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Trade-offs in CO_2-Oriented Vehicle Tax Reforms: A Case Study of Greece

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ABSTRACT

We estimate demand for automobiles in Greece using a discrete choice model of product differentiation and use the model to evaluate carbon-based tax schemes that could shift consumer purchases towards low-CO_2 cars and thus lead to the reduction of fuel use and CO_2 emissions. We find that careful policy design, supported by appropriate modeling, can bring about substantial environmental benefits without losing control of economic parameters such as public finances or firm profits. This finding comes in contrast to the results of recent vehicle tax reforms in European countries, which turned out to be more costly than initially expected. Our analysis indicates that, especially in countries with already heavy vehicle taxation, improper implementation of carbon-based taxes can have adverse unintended environmental consequences.

Key words: automobile market, carbon taxation, emissions, feebates.

1. Introduction

It is widely accepted that global transport emissions should decrease greatly if the world is to meet its climate goals by the year 2050 (IEA, 2009). Towards this objective, a policy option that has been receiving increasing attention is the change in vehicle taxation systems to encourage consumers to purchase low-CO_2 cars. This option offers some promise because it involves a market-based instrument, it is politically more attractive than fuel tax increases, and it can lead to an economically efficient outcome by equating marginal compliance costs across car models and automakers (Anderson et al., 2012).

Most European Union (EU) countries have a CO_2-based component in their vehicle taxes (ACEA, 2011; OECD, 2009). Several countries use a feebate system, which involves paying a rebate to consumers who purchase a fuel-efficient vehicle and imposing a penalty on those who purchase gas-guzzlers. The feebate option has been an object of debate in North America for many years (Bunch et al., 2011; Fischer, 2008; Greene et al., 1995), but there is little related research for Europe. Studies carried out on behalf of the European Commission, the EU's executive body, have dealt with this issue through simple statistical/econometric methods (COWI, 2002; TIS et al., 2002). Other studies have made descriptive ex-post assessments of taxation schemes implemented in specific countries, such as Rogan et al. (2011) for Ireland or Bastard (2010) for France. Recently we have explored the environmental and economic implications of feebate schemes in Germany in an ex ante analysis which is – to our knowledge – the first one of its kind in Europe (Adamou et al., 2012)[1].

In this paper we extend our analysis to Greece. We specify a nested multinomial logit model in line with Berry (1994) and estimate it econometrically with the aid of detailed data from the Greek car market for the period 1998-2008. We simulate two alternatives: (i) the adoption of a feebate scheme and (ii) the partial replacement of the current registration tax with a system that calculates tax levels as a function of a

[1] In a related study, Vance and Mehlin (2009) examined whether tax incentives promote the purchase of more efficient vehicles in Germany. However, they estimated a variant of the nested logit equation that departs somewhat from the underlying theoretical utility framework.

vehicle's CO_2 emissions. The policy implications from the Greek case study are relevant to the large number of European countries that, like Greece, impose a registration tax on newly purchased automobiles[2].

2. The model

We employ the nested logit model proposed by Berry (1994) to estimate demand for automobiles. The utility of buying an automobile depends on its price, its observed characteristics (such as engine size) and an unobserved characteristic. The nested logit model has been widely used because it produces sensible substitution patterns depending on predetermined classes of products and is much easier to implement than the more general random coefficient model.

The model assumes that products are grouped in different categories within one or more nests. In our data the nest comprises automobile models grouped on the basis of body type and engine size (e.g. sedan cars with engine size ranging from 1.4 to 1.8 liters). Consumers are identical (up to an idiosyncratic taste shock) within each group but different across groups. Berry (1994) has shown that utility-maximizing behavior by consumers leads to the following demand equation:

$$\ln(S_j) - \ln(S_0) = x_j\beta - \alpha P_j + \sigma \ln(S_{j/g}) + \xi_j, \qquad (1)$$

where S_j is the market share of product *j* (sales divided by the size of the potential market), S_0 is the outside good share, P_j is the observed price of product *j*, x_j is a vector of observed attributes of product *j* (such as horsepower, engine size, emission levels etc.), ξ_j is a disturbance summarizing unobserved characteristics of product *j*, $S_{j/g}$ is the share of the model within its group, and β, α, σ are the demand parameters to be estimated.

