Disentangling Sources of Vehicle Emissions Reduction in France: 2003-2008*

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Abstract

We analyze the evolution of CO_2 emissions of new vehicles sold in France between 2003 and 2008. We investigate in particular the effect of two policies introduced during that time: the energy label requirement, which went into effect in the end of 2005, and a feebate based on CO_2 emissions of new vehicles in 2008. We estimate a flexible model of demand for automobiles that incorporates consumers' heterogeneity and valuation of vehicle CO_2 emissions. Our results show that there has been a shift in preferences towards low-emitting cars. Moreover, the timing of these changes is consistent with the introduction of the two policies. This suggests that the feebate had a crowding-in effect in addition to its price effect. Overall, the change in preferences accounts for 40% of the overall decrease in average CO_2 emissions of new cars in the period.

Keywords: environmental policy, consumer preferences, CO_2 emissions, automobiles.
JEL codes: D12, H23, L62, Q51.

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1 Introduction

In this paper, we study the evolution of carbon dioxide (CO_2) emissions of new vehicles sold in France over the period 2003-2008. We seek to understand the 13% average decrease in new vehicle CO_2 emissions over this period, from 156 grams per kilometer in January 2003 to 136 grams in December 2008. In particular, we investigate how people reacted to two French environmental policies that aimed at mitigating CO_2 emissions from automobiles. The first is the implementation, at the end of 2005, of a European directive compelling manufacturers to indicate CO_2 emissions by labeling every car. The second is the January 2008 introduction of a feebate that provides a financial reward for low-CO_2-emitting vehicles (less than 130 grams per kilometer) and a penalty for those with the highest emissions (more than 160 grams per kilometer).

The first reason for this interest is an environmental concern. Cutting vehicle CO_2 emissions is considered a crucial objective, as the transportation sector accounts for a third of the CO_2 emissions in developed countries. As of April 2014, 19 countries have taxation systems related to vehicle CO_2 emissions.[1] The California Clean Cars Law, introduced by the state of California and followed by 13 other states, is another example. It is unclear yet whether this growing concern for global warming at the societal level translates to the individual one, both in terms of utilities and choices. First, global warming will impact consumers in the long run only. Second, its exact consequences are still uncertain and individuals may not know their own effect on it. Finally, even if it enters into consumers' utility functions, the environment is a public good with a very large number of individuals affecting its quality. Because of the classic free-riding problem, people may not modify their choices, even if global warming and environmental issues are discussed more and more.

The second reason to investigate the effects of these policies is related to the more general issue of how consumers react to public policies. Beyond incentive effects, public policies may influence social preferences, which in turn change individual behaviors. A growing economic literature, either based on theory, experiments or natural experiments, acknowledges the importance of such effects (see, e.g., Bowles & Polanía-Reyes, 2012, for a survey). A famous experiment, conducted by Gneezy & Rustichini (2000), introduced a monetary fine for late-coming parents at day-care centers. Contrary to the expectation, the number of late-coming parents significantly increased and remained higher even after the removal of the penalty. This example shows that, by introducing the fine, the parents durably changed their behavior through non-standard channels. Public policies may also modify the information set of bounded rational consumers, affecting their choices in turn. One goal of the paper is to investigate whether such effects are at stake here, and, if so, to

[1] See European Automobile Manufacturers Association (ACEA): "http://www.acea.be/uploads/publications/CO_2_Tax_overview_2014.pdf".

assess their importance with respect to more standard price and supply-side effects. Note that we do not investigate precisely which channel the policies act through to affect consumers' preferences. One possibility is that these policies provide information on vehicle CO_2 emissions. This was clearly the initial aim of the energy label. The feebate policy, by making the CO_2 emissions more salient, may have also increased the information of consumers. Another explanation is that these policies make people more aware of the environmental effect of vehicle emissions. This would also correspond to the policies having an informational effect, but in this setting, individuals would have perfectly observed CO_2 emissions of vehicles even absent the policies. In this scenario, the policies rather inform the consumers about the effect of CO_2 emissions on the environment.

To investigate the relative importance of the evolution of preferences vis-à-vis more standard effects, we use a dataset from the association of French automobile manufacturers (CCFA) that records all registrations of new cars in France between 2003 and 2008, as well as some demographic characteristics of the buyers. Compared to most of the existing literature that deals with the measure of environmental preferences, using such data presents two main advantages. First, we observe true choices as opposed to stated preferences, thus avoiding the so-called hypothetical bias (Arrow et al., 1993). Second, the automobile constitutes a good object of interest since it represents a large share of consumers' budget and its purchase involves a long and careful decision process. We investigate, through a structural approach, how consumers' preferences for CO_2 emissions and their willingness to pay to reduce global warming have evolved over this period of time.[2] We also study whether this evolution is heterogeneous among consumers. We estimate for those purposes a nested logit model of demand incorporating observed heterogeneity through 18 demographic groups of consumers based on age, income and type of area they live in (urban or rural). Using market shares of cars at the demographic group level, this model allows us to estimate consumers' price sensitivities and preferences for car attributes, including their valuations of CO_2 emissions but also fuel costs, among others. Using the estimated parameters of preferences, we are then able to quantify the importance of changes in preferences of consumers in the observed evolution of average CO_2 emissions of new vehicles purchased over the period 2003-2008. We contrast this number with the pure price effect of the feebate, the effect of fuel price changes and other effects, including in particular changes in the composition of supplied vehicles. To do this, we simulate the three different market equilibria that would prevail without (i) the change in preferences, (ii) the feebate monetary incentive and (iii) the increase in fuel prices.[3]

Our estimates suggest that consumers indeed evolved over the period. Moreover, we find

[2] Changes in preferences should be understood in a broad sense, including informational effects of the policies.

[3] In this setting, the other effects including changes in the choice set are obtained as a residual, see Section 4.2 for more details.

a coincidence between the evolution of consumers' utility and the timing of the implementation of both policies. Our results thus suggest that environmental policies have been efficient tools for shifting consumers' utility towards environmentally friendly goods. We find that between 2003 and 2008, average new vehicle CO_2 emissions fell by more than 10%. 40% of this decrease is related to the evolution of consumers' preferences, 14% stems from the pure price effect of the feebate while 13% accounts for the increase in fuel prices. The rest, i.e. 33%, can be associated to the change in car characteristics and consumers' reaction to them. We thus find evidence that consumers value environment and the reduction of global warming, and that their valuations have increased over time. This is true for all the consumers we are considering, though we find substantial heterogeneity in this evolution. The oldest and the richest are those for whom the importance of CO_2 emissions has increased the most. Finally, combining the estimates of environmental preferences with price elasticities, the willingness to pay for a reduction of 10 grams of CO_2 per kilometer rose on average by 568 euros in 2008 compared to 2003-2005. These orders of magnitude are consistent with Brownstone et al. (2000) and the results of the MIT Survey of Public Attitudes on Energy and the Environment. In line with our interpretation of a growing environmental consciousness, we observe a positive correlation at the town level between the average evolution of the willingness to pay and the electoral results of the green party candidate in the 2007 presidential election.

To the best of our knowledge, our study is the first to provide evidence that environmental policies in the car market may affect consumers' environmental valuation. More generally, the effect of environmental policies on the car market has attracted a lot of attention. Goldberg (1998) was the first to use a structural approach to measure the effects of the CAFE standard regulation in the United States. Recent papers on the effects of feebates include those of D'Haultfœuille et al. (2014) for France, Huse & Lucinda (2014) for Sweden, and Adamou et al. (2014) for Germany. Some recent literature has also focused on the reaction of manufacturers to the evolution of gasoline prices or to specific environmental policies, in particular the CAFE standards in the United States (see for example Anderson & Sallee, 2011, Knittel, 2011, Sallee & Slemrod, 2012 and Langer & Miller, 2013) and in Europe (see Reynaert, 2014).

Our paper provides evidence that the change in consumers' preferences plays an important role in explaining the trends of average CO_2 emissions. This result is consistent with the paper of Miravete et al. (2015) that shows that the evolution of the share of diesel cars in Spain stems mostly from a change in the consumers' preferences for diesel. Because CO_2 emissions are closely related to fuel costs, our paper is also related to the vast literature on fuel efficiency valuation, which has tried to assess whether consumers undervalue or overvalue fuel costs (for recent contributions, see Allcott, 2011, Anderson et al., 2013, Busse et al., 2013 and Grigolon et al., 2014). Finally, we contribute to the literature on energy labels. The most closely related paper is the one by Houde (2014), which measures the impact of the introduction of the EnergyStar label for domestic appliances on the US refrigerator market. He finds, as is the case here, that consumers value the label beyond the energy savings associated with the certified products.

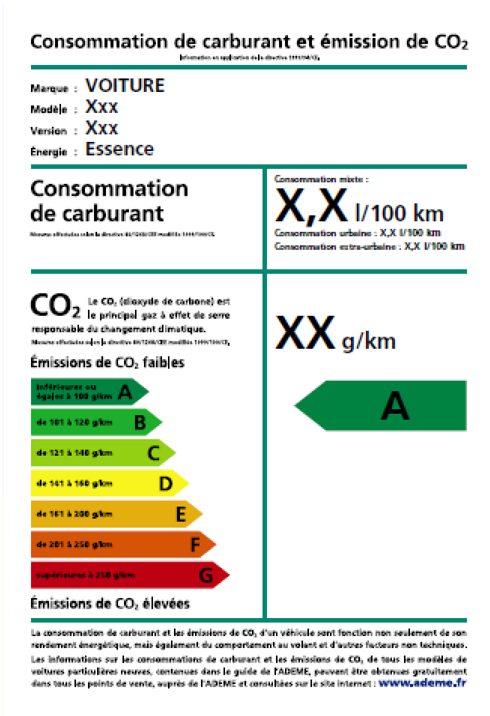
The paper is organized as follows. Section 2 presents the environmental policies, addresses the evolution of average CO_2 emissions over the period and explores succinctly the different elements explaining this evolution. Section 3 presents the demand model. Section 4 displays the estimation results and decomposes the evolution of CO_2 emissions. Section 5 concludes.

