares under the counterfactual of a symmetric GCR as compared to the GCR; Figures 8d and 8e display *changes* in market shares of high- and low-emission FFVs had all carmakers replaced their captive gasoline vehicles with FFVs as compared to the GCR (Note also the distinction between high- and low-emission FFVs when examining Counterfactual III). For the sake of clarity, the figure omits some brands for which changes in market shares were negligible.

Tables from Appendix (Not for publication)

Table B1 – Regression of Sales on Green Car Rebate and Market Characteristics

OLS - Dep. var: ln(total sales)	(1)
GCR dummy	-0.0124
	(-0.20)
ln(Potential Market)	0.705***
	(3.92)
ln(CPI)	-3,744
	(-1.65)
ln(Electricity Price)	-1.214***
	(-3.90)
ln(Industrial Production)	1.098***
	(5.83)
Constant	-1,309
	(-0.42)
N	73
R2	.7522

Note: t-statistics in brackets, standard errors clustered by brand-fuel. * p<0.10, ** p<0.05, *** p<0.01

TABLE B2 – CO2 Savings and Costs of Alternative Policies

	CF I "No GCR"	CF II "Symmetric GCR"	CF III "Full FFV Adoption"
Panel A: CO2 Savings (thousands tonCO2)			
Gasoline usage			
0%	583.6	257.7	3,353.4
25%	522.6	254.8	1,863.0
50%	503.3	253.9	1,392.4
75%	482.4	253.0	882.5
Panel B: Cost of CO2 Savings (SEK/tonCO2 saved)			
Gasoline usage			
0%	642	338	528
25%	716	341	950
50%	744	343	1271
75%	776	344	2006
		Total Cost of Program as a Percentage of the GCR	
Percentage	--	22.9	464.6

Note: This table (to be compared to Table 4 in the text) reports the total cost of the program in each scenario in Panel A, lifetime savings in tons of CO2 emissions induced by the different counterfactuals in Panel B and their associated costs in SEK/tonCO2 in Panel C. Results are reported for the assumption of Bertrand-Nash pricing as well as different levels of gasoline usage among FFV owners to illustrate the impact of fuel arbitrage on the program. All computations assume the lifetime of a vehicle to be 25 years. See Appendix A for details on the assumptions on gasoline usage and Appendix C for mileage regression results.

Table C1 – Mileage Regressions

	(1) Km/Year	(2) Km/Year	(3) Km/Year	(4) Km/Year	(5) Km/Year
Constant	19200.7*** (220.88)	20000.5*** (19.39)	17665.2*** (22.35)	17153.2*** (1267.45)	17152.1*** (1057.17)
Fuel FEs	**Yes**	No	No	**Yes**	**Yes**
Year FEs	No	No	No	**Yes**	**Yes**
Fuel-age FEs	No	**Yes**	**Yes**	**Yes**	**Yes**
Fuel-year FEs	No	No	No	**Yes**	**Yes**
Brand-model FEs	No	No	**Yes**	**Yes**	No
Brand-model-segment FEs	No	No	No	No	**Yes**
N	2031000	2031000	2031000	2031000	2031000
R-squared	.4064	.3626	.8728	.905	.9383

Note: t-statistics in brackets, standard errors clustered by brand-fuel. * p<0.10, ** p<0.05, *** p<0.01. The full set of results is available from the authors upon request.

Table C2 – Lifetime Mileage Estimates, by Fuel

	Age of Vehicle (years)															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Gasoline	16655	16158	15661	15165	14668	14171	13674	13177	12680	12183	11686	11189	10692	10196	9699	197,654
Gasoline/electric	19473	18937	18401	17865	17329	16793	16257	15721	15185	14649	14113	13577	13041	12505	11969	235,809
FFV	19621	19006	18392	17778	17163	16549	15934	15320	14706	14091	13477	12862	12248	11634	11019	229,800
Gasoline/CNG	19545	19401	19257	19113	18969	18825	18681	18537	18393	18249	18105	17961	17817	17673	17529	278,057
Diesel	25460	25068	24676	24284	23892	23501	23109	22717	22325	21933	21541	21149	20757	20365	19973	340,749

Note: Mileage disaggregated at the fuel segment based on estimates from Specification 5 in Table C1. Figures are expressed in kilometers.