Firms are assumed to compete by choosing prices to maximize total profits from all their products. Calculation of profits must carefully account for all taxes. The automobile taxation system in Greece in the 1998-2008 period had two main

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[2] Austria, Belgium, Cyprus, Denmark, Finland, Hungary, Ireland, Malta, Netherlands, Norway, Portugal, Romania, Slovenia and Spain. See ACEA (2011) and Braathen (2012).

components. One was an ad valorem tax (t) imposed on the import price (marginal cost, denoted by C_j). The second was the value added tax (v), which is applied to the final price less the amount of the ad valorem tax. The resulting first order condition is

$$P_j = C_j \ (1+v+t_j) + \frac{1-\sigma_g}{\alpha[1-\sigma_g S_{f/g} - (1-\sigma_g) S_{f,g}]}, \qquad (2)$$

where $S_{f/g} = \sum_f S_{j/g}$ denotes the share of firm f's products within group g and $S_{f,g} = \sum_f S_j$ represents the firm's group g sales as a percentage of the potential market (Verboven, 1996).[3] Estimates for public revenues and firm profits can be obtained from this first order condition and welfare can be computed using Trajtenberg's (1989) formula – see Adamou et al. (2012) for details.

3. Data

Data were obtained from a private vendor (JATO Dynamics) specializing in the collection of automotive data worldwide. For each one of a few thousand models or model versions every year, the dataset contains 17 distinct vehicle attributes such as vehicle weight and engine size, as well as information on sales volume and sales price. Details are provided in the Appendix. Table 1 below summarizes the average prices, sales, engine capacity and CO_2 emissions by vehicle class. The 'small' class contains automobiles with engine capacity between 0.6 and 1.4 liters, the 'medium' class contains cars with engine capacity from 1.4 to 1.8 liters and the rest are considered as large automobiles. As expected, larger cars have higher CO_2 emissions and prices but lower sales. This classification is the one we use in the demand estimation below.

[3] The supply model assumes that pricing decisions are taken centrally by manufacturers, rather than by retailers. Personal communications with several representatives of major car retailers in Greece have convinced us that this is a reasonable assumption.

Table 1: Descriptive statistics of the Greek dataset by vehicle class (obs: 3909)

Class	observations	Prices (thousand €’2005)	Sales	Engine Capacity (liters)	CO_2 emissions (grams per kilometer)
Small	1196	13.349	1470	1.164	153.69
Medium	1437	22.368	591	1.652	183.77
Large	1276	44.084	181	2.472	237.92

One of the most interesting features of the dataset is the variability of CO_2 emissions of relatively similar cars. If one observes the CO_2 performance of vehicles within the same segment, other attributes being equal, CO_2 emissions can vary by up to a factor of two. This indicates that appropriate incentives can encourage consumers to buy low-CO_2 cars without having to deviate radically from their preferred type of vehicle. In the United Kingdom it has been assessed that choosing the lowest CO_2 emitters in any car market segment can make a difference of about 25% to fuel efficiency and CO_2 emissions (King, 2007). The same observation has recently been made for Germany (Zachariadis, 2012). This means that even if consumers do not shift away from their preferred market segment, it is still possible to reduce new car CO_2 emissions by a considerable amount through e.g. a higher tax on high-CO_2 cars of that segment. The analysis is the following sections serves to quantify the extent to which such a shift is possible.

4. Estimation

The demand equation (1) can be estimated with the standard Ordinary Least Squares (OLS) method. However, OLS will product biased estimates because of the endogeneity of the price and within-share variables. In order to address the endogeneity problem we estimated demand using Instrumental Variable (IV) methods. In the econometric model the parameter σ was allowed to vary across groups; σ_g’s were estimated by interacting $ln\ (S_{j/g})$ with a set of group-specific dummy variables G_{jg} that take the value of 1 if product *j* belongs to group *g* and 0 otherwise.