2 Environmental policies and evolution of CO_2 emissions

2.1 Energy labels and the feebate system

In order to increase awareness of the environmental impacts of automobiles, the European Commission has compelled manufacturers to place an energy label on each new car since the end of 2005. Applying this European directive, the French government implemented the new regulation in November 2005 and manufacturers were given six months, i.e. until May 2006, to conform to it. The policy still applies today. The energy label indicates the precise average CO_2 emissions of the vehicle and its fuel consumption (in liters for 100 kilometers), its class of emissions and the position of this class among all classes (see Figure 1). Seven classes are defined, from A, corresponding to the lowest-CO_2-emitting cars (less than 100 grams per kilometer), to G, the highest emitting ones (over 250 grams per kilometer). The goal of this policy is to encourage consumers to buy greener cars by informing them about CO_2 emissions. Thanks to these energy labels, consumers have become more aware of their vehicles' contributions to global warming. This makes it easier for consumers to take emissions into account in their automobile purchase decisions than it was before the policy came into effect. This informational aspect is reinforced by the choice of the colors associated with the classes: from green for class A to red for class G. These colors were deliberately chosen to influence consumers and signal to them which purchases were "good" for the environment.

Figure 1: A typical French energy label



The second institutional change is the introduction of a green tax system called the "bonus/ malus" system in January 2008, referred to as a *feebate* hereafter. This new policy was announced on October 25, 2007. It was one of the main measures of an environmental roundtable that took place in France in 2007 and that was called the "Grenelle de l'environnement." The policy recommendation, among others, was to lower CO_2 emissions stemming from cars and to reach an average of 130 grams of CO_2 per kilometer by 2020, and the feebate was chosen as an incentive instrument to encourage the purchase of environmentally friendly new vehicles.

A financial rebate, from 200 to 1,000 euros, was given to consumers who buy low-CO_2-emitting level vehicles (less than 130g/km), while consumers buying polluting cars (more than 160g/km) were taxed from 200 to 2,600 euros. The exact amount of the rebate or the fee depended on the vehicle's emissions class. The entire scheme is presented in Table 1. These classes correspond to those of the energy label, in which the subclasses C+, C-, E+ and E- were introduced.[4] This feebate is received or paid once, at the time of the sale of

[4]We do not indicate in this table the class of emissions A+, which corresponds to emissions lower than 60g per kilometer. A rebate of 5,000 euros was associated with this class, but in 2008 no vehicle belonging to this class was sold in France. Note also that for the replacement of vehicles more than 15 years old by new vehicles, the rebates were increased by a scrapping subsidy of 300 euros. This only represents a very small fraction of the total amount of rebates (2.6%), and we neglect this measure hereafter as we do not observe which purchasers received this extra rebate.

the vehicle. The policy was implemented very quickly (January 2008) and was applied to all new cars. Those purchased abroad included the penalty as additional registration tax. On the other hand, second-hand vehicles were not in the scope of the policy. The feebate was announced to be permanent and still exists.

Table 1: Details of the feebate

Class of emissions	Emissions (in g/km)	Feebate (in euros)	Percentage of 2007 prices
A	(60-100]	+1000	8.1%
B	(100-120]	+700	4.8%
C+	(120-130]	+200	1.2%
C-	(130-140]	0	0.0%
D	(140-160]	0	0.0%
E+	(160-165]	-200	-0.98%
E-	(165-200]	-750	-3.2%
F	(200-250]	-1600	-4.3%
G	> 250	-2600	-5.2%

Contrary to the first policy, which is aimed only at modifying the information given to consumers, the feebate policy introduces financial incentives to encourage them to buy an environmentally friendly vehicle. These incentives are important in magnitude, the rebate representing up to 8.1% of the list price on average for class A, and the penalty rising to as much as 5.2% of the list price for class G.

2.2 Evolution of CO_2 emissions

Before precisely modeling car purchases, we provide a broad picture of the evolution of average CO_2 emissions of new cars in France. We rely for that purpose on a dataset provided by the Association of French Automobile Manufacturers (CCFA, *Comité des Constructeurs Français d'Automobiles*), which records all the registrations of new cars bought by households from January 2003 to January 2009.[5] Figure 2 displays the evolution of average CO_2 emissions of cars purchased during that period. To contrast the evolution of CO_2 emissions of cars purchased, we provide the evolution of average CO_2 emissions of the choice set of cars for all brands and restricting to the French brands only in Figure 3. As we do not directly observe this set of vehicles, through brand lists for instance, we assume that a car is offered during a given month if it was bought at least once before this month and after this month, or at least once during this month.[6]

[5] We exclude from this dataset exotic cars such as *Rolls-Royces* and *Maseratis* as well as commercial models and vans like *Renault Master*, which respectively represent 0.09% and 0.21% of the purchases. We also excluded purchases by companies.

[6] Consistently with the econometric analysis below, two cars with the same model name are considered to be different if they differ in at least one of the following dimensions: car body style, type of fuel, CO_2

Figure 2: Seasonally adjusted monthly average CO_2 emissions of new cars purchased

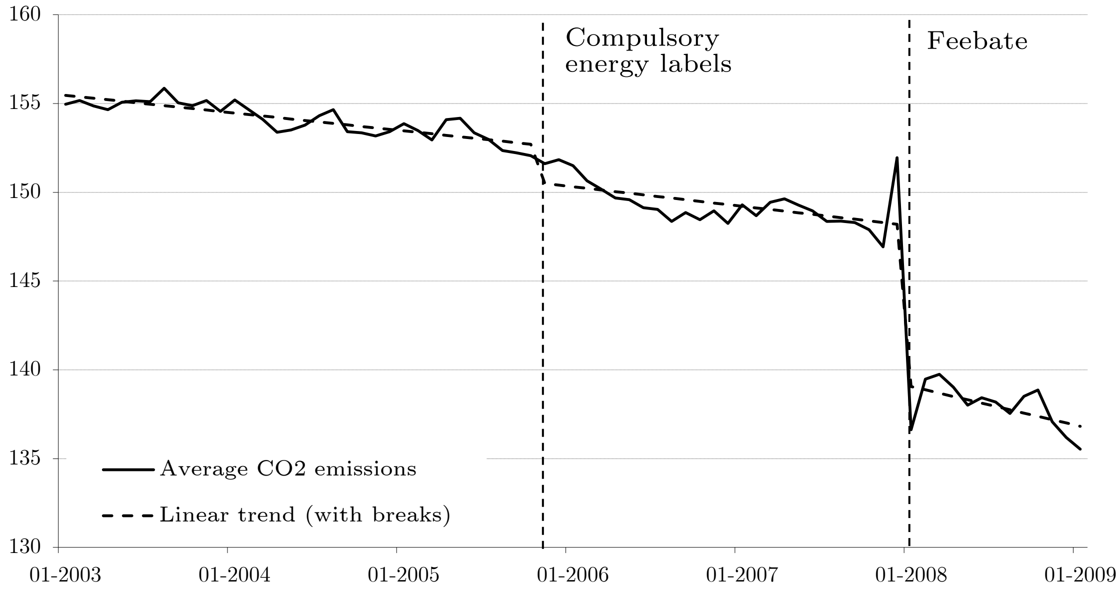
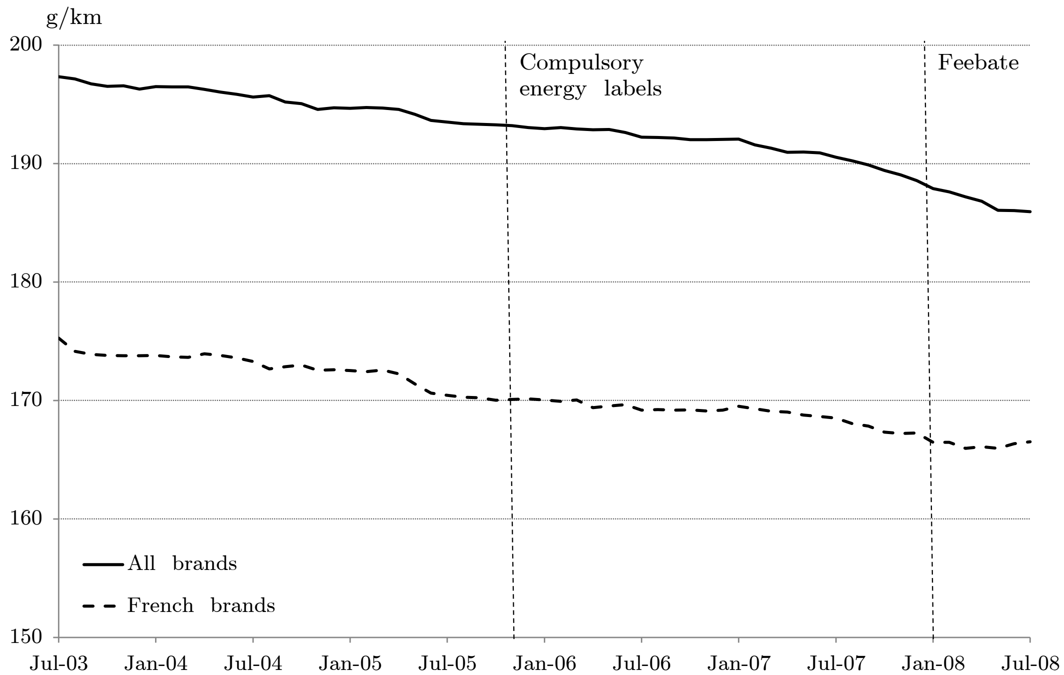


Figure 3: Monthly average CO_2 emissions of the choice set of cars



Notes: each month, average is taken over all "supplied" vehicles, namely vehicles sold once before and after the month, without weighting by their sales. Our construction of "supplied" vehicles imply that at the beginning or end of the period, only vehicles with enough sales are included. These vehicles tend to have lower CO_2 emissions. To avoid such boundary effects, we drop the first and last six months.

emissions class and number of doors.

Overall, there is an important reduction of 13% (from 156 to 136 grams per kilometer) in average CO_2 emissions of new cars between January 2003 and January 2009. In contrast, the reduction in average CO_2 emissions of the car choice set is only about 5.5% over the period. Hence, it seems that technical changes, or manufacturers' reaction to gasoline price changes, do not explain most of the evolution over the period. The first graph shows that the reduction in average CO_2 emissions can be decomposed into three parts. Between January 2003 and October 2005, before the introduction of the compulsory energy label policy, average CO_2 emissions drop from 156 to 152 grams. This negative trend indicates that there is already, before the policies, a tendency to reduce CO_2 emissions. Between the two policies, from November 2005 to October 2007, the decrease is slightly more important as the CO_2 emissions fell from 152 to 147 grams. This is reinforced by the fact that this decrease takes place in a shorter period of time (24 months as compared to 34). We finally observe a large drop after the introduction of the feebate. In February 2008, average CO_2 emissions are equal to 138 grams and this number falls to 136 grams in December 2008. The feebate policy seems thus to have a huge impact on CO_2 emissions. We also see a peak in the average emissions in December 2007, followed by a large drop. This is probably due to anticipation effects. The policy was announced at the end of October 2007, so that some households who planned to buy a high-CO_2-emitting vehicle were able to pre-empt their purchases in order to avoid the penalty.

This decomposition in three periods is confirmed by a simple econometric analysis of the impact of the introduction of both policies on the evolution of CO_2 emissions. We regress CO_2 emissions on a monthly trend with two unknown structural breaks, following Bai & Perron (1998). To eliminate the clear anticipation effects mentioned above, we consider a second specification in which December 2007 and January 2008 are excluded. The results are displayed respectively in Columns (1) and (2) of Table 2. They both indicate that important breaks appear by the end of 2005 and at the beginning of 2008. We do not reject at standard levels that they appeared actually in November 2005 and January 2008, or February 2008 if we exclude January.

Parameters	(1)	(2)	(3)
Intercept	155.35^{**} (0.258)	155.35^{**} (0.262)	197.355^{**} (0.05)
1st break date t_1	09/2005 [08/2005−11/2005]	09/2005 [08/2005−12/2005]	05/2005 [02/2005−06/2005]
2nd break date t_2	01/2008 [12/2007−02/2008]	02/2008 [11/2007−03/2008]	05/2007 [04/2007−06/2007]
dummy after t_1	-2.548^{**} (0.392)	-2.257^{**} (0.364)	-0.389^{**} (0.091)
dummy after t_2	-8.572^{**} (0.571)	-7.448^{**} (0.471)	0.149 (0.099)
Trend	-0.062^{**} (0.016)	-0.062^{**} (0.016)	-0.135^{**} (0.004)
Additional trend after t_1	-0.035 (0.029)	-0.065^{**} (0.024)	0.027^{**} (0.008)
Additional trend after t_2	-0.118^{*} (0.053)	-0.167^{**} (0.042)	-0.307^{**} (0.008)

Notes: Columns (1) and (2) report estimates for average CO_2 emissions of cars purchased, while in Column (3) the dependent variable is the average CO_2 emissions of the choice set. In Column (2), December 2007 and January 2008 are excluded because of anticipation effects. Standard errors are heteroskedasticity-autocorrelation robust. Significance levels: ** 1%, * 5%, † 10%. The intervals displayed below the break dates correspond to 70% confidence intervals.

Table 2: Linear regression of CO_2 emissions on a monthly time trend, with structural breaks

On the other hand, the decrease of average CO_2 emissions of the vehicle choice set is quite constant over the period and approximately identical for French manufacturers and others. Beyond technological change effects, this trend could partly be due to the fuel price increase over this period. The gasoline price increases on average by 6.3% per year, well above the average inflation in France over this period (2.2%). Long-term objectives such as Voluntary Agreements may have also played a role. Since the end of the 1990s, automobile manufacturers committed to reducing the level of CO_2 for passenger cars in the European Union, the latest targets being an average of 130 g/km for 2015 and 95 g/km for 2020. Furthermore, the European Commission announced in 2007 the introduction of a standard at the European level starting in 2015. Reynaert (2014) analyzes the evolution of car characteristics, and in particular CO_2 emissions. Using a production possibility frontier approach similar to Knittel (2011), he estimates how the emission abatement technology evolves over time. He finds that manufacturers' technology improved steadily between 2002 and 2007 (-2% per year) and this improvement accelerated from 2008 (-3%) and after (-5% for 2010 and 2011). Even though our descriptive analysis does not take into account the trade-off between car characteristics and only looks at the evolution of CO_2 emissions, we observe an acceleration of the decrease of average CO_2 emissions of the choice set after mid-2007 (see Figure 3). This is once more confirmed by the estimates of a linear model with structural breaks (see Column 3 of Table 2). We obtain significant coefficients on the dummies of being after 2008 and the additional trend. The dummy coefficient is nevertheless far below the one obtained in the decomposition of average CO_2 emissions of the cars purchased. In any case, the structural model estimated below allows for changes in the choice set over time and thus technical progress will be accounted for in our quantitative analysis.

Note also that the break dates we estimate for CO_2 emissions of the choice set do not match with the beginning of the two policies. Hence, it seems that there was limited immediate change in the products offered in response to both policies. There are several reasons why we do not observe an immediate adjustment on the supply side. First, the manufacturers' incentives may not have been that large, because in January 2008, the feebate policy was conducted in France only. Although taxes related to CO_2 emissions of vehicles exist in most other European countries, they do not display similar discontinuities at the emission class level. The advantage of exploiting these thresholds for the French market only may not overcome the costs of developing specific models, especially for non-French manufacturers.[7] Second, the feebate policy was announced only two months before it became effective, and the very quick implementation of the reform contrasts sharply with the time needed by manufacturers to improve fuel efficiency. It is usually thought to take several years to develop new technologies and incorporate them in new vehicles. Berry et al. (1993), for instance, observed a two-year delay between the increase in the fuel price following the first oil crisis and the corresponding technological innovations. Furthermore, manufacturers can make some changes to car specifications in the medium run, but this typically takes several years. Klier & Linn (2012), for example, analyze manufacturers' medium run reactions to CAFE standards in the US considering a time scale of four or five years. Similarly, we do not observe any particular acceleration or changes between 2003 and 2008 in the number of patents on domains related to CO_2 emissions. Finally, even if horsepower, and thus CO_2 emissions, could be adjusted quickly, the modified vehicles must be certified before appearing on the market. This certification, together with the distribution of the new vehicles, typically takes several months.

3 The model

The previous section provides evidence on significant changes in CO_2 emissions following the two policies. While standard explanations may obviously be at stake, this could also result from changes in consumers' preferences. First, it is documented that people value environment *per se*, and are thus ready to pay for environmentally-friendly goods (on

[7] Note also that tax systems evolve rapidly within countries. The feebate cutoffs and rebates/taxes were modified each year since 2010. This further limits manufacturers' incentives to adapt their product lines.

automobiles, see, e.g., Brownstone et al., 2000, or Potoglou & Kanaroglou, 2007). It seems plausible then that environmental policies shape and reinforce these preferences. Such changes in preferences would explain the decreases at the end of 2005 and at the beginning of 2008. Second, these policies may have modified the information set of consumers by putting forward the CO_2 emissions levels of automobiles. With this information being easier to incorporate in their choices, consumers may have taken it more easily into account. In the model developed by Gabaix (2014), consumers face too many characteristics and only select some of them to make their choices. If policies reduce the cost of gathering information about CO_2 emissions, consumers will rely more on this characteristic when purchasing a car. The feebate could also modify people's preferences through the informational content of the policy (see, e.g. Barigozzi & Villeneuve, 2006). Basically, the tax could be seen as a credible signal that environmental issues really matter in a world where consumers may have trouble making up their minds about the negative impact of CO_2 emissions. The introduction by the state of a tax, or a feebate as described here, is a way to convince consumers that CO_2 emissions constitute a first-order problem.

To disentangle between such effects and more standard ones, we rely hereafter on a structural model of automobile market equilibrium estimated using the CCFA registration dataset. CO_2 emissions, brand, model, type of fuel, number of doors, car body type, horsepower, weight and cylinder capacity are reported for each registration. These characteristics have been complemented with list prices and fuel prices, allowing us to compute the cost of driving (in euros per 100 kilometers).[8] On the demand side, we estimate a nested logit with observed heterogeneity, taking advantage of the availability of consumers' characteristics in our database. The French new car registration dataset provides indeed information on the owner of the car. We observe the age and the area in which the owner lives. We create 18 groups of individuals depending on their age classes (18-39, 40-59 or 60 and more), geographical areas (cities of less than 20,000 inhabitants, called *rural* areas, and cities with 20,000 or more inhabitants, called *urban* areas) and imputed income classes (0-22,000, 22,000-32,000 or more than 32,000 euros). These three variables are chosen because they turn out to account for a large part of the heterogeneity in purchase patterns. Details on the income imputation and market definition are provided in Appendix A.1.

We suppose that each year,[9] consumers can choose to buy one of the J different products offered in the market. The set of products supplied to the consumer is assumed to be exogenous. The automobile market is supposed to be segmented according to the main use of the car and we have created 8 nests accordingly: supermini, small family, large family, small MPV, large MPV, executives, sports cars and allroad/SUV. Our segmentation is

[8] Transaction prices (including potential discounts by dealers) would be preferred, but are not available, as usually occurs in this literature (see, e.g. Berry et al., 1995).

[9] To avoid the aforementioned anticipation and post-anticipation effects of 2007 and 2008, the years we consider hereafter exclude January and December.

close to that of the European New Car Assessment Program (Euro NCAP), Appendix A.2 provides the entire segmentation of the car market. We define a product by its brand, model name, car body style, type of fuel, CO_2 emissions class and number of doors. Product 0 corresponds to the outside option, namely not purchasing a new car during the year. For each product, we impute the values of the continuous characteristics (price, horsepower, fuel consumption, weight and CO_2 emissions) of the most frequently chosen version of a product.[10] We explored alternative imputations and found that our imputation generates the lowest errors on average CO_2 emissions. We also show in Appendix B.1 that our estimates are robust to variations in product definition and in the way we impute continuous characteristics.