Table 2 presents the estimation results using OLS and IV methods. The choice of instruments for the IV estimation (number of models in the group, CO_2 emission of own models and CO_2 emission of own models squared) was guided by the appropriate tests for instrument relevance and overidentification. The Anderson canonical correlation LM statistic – a test of the null hypothesis that the model is under-identified – was rejected. The Sargan statistic – a test of the null hypothesis that the instruments are valid – could not be rejected. Instrumenting for the endogenous variables causes their coefficients to fall, as expected. This means that IV is indeed an improvement on OLS and hence the discussion in the rest of the paper is based on the IV estimates.

Engine capacity, horsepower, torque, climate control and airbags are important car attributes for the demand side. CO_2 emissions turned out to be statistically insignificant; this supports the statement made by Greene (2010) that consumers substantially undervalue fuel economy relative to its expected present value. SUVs, sports and luxury cars have a positive and significant coefficient but MPVs have a significantly negative coefficient. Dummy variables denoting the country of origin of car models have the expected sign (e.g. German cars are highly regarded while Chinese and Romanian cars are not).

Based on these estimates, the average own price elasticities are -6.08 (-1.66 for small, -3.78 for medium and -12.84 for large cars). Average markups per model are €5,881 (€8,171 for small, €6,050 for medium and €3,545 for large cars). Public revenues for year 2008 are found to be €1,089 million (at 2005 prices) or €4,372 per car; these represent the total revenues from both the *ad valorem* tax and the VAT. Average CO_2 emissions are 167.5 grams per kilometer per car. Retailer profits are found to be 20,490 million €2005 throughout 1998-2008, or €7,219 per car; for 2008 the corresponding profits are 1,765 million €2005 or €7,086 per car. Finally, welfare – as defined in this specification – is about €728 per car in 1998, increases to €1069 for 1999 and €1199 for 2000, and then gradually declines to €882 for 2008.

Table 2: Estimation results.

Variables	OLS	IV
Price (thousand 2005 €)	-0.013***	-0.077***
σ_{small}	0.866***	0.383***
σ_{medium}	0.981***	0.544***
σ_{large}	1.178***	0.736***
Engine capacity	0.297***	0.561***
CO_2 emissions	-0.0021***	0.0013
Horsepower	0.0022***	0.0061***
Torque	-0.00043	0.0025***
Climate control	0.038***	0.280***
Airbags	-0.259***	0.167***
SUV	-0.071***	0.547***
MPV	-0.025	-0.439***
Luxury	0.020	0.822***
Sports	-0.0044	0.151*
Country of origin effects		
China	-0.168	-1.163**
Czech Rep.	0.037	0.140
England	0.0057	-0.030
France	0.038**	0.017
Germany	0.101***	0.506***
Italy	0.035*	-0.176***
Korea	-0.014	0.00028
Romania	-0.219	-1.219**
Russia	-0.214***	-0.885***
Spain	0.082***	-0.092
Sweden	0.092***	0.221***
Switzerland	0.055	-0.132
USA	-0.185***	-0.278**
Constant	-4.237***	-7.109***
F-test	3363.54***	189.69***
Underidentification test		79.42, P-value: 0.000
Overidentification test		1.81, P-value: 0.178

Notes: *, ** and *** denote significance at 1%, 5% and 10% level respectively. Year fixed effects have also been included in the estimations but are not reported here for brevity.

5. Policy simulations

Having estimated the parameters of our model as described above, we proceeded to simulate the effects of two different vehicle taxation policies on automobile sales, prices, public revenues, firm profits, consumer welfare and sales-weighted CO_2 emissions[4]. We used a set of J first order conditions (as in equation 2) to solve for the new optimal prices after each new taxation scheme is introduced. All calculations show the effect of taxation in the year 2008 because this is our last year of data. This may not be a disadvantage as automobile demand in the Greek market may have changed considerably post-2008 due to economic conditions in the country; years 2009-2011 have certainly not been representative of long run demand patterns.