We assume that the utility of consumer i, belonging to the demographic group d, for purchasing car j at year t satisfies

$$U_{ijt}^{d} = p_{jt}\alpha^{d} + \mathrm{fc}_{jt}\beta^{d} + X_{jt}\gamma^{d} + g_{t}^{d}(\mathrm{CO}_{2jt}) + \xi_{jt}^{d} + \varepsilon_{ijt}. \tag{1}$$

p_{jt} denotes the price of vehicle j at t faced by the consumer, including the potential tax or rebate in 2008. fc_{jt} represents the fuel cost, that is to say the cost of driving 100 kilometers with car j at t, computed using the average price of fuel each year. This variable allows us to control for the evolution of fuel prices over the period. X_{jt} denotes other standard vehicle attributes: weight, horsepower, engine capacity, number of doors and body style. We also include model fixed effects (e.g. Golf) that are common to all demographic groups in order to control for unobserved heterogeneity of products. Controlling for such heterogeneity is important to estimate correctly in particular the sensitivity to fuel cost, as shown in particular by Busse et al. (2013) and Allcott & Wozny (2014). Due to the fine definition of products and the introduction of the feebate, we still have sufficient variations within models to allow for models fixed effects. For instance, we observe 22 different types of the Volkswagen Golf model in 2007.

X_{jt} also includes time fixed effects to control for macroeconomic shocks. It is well documented that the automobile industry is sensitive to macroeconomic shocks (see, e.g., Bar-Ilan & Blinder, 1992, Hassler, 2001). Even microeconomic studies put forward the importance of aggregate shocks (see, e.g., Goldberg, 1995). The negative economic conditions due to the economic crisis in the fourth quarter of 2008 may have refrained some people from buying a car. The year dummies capture the effect of such aggregate shocks. By segmenting the consumers into demographic group, we allow demographic groups to be impacted differently by the change of the economic condition. It might still be the case, however, that the 2008 crisis modified the substitution patterns between vehicles, and encouraged households to buy smaller, lower-emitting cars. We therefore consider in

[10] For more details on the construction of products, see Appendix A.3.

the robustness checks (see Section 4.4.1) a restricted sample excluding the fourth quarter of each year.

To capture potential time-varying environmental concerns of the consumers, we also include CO_2 emissions through the term $g_t^d(CO_{2jt})$, where we consider several specifications for g_t^d hereafter. If the environmental policies affect consumers' utility, we should observe a change in the impact of CO_2 emissions in 2006, 2007 and 2008 compared to the previous years, all other things being equal. Note that CO_{2jt} is not collinear with the fuel cost variable because the link between CO_2 emissions and fuel efficiency depends on fuel type and because fuel prices evolve over time. Formally, the cost of driving relates to the CO_2 emissions of a vehicle through

$$\text{fc}_{jt} = \frac{CO_{2jt} \times q_{f(j)t}}{K_{f(j)}}.$$

Here $q_{f(j)t}$ is the fuel price for the type of fuel $f(j)$ of car j at year t. $K_{f(j)}$ is a constant that depends only on the fuel type, equal to 22.87 for gasoline and 26.86 for diesel. Even if consumers value diesel per se, CO_2 emissions are not merely a function of fuel cost, fuel type and year dummies because diesel and gasoline prices evolve differently over the period, as Table 3 below shows. It is therefore possible to separately identify the effect of CO_2 emissions from those of fuel cost, fuel type and year dummies. For the same reason, it is possible to identify these effects even if the parameters of fuel cost or fuel type in Equation (1) evolve over time. We consider such specifications in our robustness checks in Table 10. On the other hand, we would not be able to identify the same model if we supposed that individuals also value fuel consumption, in addition to CO_2 emissions and fuel cost. Our identification strategy therefore rests on this exclusion restriction. Put it differently, we assume hereafter that $g_t^d(CO_{2jt})$ captures environmental concerns rather than a specific valuation for fuel consumption.

Table 3: Evolution of average gasoline and diesel prices

Gasoline	1.04	1.07	1.18	1.24	1.28	1.36
Diesel	0.79	0.88	1.02	1.08	1.1	1.27

Notes: Average prices are computed using monthly data on nominal gas prices from the National Survey Institute. Prices are deflated to be expressed in 2008 euros.

ξ_{jt}^d and ε_{ijt} correspond to variables that are unobserved by the econometrician. ξ_{jt}^d represents the mean valuation of unobserved attributes, such as the reliability or the design of the vehicle, for instance. Finally, ε_{ijt} is the individual and product-specific error term. In the nested logit model we consider, the $(\varepsilon_{ijt})_{j=1...J}$ are allowed to be correlated for two vehicles in the same nest g. This takes into account the correlation in individual preferences for vehicles belonging to the same nest (family, executive, sports car...).

The nested logit specification, together with the normalization to zero of the mean utility level of the outside option, yields (see, e.g., Rust & Berkovec, 1985)

$$\ln(s_{jt}^d) - \ln(s_{0t}^d) = p_{jt}\alpha^d + \text{fc}_{jt}\beta^d + X_{jt}\gamma^d + g_t^d(\text{CO}_{2jt}) + \sigma^d \ln(\bar{s}_{j/gt}^d) + \xi_{jt}^d \ , \qquad (2)$$

where s_{jt}^d is the market share of product j and $\bar{s}_{j/gt}^d$ denotes the intra-segment share of product j among nest g. σ^d represents the correlation of consumers' utility across automobiles of the same nest and lies between zero (no correlation) and one (perfect correlation). This equation is very convenient for estimation because it provides a linear relationship between the market shares and the characteristics of the product. This equation also incorporates consumers' heterogeneity through the dependence in d of α^d, β^d, γ^d, g_t^d, σ^d and ξ_{jt}^d.

As usual (see, e.g., Berry et al., 1995, Nevo, 2000, and Nevo, 2001), we suppose that, excluding prices, all characteristics are predetermined and uncorrelated with the error term ξ_{jt}^d. On the contrary, prices are allowed to be endogenous. This is typically the case if manufacturers observe the $(\xi_{jt}^d)_{d,j}$ and take them into account in their pricing strategy. By construction, conditional market shares $\bar{s}_{j/gt}$ are also endogenous, so at least two instruments are necessary to identify the demand model. Following the literature (see, e.g., Berry et al., 1995), our instruments are based on the characteristics of other products. If firms compete in prices on an oligopolistic market with differentiated products, they are constrained in their pricing strategy by the existence of close substitutes. The characteristics of the other products are thus likely to affect all prices, but are not correlated with the unobserved demand term ξ_{jt}^d. Following this logic, we rely hereafter on four sets of instrumental variables. The first is the sums of characteristics of other brands' models. The second is the sums of characteristics of other brands' products of the same segment. The third consists of the sums of characteristics of other models of the brand. The last set is composed of the sums of characteristics of other models of the brand in the same segment. Formally, to instrument price and the intra-segment market share for a product j which is a version of model m in segment g that belongs to the manufacturer that produces the set of cars $\mathcal{M}$, we use:

$$\sum_{k,k\notin\mathcal{M}} X_k, \sum_{k,k\in\mathcal{M},k\notin m} X_k, \sum_{k,k\in g,k\notin\mathcal{M}} X_k, \sum_{k,k\in g,k\in\mathcal{M},k\notin m} X_k$$

Finally, in order to assess the importance of preference changes relative to, e.g., price changes, in the overall evolution of CO_2 emissions, we also model the supply side. We consider, as usually, that the firms fix their prices through a Nash-Bertrand equilibrium. Letting $\mathcal{J}_f$ denote the set of products sold by firm f, the profit of f satisfies

$$\Pi_f = M \sum_{d=1}^{18} P(D=d) \sum_{j \in \mathcal{J}_f} s_j^d(p) \times (p_j - c_j),$$

where $P(D=d)$ is the fraction of the group of consumers d, $s_j^d(p)$ is the market share of product j for group d when the vector of all prices is equal to p, c_j is the marginal cost of the product j and M is the total number of potential consumers. The first-order condition for the profit maximization then satisfies

$$c_f = p_f - \sum_d P(D=d) \left(\Omega_f^d\right)^{-1} s_f^d. \tag{3}$$

where c_f, p_f and s_f^d are respectively the vectors of marginal costs, observed prices and market shares for firm f, while Ω_f^d is the matrix of typical (i,j) term equal to $-\partial s_j^d / \partial p_i$.

4 Estimation results

4.1 Preferences for car attributes

We estimate different versions of the demand model by endogenizing or not endogenizing prices and choosing different specifications for the function g_t^d corresponding to CO_2 emissions. In Specification (1), price is not instrumented, whereas all other specifications allow for price endogeneity. Specifications (2) through (4) differ in the way CO_2 emissions are included in the regressions. In Specification (2), the evolution of CO_2 preferences are captured through a temporal trend. In Specification (3), CO_2 emissions are interacted with year dummies whereas CO_2 emissions are interacted with two period dummies (2006-2007 and 2008) in Specification (4). Specification (5) is identical to Specification (4) except that we estimate a model without heterogeneity in preferences. In all specifications, we include the cost of driving 100 kilometers. Results are displayed in Table 4. For the sake of conciseness, we present the average of the preferences parameters $(\alpha^d, \beta^d, \sigma^d, \gamma^d)_{d=1\ldots18}$ among the population of purchasers. For example, $\bar{\gamma} = \sum_{d=1}^{18} \phi_d \gamma_d$, where ϕ_d is the fraction of the population in the demographic group d. Tables 21 and 22 in Appendix B.2 display the detail of the estimated price parameters α^d and σ^d and the average of estimates of preference parameters according to the different demographic characteristics.

Before studying the way consumers value CO_2, we describe the results we obtained on their preferences for standard attributes. When not instrumented, the price coefficient does not have the correct sign but becomes negative when instrumented. Moreover, Table

21 in Appendix B.2 suggests that once instrumented, the model is consistent as all the price sensitivity parameters are negative and the intra-group correlation parameters are between 0 and 1. The means of the parameters are globally stable from one specification to another. Weight and horsepower are positively valuated. On average, households dislike coupe/convertible, station wagons and three-door vehicles and prefer vehicle with a standard body with four or five doors.[11] Consumers value fuel economy; the parameter of the fuel cost variable is negative. We obtain estimates around 0.7 for σ, reflecting the fact that products within segments are fairly strong substitutes.