5.1. Simulation of the effect of a CO_2 feebate

Our first policy exercise assumes that a feebate A_j is introduced, while all other taxes remain the same as before. As sales-weighted average CO_2 emissions of cars sold in Greece in 2008 are found to be 159.5 grams per kilometer (g/km) per automobile, a linear tax is introduced in such a way that it is positive for cars with CO_2 emissions over 159.5 g/km and negative for cars with emissions lower than this pivot point:

$A_j = \mu\ (CO2 - 159.5)$, where $CO2$ is the CO_2 emissions level of model j.

In this exercise, coefficient μ is equal to €31, which implies that retail prices may decline by up to 20% for individual low-CO_2 car models, while they can rise by more than 10% for big models with very high CO_2 emissions. The value of μ has been set at such a level that the government cannot subsidize any car model with a rebate higher than the average tax imposed on all models; this ensures that the government does not risk losing too many public revenues due to the new taxation system.

Table 3 reports the changes in sales volume resulting from the introduction of this feebate. Total automobile sales remain essentially unchanged; they increase by only 0.4% in the feebate scenario. Low-CO_2 cars experience a decline in their prices and a consequent increase in their sales, which is stronger for the group of cars with

[4] For technical details on the simulation procedure see Adamou et al. (2012).

emission levels below 130 g/km. As regards the feebate effect within engine size classes, it is evident that the CO_2-based tax not only shifts sales towards smaller cars, but also provides an incentive for consumers to shift towards low-CO_2 models within their preferred size category. The shift is particularly pronounced in the cases of cars with very high and very low CO_2 emissions; especially in medium and large cars the feebate affects very high-CO_2 vehicles substantially, reducing their sales by more than 20%, so that even models with relatively high emissions (of the group 180-200 g/km) gain sales shares despite the increase in their retail prices.

As a result of these changes in prices and sales, sales-weighted CO_2 emissions are reduced to 156.3 g/km per automobile, a 2% decline compared to observed emission levels in 2008. Public revenues decrease by €339 per car or €81 million in total, which represent a decrease of government revenues in 2008 by 7.4%. This is primarily due to a significant drop in the sales of large cars, which will generally experience an increase in their taxation under the feebate system because most large car models emit more than 159.5 g/km. Retailer profits are found to be €7,170 per car, which corresponds to an increase in retailer markups by €84 per car or 1.2%; this is due to the shift of sales towards smaller cars which, as shown in section 4.1, have higher markup levels. Finally, consumer welfare rises from €882 per car in the actual sales of 2008 to €885 per car in the feebate scenario because of the slightly increased car sales in the feebate case.

In summary, the feebate policy simulated here leads to modest results because of the selected values for the implied carbon tax rate μ and the pivot point. As we have shown in the case of Germany (Adamou et al., 2012), different values of these two parameters can crucially influence the results. A lower pivot point, in particular, can lead to greater environmental benefits without being detrimental to public finances.

It should be noted at this point that we have not accounted for any rebound effects in these simulations. In theory, when consumers purchase a more fuel efficient (and low-carbon) car it is possible that they drive more with it because fuel costs are cheaper or that they drive more with it and drive less with a second, less fuel efficient car that they own. Such an effect might partly offset the environmental benefit of a low-carbon car. We have implicitly assumed here that each consumer chooses the mileage to drive with a car before purchasing a specific car model, regardless of its size. In any case, Small and Van Dender (2007) have found the rebound effect to diminish in recent years in the US, which probably indicates a similar trend in other high-income countries.

5.2. Partial abolition of existing automobile taxes and introduction of a CO_2-based tax

The second policy exercise assumes that a part of the existing *ad valorem* tax on cars is abolished and replaced by a tax based on a car's CO_2 emission levels. This is in line with policies currently implemented in many EU countries, where a part of a car's registration tax is calculated on the basis of emissions and another part on another vehicle attribute such as engine size. We chose to impose a tax equal to €15 (at 2005 prices) for each gram of CO_2 emitted per kilometer above a threshold of 100 g/km; it is straightforward to show that such a tax, for a lifetime of 150,000 kilometers, corresponds to a carbon price of €20-30 per ton of CO_2. At the same time we reduced the *ad valorem* tax rates by 43% so that, if sales volumes did not change in comparison to actual sales of 2008, government revenues would remain equal to the actual 2008 revenues. Although it is obvious that such a taxation change will shift sales among different engine size classes, this assumption intends to ensure that public revenues do not deviate too much from those observed in 2008.