All the previous estimates correspond to the average parameters of preferences of purchasers. Table 22 in Appendix B.2 shows that there is substantial heterogeneity across them, in particular along the dimensions of age and type of area. Heterogeneity along the income is less pronounced, probably because the income is not observed but rather imputed. The price sensitivity decreases with income and age. Households in urban areas are also slightly less sensitive to price than households in rural areas. Rural municipalities in France are indeed associated with lower income and lower levels of education. The sensitivity to fuel cost follows the same pattern as price sensitivity and decreases with age and income. However, the difference between rural and urban households is much stronger. Purchasers living in large agglomerations are much less sensitive to fuel cost, reflecting the shorter distances driven by urban residents.

[11]Small cars in Europe can have three doors. Such cars correspond to baseline models.

Table 4: Estimates of average preferences for vehicle characteristics (robust standard errors computed using the delta-method)

	Specifications				
Variable	(1)	(2)	(3)	(4)	(5)
Price ($\bar{\beta}$)	0.002^{**} (0.001)	-0.077^{**} (0.004)	-0.067^{**} (0.004)	-0.057^{**} (0.004)	-0.064^{**} (0.014)
$\ln(\bar{s})$ ($\bar{\sigma}$)	0.675^{**} (0.006)	0.708^{**} (0.006)	0.707^{**} (0.006)	0.708^{**} (0.006)	0.827^{**} (0.017)
Fuel cost	-0.02^{**} (0.002)	-0.094^{**} (0.005)	-0.084^{**} (0.005)	-0.076^{**} (0.005)	-0.082^{**} (0.015)
Weight	0.048^{**} (0.003)	0.123^{**} (0.006)	0.113^{**} (0.006)	0.101^{**} (0.006)	0.112^{**} (0.02)
Horsepower	0.003^{*} (0.001)	0.141^{**} (0.008)	0.122^{**} (0.008)	0.105^{**} (0.008)	0.119^{**} (0.025)
Station wagon car-body	-0.28^{**} (0.007)	-0.216^{**} (0.008)	-0.221^{**} (0.007)	-0.224^{**} (0.007)	-0.159^{**} (0.026)
Coupe/convertible	-0.318^{**} (0.01)	-0.066^{**} (0.017)	-0.098^{**} (0.016)	-0.123^{**} (0.016)	-0.014 (0.054)
Three-door	-0.2^{**} (0.006)	-0.23^{**} (0.006)	-0.224^{**} (0.006)	-0.219^{**} (0.006)	-0.148^{**} (0.02)
CO_2 emissions	-0.373^{**} (0.022)	-0.013 (0.03)	-0.133^{**} (0.03)	-0.187^{**} (0.028)	-0.05 (0.095)
CO_2 emissions $\times$ Trend	-0.052^{**} (0.002)	-0.058^{**} (0.002)			
CO_2 emissions $\times$ 2004			-0.025^{*} (0.011)		
CO_2 emissions $\times$ 2005			-0.1^{**} (0.013)		
CO_2 emissions $\times$ 2006			-0.129^{**} (0.012)		
CO_2 emissions $\times$ 2007			-0.141^{**} (0.013)		
CO_2 emissions $\times$ 2008			-0.324^{**} (0.013)	-0.284^{**} (0.011)	-0.375^{**} (0.039)
CO_2 emissions $\times$ (2006-2007)				-0.082^{**} (0.008)	-0.104^{**} (0.025)

Notes: Column (1): price not instrumented, (2): evolution of CO_2 preferences captured through a temporal trend. (3): CO_2 interacted with all year dummies. (4): CO_2 interacted with three periods (2003-2005, 2006-2007 and 2008). (5): Same specification as (4) but the model is without individual heterogeneity. All specifications include model and year fixed effects. Standard errors are in parentheses. Significance levels: ** 1%, * 5%, † 10%. Price is in 1,000 euros, Fuel costs are computed per 100 kilometers, weight is in 100 kilograms, CO_2 emissions are in 100 grams. The sample is composed of 134,532 observations for Specifications (1)-(4) and 7,474 for Specification (5).

Using these estimates, we compute the price elasticities for each demographic group using the fact that in our framework, the price elasticity of product j for group d is equal to $-\alpha^d p_j(1-\sigma^d \bar{s}^d_{j/g} - (1-\sigma^d)s^d_j)/(1-\sigma^d)$. Sales-weighted average price elasticities are reported in Table 5. These elasticities lie between -8.07 and -1.27, the mean being -4.5. These orders of magnitude are similar to those found in the literature. They are in the same range as those of Berry et al. (1995), who report price elasticities between -6.5 and

-3.5 (see their Table 4) and slightly above those of Train & Winston (2007), who obtain -2.4 on average. Moreover, as expected, the less elastic buyers are rich, older and urban individuals. The more elastic group appears to be the younger consumers with high income in urban municipalities.

Table 5: Average price elasticity (sales-weighted) according to demographic characteristics

	Rural area			Urban area		
Income/Age	18-39	40-59	≥ 60	18-39	40-59	≥ 60
0-22,000	-6.25	-5.95	-2.97	-5.31	-5.09	-1.63
	(1.917)	(0.574)	(0.265)	(0.451)	(0.368)	(0.287)
22,000-32,000	-7.8	-6.07	-3.01	-7.13	-4.99	-2.02
	(0.788)	(0.419)	(0.276)	(0.482)	(0.333)	(0.29)
$\geq$ 32,000	-7.24	-5.33	-2.1	-8.07	-4.14	-1.27
	(0.717)	(0.371)	(0.272)	(0.555)	(0.364)	(0.278)

Notes: Standard errors, in parentheses, are computed by bootstrap.

Overall, the previous results on consumers' preferences for standard attributes and price elasticities are reasonable and give credit to the model and the estimations. We now turn our attention to the estimates of the valuations of CO_2 emissions. The valuation of CO_2 emissions is negative and significant in all specifications except when CO_2 is interacted with a time trend and when we use the model without heterogeneity in preferences. We also observe a clear negative pattern on evolutions. All specifications indicate a growing importance of CO_2 emissions in purchases. From 2003-2005 to 2008, our estimates show that the average of the parameter on CO_2 emissions, which is negatively related to consumers' concerns about global warming, has decreased by around 0.28 according to Specification (4).

Moreover, while the trend is quite large (-0.058), Specification (3) indicates that there have actually been two main steps in this evolution: a first one in 2005/2006, and a second one in 2008 whereas 2007 closely resembles 2006. Specification (4), which summarizes these results, indicates that both effects have a different magnitude with an initial decrease of -0.082 in the years 2006-2007 compared to the years 2003-2005 and a second decrease of -0.202 (-0.284 + 0.082) in 2008 compared to the period 2006-2007. We chose here to place the cut at the beginning of 2006 keeping in mind that the change may have occurred slightly earlier, as Specification (3) and the aggregate time series suggest (see Columns 1 or 2 of Table 2). Aggregating 2005 with 2006-2007 would lead to very similar results as with Specification (4). Because the compulsory energy label policy was introduced by the end of 2005 and the feebate took effect at the beginning of 2008, this timing suggests that the shift in preferences is related to the policies introduced during this period. We consider hereafter Specification (4) to be the main one and rely on its estimates for the remaining part of the analysis.

4.2 Importance of preference changes

While our estimates suggest that preferences have evolved over time, we now measure the importance of the preference changes to rationalize the evolution of CO_2 emissions. For that purpose, we decompose the evolution of the average CO_2 emissions of new vehicles, using our structural model. Here we rely not only on the demand model but also on the supply side, using in particular Equation (3) to recover the marginal costs. For each counterfactual defined below, we solve for the new equilibrium, i.e. prices and market shares of each car.

We consider four main driving forces behind the evolution of average CO_2 emissions, namely the fuel price increase, the monetary effect of the feebate, the change in preferences and the effect of technological progress, i.e. the change in the characteristics of the choice set. To identify the partial effect of fuel prices, we simulate the market shares and prices that would have prevailed if fuel prices had remained at their 2003 level using our structural models of demand and supply and then compute average CO_2 emissions. In a second simulation, we compute the average CO_2 emissions without any change in consumers' preferences. Again, we allow prices to change. Third, we simulate the evolution of CO_2 emissions in 2008 without any feebate. The residual effect includes the technological progress, the change in the choice set and the corresponding reactions of consumers.

These results are summarized in Figure 4 and Table 6.[12] The shifts in preferences have the largest explanatory power and account for 40% of the decrease of average CO_2 emissions over the period. The effect of the label policy can be directly measured by the difference in CO_2 emissions in 2006 with and without the change of preferences and corresponds to 2.03 grams (13% of the total decrease). The second shift in preferences is more important than the first one, and accounts for 4.29 grams, that is to say 27% of the total decrease. The monetary effect of the feebate represents 14% of the decrease. Hence, we estimate that both monetary and non-monetary effects of the environmental policies account for more than half of the reduction of CO_2 emissions. 13% of the decrease can be attributed to the reaction to the increase of fuel prices. The residual, which represents technological progress and consumers' reaction to the changes in the choice set, is responsible for 33% of the decrease. This decrease of 5.3 grams over five years is consistent with the descriptive evidence analyzed in section 2.2. Furthermore, we observe a larger effect in 2008 than over the period 2003-2007, which is consistent with Reynaert (2014) who finds an acceleration in technological progress from 2008.

[12] See the details of the simulations in Table 23 in Appendix B.3.