Table 4 reports the changes in sales volume as a result of the introduction of this tax for a combination of engine size and emissions classes. Since the CO_2-related portion of the new tax is a linear function of emission levels above 100 g/km, whereas the current taxes are strongly non-linear as they grow rapidly with increasing engine size, the change in taxation system is beneficial for large cars: their engine size-related tax decreases by a large amount, so that their retail prices decline substantially (by 5.8%). As a result, their sales shares increase by more than 19% compared to actual shares observed in the Greek market in 2008. Conversely, small cars experience an increase in their prices and a subsequent fall in their sales volume.

It is interesting to observe the effects of this policy on emissions as well as public finances and firm profits. Although the existence of a CO_2-based tax mitigates a little the increase in sales of high-CO_2 cars, still the overall decline in the tax burden of large automobiles dominates and leads to significantly higher sales of large cars, even of those emitting more than 200 grams CO_2 per kilometer. As a result, average emission levels rise by 2 g/km per car, a 1.3% increase compared to actual emission levels in 2008; combined with a slight increase in total car sales, total CO_2 emissions rise by 1.8%. Public revenues rise considerably, by €598 per car or by €155 million (14.2%) in total, because of the increased sales of bigger cars as well as the increased taxes imposed on smaller cars. As a result of the slight increase in total automobile sales, consumer welfare also rises by €4.5 per car or 1% in total. Finally, firm profits decline by €82 per car, or by -0.7% in total, because consumers increasingly purchase larger cars, whose markups are lower as their demand is more elastic.

Overall, results of this simulation show that such a policy is environmentally ineffective because of the current taxation system, which puts a heavy tax burden on large cars irrespective of their emission levels; a partial abolition of this system may have negative environmental repercussions, although it could be beneficial for public revenues. This finding is not relevant only for Greece but also for several European countries with similarly increasing registration taxes, such as Denmark, Ireland, the Netherlands and Norway (Kunert and Kuhfeld, 2006).

Table 3: Effect of a feebate on sales volumes of cars by engine size and CO_2 emissions class.

	Actual sales by engine size class			Simulated sales by engine size class			Change compared to actual sales		
CO_2 emissions class	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
< 130	29283	0	0	33553	0	0	14.6%	-	-
130-160	101742	19608	1709	104574	20723	2561	2.8%	5.7%	49.9%
160-180	14175	38305	1019	13491	37504	1291	-4.8%	-2.1%	26.7%
180-200	3787	11878	6978	3202	10418	7219	-15.4%	-12.3%	3.5%
> 200	0	2929	17593	0	2299	13077	-	-21.5%	-25.7%
Total:	148987	72720	27299	154820	70944	24148	3.9%	-2.4%	-11.5%

Table 4: Effect of a CO_2 tax on sales volumes of cars by engine size and CO_2 emissions class.

	Actual sales by engine size class			Simulated sales by engine size class			Change compared to actual sales		
CO_2 emissions class	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
< 130	29283	0	0	29207	0	0	-0.3%	-	-
130-160	101742	19608	1709	98084	19931	2355	-3.6%	1.6%	37.8%
160-180	14175	38305	1019	13380	38326	1348	-5.6%	0.1%	32.3%
180-200	3787	11878	6978	3550	12532	6991	-6.3%	5.5%	0.2%
> 200	0	2929	17593	0	2708	21822	-	-7.5%	24.0%
Total:	148987	72720	27299	144221	73497	32516	-3.2%	1.1%	19.1%

Summarizing the above results, Figures 1 and 2 illustrate simulated sales shares by emissions class and engine size respectively and compare them with actual sales shares observed in the Greek market in 2008.

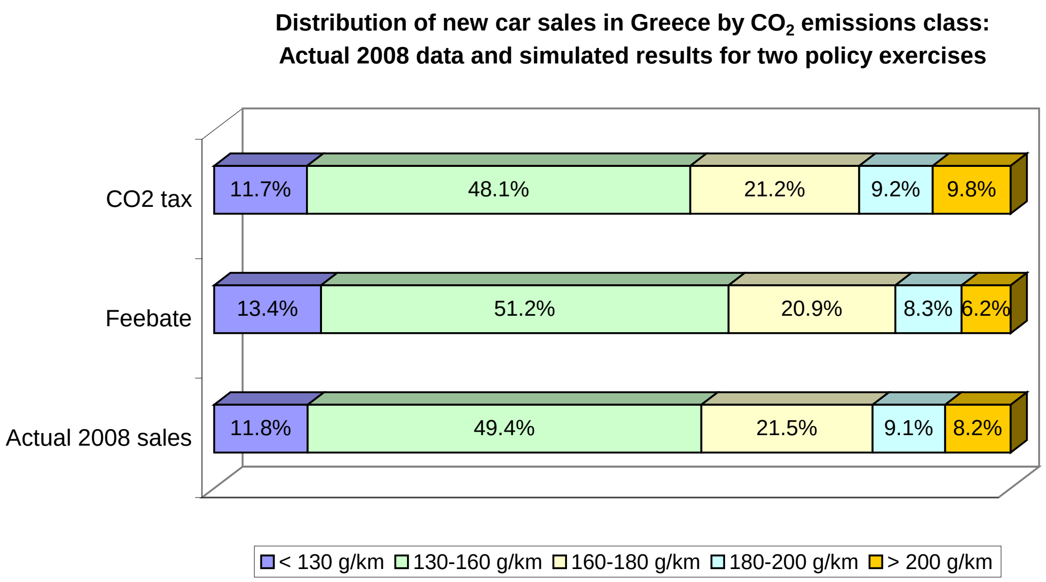

Figure 1: Comparison of actual and simulated automobile sales shares in Greece by emissions class. Note that sales-weighted average CO_2 emissions are 159.5 g/km for actual sales of 2008, 156.3 g/km in the feebate case and 161.5 g/km in the ‘CO_2 tax’ case.

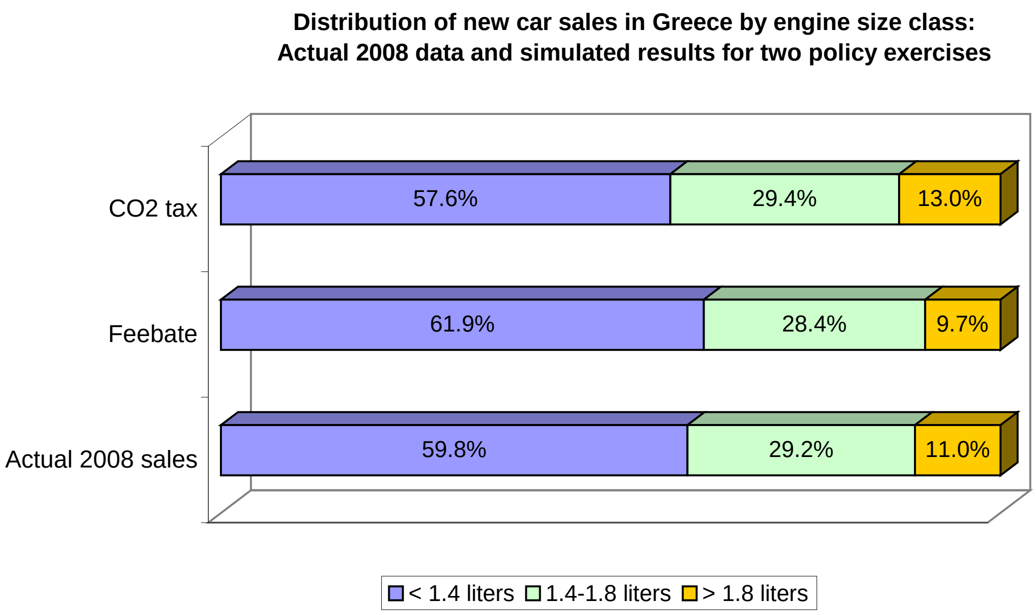

Figure 2: Comparison of actual and simulated automobile sales shares in Greece by engine size class.