Figure 4: Decomposition of average CO_2 emissions over time

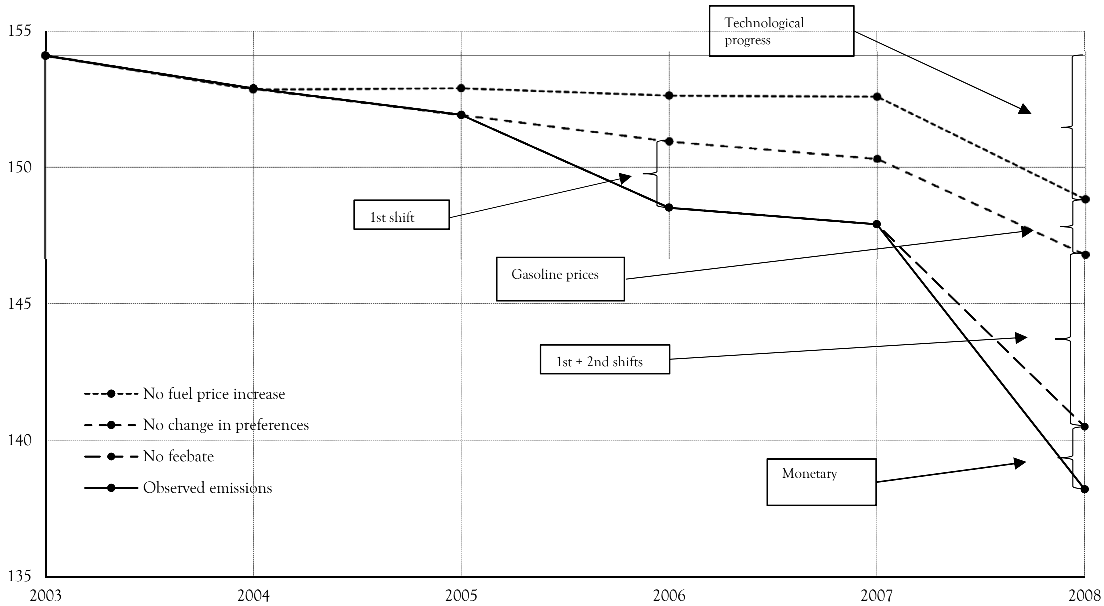


Table 6: Decomposition of the decrease in average CO_2 emissions

Changes in preferences	6.32	40 %
2006-2007	2.03	13 %
2008	4.29	27 %
Fuel price	2.02	13 %
Monetary effect of feebate	2.29	14 %
Residual	5.26	33 %
Overall decrease	15.89	

4.3 Heterogeneity of preference changes

The evolution of preferences is heterogeneous among consumers, see Table 22 in Appendix B.2 for details. The evolution in 2006-2007 is stronger for the young purchasers and decreases with age. Poor households also increased their valuation of the environment less than medium and high-income classes. In 2008, there is again a clear effect of income; richer consumers again increased their valuation of environmental quality more. In 2008, on the other hand, we observe no significant age effect. The three age classes increased their preference by almost the same magnitude (-0.21, -0.212 and -2.02 for the young, middle-age and old purchasers, respectively).

With the previous estimates in hand, we can compute the increases in willingness to pay for a 10g reduction in CO_2 emissions. Because CO_2 emissions also affect fuel costs, the willingness to pay WTP_j^d of individuals in group d purchasing product j satisfies, assuming that the $g_t^d(.)$ function in Equation (1) is linear,[13]

$$\text{WTP}_j^d = 100\frac{\beta^d q_{f(j)t}/K_{f(j)} + g_t^d}{\alpha^d}.$$

We consider hereafter the evolution ΔWTP^d of this willingness to pay, assuming that fuel prices are constant over the period. Then $\Delta\text{WTP}^d = 100\Delta g_t^d/\alpha^d$, which does not depend on the way individuals value fuel costs. The average evolution of this willingness to pay for the whole population is substantial. With Specification (4) described above, we obtain an average increase of 151 euros in 2006-2007 compared to 2003-2005, and 568 euros in 2008 (all in 2008 euros). This corresponds to an increase in the willingness to pay of approximately 1,216 euros for going from the lower threshold of class C+ (121g per kilometer) to the lower threshold of class B (101g per kilometer), an amount that is a slightly more than twice as big as the difference in the rebates between these two classes (namely, 500 euros).

Even if it is difficult to find an exact benchmark, these amounts are consistent with Brownstone et al. (2000), who study preferences for alternative-fuel vehicles using data on Californian households. They find that respondents preferred compressed natural gas and methanol to gasoline and that they were ready to pay about \$500-600 to reduce CO_2 emissions by 10%.[14] Our results are also in line with those of the MIT Survey of Public Attitudes on Energy and the Environment, which shows that almost three quarters of the respondents felt the government should do more to deal with global warming and that they were ready to pay \$7 more per month to mitigate it in 2006 compared to 2003. If we posit an annual discount rate of 10% and a replacement of new cars by consumers every 10 years, we obtain an increase in the willingness to pay of around \$600, broadly consistent with our estimates.

This overall shift in the willingness to pay, however, mixes important differences among consumers (see Table 7). We find that if some groups did not significantly modify their willingness to pay in 2006-2007, all the groups increased their willingness to pay in 2008. This increase is however very heterogeneous across demographic groups. While the willingness to pay increased in 2008 by only 91 euros for younger, lower-income people living

[13]The coefficient of 100 appears because prices are measured in thousands of euros while CO_2 emissions are measured per 100 grams and we consider a reduction of 10 grams.

[14]Few other papers have studied the automobile market but do not give precise estimates of the willingness to pay for the reduction of global warming. Potoglou & Kanaroglou (2007) analyze the factors affecting adoption of cleaner vehicles, and find that beyond price reductions, low emissions have an impact *per se*. Kishi & Satoh (2005) also explore the incentives to buy a low-CO_2-emitting car in Japan.

in rural areas, this increase reaches 1,722 euros for older, wealthier people living in urban areas. The income effect is non-ambiguous on the willingness to pay because it has both a positive impact on preferences and a negative one on price elasticity. Rich people thus have a higher willingness to pay than others and this effect is particularly important in 2008. The effect of age, on the other hand, is more complicated. Young consumers have higher preferences for environmental quality but high price sensitivities whereas old ones do not strongly care about global warming but have small price elasticities. The effect of environmental preferences is dominated by the price elasticities and young people usually have a lower willingness to pay to reduce global warming than their elders. These results are consistent with a French governmental report on environmental consciousness between 1995 and 2011.[15] This report highlights an increase in environmental concerns over the period, 46.1% of French people being sensitive to environment versus 35% in 2002. It also concludes that rich consumers are more willing to pay to fight against environmental degradation.

Table 7: Evolution of willingness to pay for a 10g reduction in CO_2 emissions

		Rural area			Urban area		
Income/ Age		18-39	40-59	≥ 60	18-39	40-59	≥ 60
0-22,000	2006-07	2 (47)	72 (38)	-121 (70)	177 (36)	58 (38)	-9 (110)
	2008	91 (140)	283 (57)	119 (63)	397 (56)	237 (52)	157 (97)
22,000-32,000	2006-07	185 (34)	141 (37)	122 (58)	197 (34)	128 (41)	221 (74)
	2008	385 (62)	522 (65)	627 (72)	477 (64)	587 (72)	899 (116)
$\geq$ 32,000	2006-07	230 (35)	196 (38)	266 (65)	231 (36)	208 (46)	452 (104)
	2008	524 (70)	679 (61)	1,077 (128)	484 (58)	737 (89)	1,722 (396)

Notes: We compute the change in the willingness to pay for a 10g reduction in CO_2 emissions between 2003-2005 and 2006-2007 or 2008 (in 2008 euros). Standard errors are computed by bootstrap.

To put the estimates of the willingness to pay for reducing car CO_2 emissions in perspective, we also compute the willingness to pay for a reduction in fuel cost through a decrease of gas prices. Specifically, we present in Table 8 the willingness to pay for a reduction in fuel prices (gasoline and diesel) of 0.10 euros. Since this willingness to pay varies with the car's fuel efficiency, we compute the average across cars purchased. We obtain an average of 738 euros, with important heterogeneity. The willingness to pay is always higher in rural

[15] See Commissariat général au développement durable: "Les perceptions sociales et pratiques environnementales des Français de 1995 à 2011", http:
www.developpement-durable.gouv.fr/IMG/pdf/Revue_CGDD_octobre_2011.pdf

areas than in urban areas, which reflects different vehicle usage, as people generally drive more in rural areas than in urban areas. The young and middle-age purchasers are willing to pay more to save on fuel costs. The elder purchasers, especially in urban areas are not very sensitive to fuel cost and are not willing to pay to reduce their driving expenses. The heterogeneity patterns in the willingness to pay for the reduction in CO_2 emissions and the reduction in fuel cost differ in some dimensions. First, the difference between urban and rural purchasers is not very significant in their willingness to pay to reduce CO_2 emissions. Furthermore, the older consumers are not willing to pay to reduce fuel costs but they are willing to pay to reduce the CO_2 emissions of their cars. To relate our estimates to the literature on the valuation of future fuel costs, 10 cents of fuel price reduction corresponds to annual savings of 62 euros for an average driving distance of 10,000 kilometers. Assuming an average lifetime of 15 years, our average willingness to pay of 738 euros implies a discount factor of 4.4%. This shows that consumers do not undervalue future fuel costs, a result in line with the findings of Grigolon et al. (2014) for the European car market.

Table 8: Willingness to pay for a reduction of 10 cents in the fuel prices.

	Rural area			Urban area		
Income/Age	18-39	40-59	≥ 60	18-39	40-59	≥ 60
0-22,000	981 (548)	1309 (86)	1057 (88)	916 (55)	923 (55)	227 (150)
22,000-32,000	933 (64)	1294 (70)	919 (94)	749 (46)	999 (62)	270 (142)
$\geq$ 32,000	811 (56)	1118 (68)	670 (117)	581 (46)	787 (81)	−602 (270)

Notes: We compute the willingness to pay for a reduction of 10 cents in the gasoline and diesel prices. Standard errors are computed by bootstrap.

To assess the credibility of our results, we also relate the willingness to pay to the general environmental preoccupation using data on electoral votes at the town level. An estimate of the average willingness to pay of the town is computed and regressed on the rate of electoral votes for different parties.[16] We use the electoral votes during the first ballot of the 2007 presidential elections, and look in particular at the relationship between the average willingness to pay and votes for the green political party.[17] The green political party prioritizes and emphasizes environmental issues while its views on economic issues are very close to the left parties. The rate of green voters is considered to be the number of

[16]The voting results were obtained through publicly available data from the French home affairs minister.

[17]French presidential elections are organized in two consecutive rounds: the two candidates with the highest number of votes after the first round run in the second round of the election. The two final candidates were Royal and Sarkozy (the latter won the elections).

votes in favor of Dominique Voynet, the candidate of the green party, divided by the total number of valid votes.[18] For the sake of clarity, we gather together here the extreme left parties (namely, Besancenot, Bové, Buffet, Laguiller and Schivardi) and the extreme right parties (Le Pen, Nihous and De Villiers), but results are similar when considering each of them separately.

It is reassuring to find a very high correlation between the votes for the green party and the willingness to pay for environmental quality. As expected, the green party voters are those who care the most about CO_2 emissions. It also does not come as a surprise that both extreme left and right voters do not pay much attention to these issues. In the middle of the political chessboard, our results are in line with the idea that rich people, who are more likely to vote for the party on the right, have a higher willingness to pay for environmental quality.

Table 9: Link between the evolution of average willingness to pay (ΔWTP) and political preferences at the town level

	ΔWTP 2006-07	ΔWTP 2008
Constant	234** (8.1)	779.3** (18.5)
Voynet (Green politics)	1083.3** (50.7)	2398.8** (116.7)
Extreme left	−400.2** (15.7)	−1019.9** (36)
Royal (left)	−229.8** (11.7)	−491** (26.8)
Sarkozy (right)	−13.6 (11.6)	2.2 (26.6)
Extreme right	−201.4** (10.9)	−632** (25.1)
Nb. observations	31,373	

Notes: We regress the change in the willingness to pay on results of the presidential elections at the municipal level.

4.4 Robustness checks and alternative explanations

4.4.1 Specification and sample selection issues

We first check the robustness of our results to different specifications and sample selections. Because the economic crisis started in the last quarter of 2008, we consider a restricted sample including only the sales of February to June. Results are displayed in Specification (6) of Table 10. Because the correlation between CO_2 emissions and the cost of driving

[18]The green party gathered 1.57% of the votes with an important variation across municipalities from 0% to 20%.

is large ($r = 0.88$), we may be worried that we actually capture, through CO_2 emissions interacted with time, the effects of the fuel cost. First, there may have also been a trend in the way individuals value the cost of driving. Second, we might partly capture a specific preference for diesel, which is popular in France, or a growing preference for diesel. Third, because we might suffer from a specification error on the cost of driving, we consider the variable kilometers per euro instead of the fuel cost. Results are displayed as Specifications (7), (8), (9) and (10) respectively. We also test the sensitivity of results to the model specification by allowing non-linear effects of fuel cost (Specification 11) and of the CO_2 emissions (Specification 12). We explore in Specifications (13) and (14) the possibility that the preferences for car characteristics change, in particular the parameters related to price (α^d and σ^d) and the preference for horsepower. We chose this latter variable because it is fairly correlated with CO_2, so once again one could worry that the estimates we find on CO_2 emissions interacted with time capture such effects.

Table 10: Model parameters under other specifications (average of parameters across groups).

	Specifications									
Variable	(4)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Price (β)	−0.057**	−0.024**	−0.048**	−0.05**	−0.05**	−0.055**	−0.06**	−0.055**	−0.025**	−0.071**
	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
$\ln(\bar{s})$ ($\bar{\sigma}$)	0.708**	0.718**	0.71**	0.707**	0.718**	0.705**	0.704**	0.702**	0.868**	0.716**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)	(0.006)
Weight	0.101**	0.069**	0.093**	0.1**	0.099**	0.154**	0.107**	0.104**	0.064**	0.112**
	(0.006)	(0.005)	(0.005)	(0.005)	(0.005)	(0.007)	(0.006)	(0.006)	(0.005)	(0.006)
Horsepower	0.105**	0.046**	0.088**	0.099**	0.097**	0.095**	0.105**	0.093**	0.056**	0.143**
	(0.008)	(0.005)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)
Station wagon body	−0.224**	−0.222**	−0.227**	−0.229**	−0.221**	−0.245**	−0.227**	−0.231**	−0.185**	−0.211**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Coupe/convertible	−0.123**	−0.196**	−0.149**	−0.151**	−0.142**	−0.169**	−0.115**	−0.126**	−0.152**	−0.075**
	(0.016)	(0.013)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)	(0.014)	(0.016)
Three-door	−0.219**	−0.191**	−0.211**	−0.214**	−0.207**	−0.2**	−0.22**	−0.215**	−0.175**	−0.223**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Fuel cost	−0.076**	−0.031**	−0.08**	−0.168**	−0.152**		−0.106**	−0.074**	−0.038**	−0.089**
	(0.005)	(0.004)	(0.004)	(0.006)	(0.006)		(0.007)	(0.005)	(0.004)	(0.005)
CO_2 emissions	−0.187**	−0.359**	−0.189**	0.182**	0.142**	−0.641**	−0.167**	−0.669**	−0.308**	−0.177**
	(0.028)	(0.025)	(0.026)	(0.029)	(0.029)	(0.021)	(0.029)	(0.042)	(0.025)	(0.028)
CO_2 × 2006-07	−0.082**	−0.072**	−0.133**	−0.048**	−0.064**	−0.118**	−0.093**	−0.063**	−0.015	−0.04**
	(0.008)	(0.007)	(0.01)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.011)	(0.01)
CO_2 × 2008	−0.284**	−0.314**	−0.386**	−0.257**	−0.282**	−0.339**	−0.293**	−0.248**	−0.21**	−0.18**
	(0.011)	(0.009)	(0.018)	(0.011)	(0.011)	(0.011)	(0.011)	(0.012)	(0.018)	(0.018)
Fuel cost × Trend			0.004**							
			(0.001)							
Diesel				−0.286**	−0.203**					
				(0.014)	(0.019)					
Diesel × Trend					−0.012**					
					(0.002)					
km/euro						0.011**				
						(0.002)				
Fuel cost^2							0.015**			
							(0.002)			
CO_2 emissions^2								0.122**		
								(0.011)		
Price × Trend									−0.001**	
									(0)	
$\ln(\bar{s})$ × Trend									−0.031**	
									(0.001)	
Horsepower × Trend										−0.003**
										(0)
No. of observations	134,532	121,626	134,532	134,532	134,532	134,532	134,532	134,532	134,532	134,532

Notes: Specification (4) is the same as in Table 4. (6): Same specification but the sample selection is different and excludes the fourth quarter. (7): Fuel cost × Trend added to the baseline specification. (8): Diesel attribute added to the baseline specification. (9): Diesel and Diesel × Trend added to the baseline specification. (10): km/euro variable instead of fuel cost. (11): Non-linear effect of fuel cost added. (12): Non-linear effect of CO_2 emissions added. (13): Price × Trend and $\ln(\bar{s})$ × Trend are added. (14): Horsepower × Trend is added. Robust standard errors computed using the delta-method. Significance levels: ** 1%, * 5%, † 10%.

First of all, our results are robust to the sample selected since the coefficients on CO_2 $\times$ period dummies do not change. We obtain a similar robustness for the specification in which CO_2 emissions are interacted with a trend. In Column (7), we observe a positive trend in the valuation of fuel cost, which means that consumers tend to care less about the cost of driving. Consequently, the change in the valuation of CO_2 emissions is reinforced under this specification. Specifications (8) and (9) show that the result on the evolution of CO_2 emissions is also robust to adding diesel as a vehicle characteristic and does not hide a growing preference for diesel. We obtain a negative coefficient on the diesel interacted with the trend, suggesting, on the contrary, a depreciation of diesel vehicles. Specification (10) indicates that using the variable km/euro instead of the cost of driving does not qualitatively change the results and slightly reinforces the changes on CO_2 emissions. Moreover, adding a square term on the fuel cost or on the valuation of CO_2 emissions does not substantially affect the results (see Specifications 11 and 12). Finally, allowing the price sensitivity and the intra-group correlation to vary over the period only changes the results on CO_2 $\times$ 2006-2007 which becomes insignificant (see Specification 13). Introducing a trend on the preference for horsepower slightly decreases the magnitude of the change in preferences for CO_2 emissions (see specification 14). We consider here price and horsepower interacted with a time trend but we obtain similar results when these variables are interacted with period dummies. Hence, overall, our results show that the evolution of the valuation of CO_2 emissions does not seem to be driven by our specific functional form. On the other hand, these results show that caution should be taken on the interpretation of the estimate of the initial valuation of CO_2 emissions.

Up to now, we have assumed that at each period, consumers value CO_2 emissions linearly. The idea behind is that consumers pay an implicit price on each ton of carbon they emit. They may however value CO_2 emissions of vehicle in a nonlinear way. We now consider another specification where consumers' true valuation of CO_2 emissions is the same within each class, but may differ arbitrarily from one class to another. Given that both the energy label and the feebate policies are based on classes of emissions, it is possible that consumers focus on such classes rather than directly on CO_2 emissions. This may be especially true after energy labels became compulsory, as the information was more easily transmitted through these labels. To assess the plausibility of this interpretation, we estimate a model similar to Specification (4) above, in which CO_2 emissions are replaced by the classes of emissions. Parameters are interpreted as the effect of belonging to a given class of emissions compared to belonging to the intermediary class D, for which the feebate was neutral.

The results, displayed in Table 11, are in line with those we found for CO_2 emissions. We observe a sharp evolution of consumers' preferences towards environmentally friendly classes during this period. The results are also consistent with the previous interpretation. The rise in the valuation of low-emitting classes (namely, A through C) contrasts with the drop in the high-emitting ones (E through F). Only class G, which represents less than 1% of total sales in 2008, has a profile that does not entirely fit with our other results, suggesting no effect of the label for this class of vehicles. The increase is especially striking in 2008 for classes A and B. Similarly, the decrease for E- and F cars is larger in 2008 than in 2006-2007. For the class E-, the shift appears to be similar in 2006-2007 and in 2008. In the end, the signals given by these policies, first with colorful labels, then with both labels and prices, seem to have been successful in shifting consumers preferences towards environmentally friendly cars and to align the preferences of the consumers with the classes promoted by the French government.