6. Concluding remarks

We estimated a model of oligopolistic competition in order to evaluate policies aimed at shifting consumer automobile purchases towards low-CO_2 cars in Greece. We presented the econometric analysis and the results from two simulated taxation schemes: a feebate system, in which consumers receive a rebate when purchasing low-CO_2 cars or incur an additional fee when purchasing a high-CO_2 car, and a partial replacement of the existing Greek registration tax with an emissions-based tax. The feebate simulation showed that a reduction of new car CO_2 emissions is possible without adverse effects on the economy, provided that crucial policy settings are selected carefully. Conversely, the second simulation illustrated that adoption of a CO_2-based registration tax in countries that already impose a registration tax which increases sharply with vehicle size can have negative environmental consequences, namely higher average carbon emissions of new cars.

Overall, our simulations have shown that careful policy design can lead to appropriate measures that bring about substantial environmental benefits without losing control of public finances and private welfare. In recent practice, environmental reforms in automobile taxation have often been designed without a sound analysis of consumer response to these policies, thus leading to a significant loss of public revenues[5]. The use of a theoretically appropriate and empirically robust modeling framework like the one used in this paper is essential for the design of effective low-carbon transportation policies.

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[5] This was indeed so in at least three cases: the CO_2 rebate system in the Netherlands in year 2002, the French feebate system ('bonus-malus') that was launched in 2008 (Bastard, 2010) and a CO_2-based car taxation scheme introduced in Ireland in 2008 (Rogan et al., 2011).

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APPENDIX

Table A1 summarizes the automobile data used in the estimation.

Table A1: Description of the Greek automobile market data.

Years: 1998-2008

Vehicle attributes:

Variable	*Unit*
Make	
Model	
Vehicle length	Meters
Vehicle width	Meters
Engine size	Liters
Max. engine power	HP
Max. torque	Newton-meters
Fuel type	(petrol, diesel etc.)
Transmission type	(manual, auto)
Body type	(hatchback, convertible etc.)
Max. speed	kilometers per hour
Acceleration 0-100 km/h	Seconds
Fuel consumption, combined cycle	liters per 100 kilometers
CO_2 emissions, combined cycle	grams per kilometer
Airbag for driver seat offered as standard	Yes/No
Airbag for passenger seat offered as standard	Yes/No
Air conditioning system offered as standard	Yes/No
Climate control offered as standard	Yes/No
Segment type	(small, lower medium etc.)
Retail price	Euros
Sales volume	

The dataset of the Greek car market initially consisted of 50,701 observations for market years 1998-2008, containing data about sales, prices and car model characteristics. The database records two car models with the same engine size, fuel and transmission type but differing in a minor characteristic (e.g. the availability or not of climate control) as different observations. We merged such models in one, by summing up their sales and calculating a sales-weighted average price. We then removed from the dataset a few outliers such as models with a sales volume less than 10, models with a sales price of over €100,000 and models with engine capacity more than 5 liters; these can be considered to belong to a very special market, oriented only to very high income consumers. This process of model aggregation and removal led to a dataset of 3,909 observations in total. Out of these, 546 observations involve Sport Utility Vehicles, 442 Multi-Purpose Vehicles, 171 luxury cars and 318 sports cars; the rest, or 62% of the sample, comprise ‘regular’ cars. Some summary statistics for key variables are provided in Table A2 below.

Table A2: Descriptive statistics of the Greek dataset (obs: 3909)

Stats	Sales	Prices (thousand €2005)	Engine Capacity (liters)	CO_2 emissions (grams per kilometer)	Horsepower (kilowatts)	Torque (Newton-meters)
Minimum	11	6.735	0.599	103	39	53
Percentile 5%	15	10.155	1.108	139	61	93
Percentile 25%	52	14.766	1.390	161	90	126
Percentile 50%	198	21.289	1.598	184	113	150
Percentile 75%	811	32.757	1.995	212	150	203
Percentile 95%	3272	61.815	3.192	286	240	320
Maximum	12844	120.866	4.966	405	420	483
Mean	726	26.697	1.801	192	127	175
Std. Dev.	1312	17.077	0.638	45	54	71