Table 11: Model with class of emissions (average of parameters across groups)

Classes with rebate ≥ 0			Classes with rebate < 0		
Class of emissions	Parameter	Std err	Class of emissions	Parameter	Std err
A ×(2006-2007)	0.025	0.046	E ×(2006-2007)	-0.026**	0.01
A ×(2008)	0.36**	0.046	E+ ×(2008)	-0.033*	0.015
B ×(2006-2007)	0.177**	0.019	E- ×(2008)	-0.103**	0.012
B ×(2008)	0.602**	0.021	F ×(2006-2007)	-0.028*	0.011
C ×(2006-2007)	0.115**	0.013	F ×(2008)	-0.209**	0.013
C+ ×(2008)	0.19**	0.018	G ×(2006-2007)	0.007	0.013
C- ×(2008)	0.173**	0.017	G ×(2008)	-0.051**	0.018

Notes: The parameters are obtained with the same model as in Column (4) of Table 4, except that we replace CO_2 by classes of emissions dummies. Robust standard errors are computed using the delta-method. Significance levels: ** 1%, * 5%, † 10%.

4.4.2 Dynamic issues

Cars are durable goods, so purchasing decisions are dynamic rather than static. We investigate here whether these dynamic aspects threaten our results. First, consumers not only choose their car, but also the moment they replace it. The introduction of the feebate may have not only modified car choices through the changes in prices, but also their replacement rate. Cars benefitting from the feebate may be replaced more often because they reach their scrapping values more quickly. Then, one possibility is that the increase of cross-sectional market shares of vehicles benefitting from the feebate, beyond standard price effects, would be due, not to changes in preferences, but simply to a quicker replacement of these models. Note that taking into account such effects is challenging because to the best of our knowledge, no information on French cars' lifetimes is available at the micro-level. We therefore have to make several assumptions to account for such effects.

Formally, we consider here that the model developed in Section 3 applies for the decision of owning product j, rather than choosing j at period t. If individuals make stable choices (e.g., long before, or after, the introduction of the feebate) and optimal lifetimes are deterministic, which they are in the simple model we consider below, we have Pr(owning j) = Pr(choosing j at period t) $\times T_j$, where T_j denotes the optimal lifetime of j. We therefore estimate the same model as Equation 2, but replacing $\ln s_{jt}$ by $\ln s_{jt} + \ln T_j$. In the absence of precise information, we suppose that without the feebate, $T_j = T(0)$ independent of j. We consider several values on $T(0)$ (12, 15 and 18 years) that are in the ballpark of the estimate of 67 quarters obtained by D'Haultfœuille et al. (2014) using the 2007 French transportation survey. To estimate the effect of the feebate on optimal lifetimes, we rely on the same simple model as D'Haultfœuille et al. (2014), which is derived from Engers et al. (2009). We suppose that each year, consumers make the decision of whether to hold the car or sell it on the second-hand market at an exogenous price. We also suppose that the current net surplus of owning a vehicle decreases at a constant rate r each year. If prices $\tilde{p}_{jk}$ perfectly adjust at equilibrium, consumers keep their cars as long as their price remain above the scrapping values, and one can show (see D'Haultfœuille et al., 2014) that optimal lifetimes with the feebate, denoted by $T_j(1)$, can be approximated by

$$T_j(1) = \frac{\ln\left[1 - \left(1 - (\rho r)^{T(0)}\right) \frac{p_j(1)}{p_j(0)}\right]}{\ln(\rho r)},$$

where ρ denotes consumers' discount factor while $p_j(1)$ (resp. $p_j(0)$) denotes the price of j in the market of new cars with the feebate (resp. without the feebate). To compute $T_j(1)$, we fix $\rho = r = 0.95$ and use for $p_j(1)$ the observed price, while the counterfactual prices $p_j(0)$ are obtained with our structural supply model.
This simple model generates substantial variation in optimal lifetime under the feebate. Under the scenario $T(0) = 15$, the average of $T_j(1)$ among cars in class B is 13.4 years, versus 16.1 years for vehicles in class E-. The results are displayed in Columns (15) - (17) of Table 12. As expected, accounting for lifetime effects decrease the changes in preferences for low-CO_2 emitting vehicles, especially when $T(0)$ is set to large values. Nonetheless, our estimates are still significant and substantial. Even in the most unfavorable case where $T(0) = 18$ years, we obtain a coefficient for $CO_2 \times 2008$ that is more than twice as large as the one for 2006-2007. This shows that our results are not driven by this issue of car replacement.

Second, we investigate whether consumers' anticipations about future gas prices could affect our results. Because gas prices were increasing over the period, it might be possible that consumers anticipate further gas price increases and substitute towards fuel efficient vehicles.[19] Although it is usually assumed, and empirically confirmed by Anderson et al.

[19] A related possibility would be that consumers anticipated rises in fuel taxes. But fuel taxes remained overall constant over the period and until 2014. If anything, they decreased rather than increased.

(2013), that consumers have rather constant anticipations, we allow for such a possibility here. Specifically, we consider that consumers use the past observations of gas prices to estimate a trend they use to forecast future prices. Formally, in year t, the anticipated gas price for year $t+k$ and type of fuel f, q^a_{ft+k}, is supposed to satisfy:

$$q^a_{ft+k} = a_{ft} + x_{ft}(t+k),$$

where a_{ft} and x_{ft} are estimated using the annual prices of the five previous years $t, t-1, ..., t-4$. We also assume that consumers discount future costs at a rate $1-\delta = 0.05$ and posit a lifetime of $T = 15$ years. Thus the average expected fuel costs fc^a_{jt} are:

$$fc^a_{jt} = fc_{jt} + \sum_{\tau=1}^{T} \delta^\tau \left(a_{f(j)} + x_{f(j)t}(\tau+5)\right) \frac{fc_{jt}}{q_{f(j)t}},$$

where $\frac{fc_{jt}}{q_{f(j)t}}$ is the fuel consumption of the car. The results are displayed in Specification (18) of Table 12. While the coefficient on CO_2 emissions is smaller than in our main specification, the estimates of the CO_2 emissions interacted with period dummies parameters are very close to those of our benchmark specification.

Finally, we examine whether anticipations on the future resell price of cars may affect our results. The idea behind is that the change in preferences for CO_2 emissions of new cars that we find may also exist on the second-hand market. If so, current or future resell values of low CO_2-emitting cars should increase. Because consumers take into account this resell value in their purchasing decisions, this could lead more consumers to buy low CO_2-emitting new cars. To informally test for such a possibility, we consider a specification in which (i) we incorporate the anticipated resell prices, (ii) such resell prices depend on the CO_2 emissions of cars. We compute the anticipated resell prices using the average price decrease observed by Esteban & Shum (2007) and assume consumers anticipate the resell price after five years with a discount factor of 5% per year.[20] To account for a change of resell value, we consider that low-CO_2-emitting car resell prices increase in 2008. Specifically, we assume that their discount rates decrease by 10 or 20 percentage points. At the end of the day, we consider Specification (4), except that prices p_{jt} are replaced by

$$\tilde{p}_{jt} = p_{jt} - \delta^5 \left(d_{g(j)t} p_{jt}\right),$$

where $d_{g(j)t}$ is the discount rate of car j after five years occurring at year t. We fix it to

[20] In their online Appendix, they provide details on prices of new cars and their resell values for three segments (compact, subcompact and middle-large) and three manufacturers (GM, Ford, Chrysler). We simply take the average over the three manufacturers. This leads us to discounts of 57.9% for the supermini segment, 61.9% for small family cars and 66.3% for other segments.

the value $\bar{d}_{g(j)}$ obtained by Esteban & Shum (2007) for t = 2003,...,2007 and $\bar{d}_{g(j)} + x$ for t = 2008, with $x = \{0.10, 0.20\}$. As a benchmark, we also consider a specification without any anticipation of change in the resell value, where $x = 0$.

The results are presented in Columns (19) - (21) of Table 12. Without any anticipation of change in the resell value ($x = 0$), the estimates of the CO_2 emissions interacted with time period dummies remain virtually unaffected. The only substantial change compared to the main specification is the increase in absolute value of the price coefficient, which could be expected given that much lower values of prices are used in this specification. In Columns (20) and (21), we obtain, as expected, a decrease in the shift in preferences for 2008. In the two corresponding specifications, it is indeed as if the rebate was much more important than its face value, because of anticipation considerations. Nonetheless, we still obtain a large effect with an increase in resell value as important as 20%. The bottom line is that anticipations on the resell values of vehicles seem unlikely to offset our findings.

Table 12: Estimation accounting for dynamic and anticipation effects

	(4)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Price (β)	−0.057**	−0.054**	−0.054**	−0.055**	−0.076**	−0.093**	−0.094**	−0.093**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.006)	(0.006)	(0.005)
ln($\bar{s}$) ($\bar{\sigma}$)	0.708 **	0.722 **	0.72 **	0.718 **	0.72 **	0.715 **	0.716 **	0.716 **
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Fuel cost	−0.076**	−0.071**	−0.072**	−0.073**	−0.069**	−0.084**	−0.084**	−0.084**
	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)	(0.004)
Weight	0.101 **	0.097 **	0.098 **	0.099 **	0.131 **	0.11 **	0.111 **	0.111 **
	(0.006)	(0.005)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
Horsepower	0.105 **	0.098 **	0.099 **	0.1 **	0.138 **	0.124 **	0.124 **	0.122 **
	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)
Station wagon	−0.224**	−0.215**	−0.217**	−0.218**	−0.21**	−0.215**	−0.216**	−0.216**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
Coupe/convertible	−0.123**	−0.121**	−0.121**	−0.122**	−0.07**	−0.094**	−0.092**	−0.092**
	(0.016)	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)
Three-door	−0.219**	−0.209**	−0.21**	−0.212**	−0.22**	−0.224**	−0.224**	−0.223**
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
CO_2 emissions	−0.187**	−0.187**	−0.187**	−0.187**	−0.088**	−0.128**	−0.116**	−0.109**
	(0.028)	(0.027)	(0.027)	(0.027)	(0.028)	(0.029)	(0.029)	(0.029)
CO_2 × 2006-07	−0.082**	−0.081**	−0.081**	−0.081**	−0.084**	−0.11**	−0.109**	−0.107**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
CO_2 × 2008	−0.284**	−0.189**	−0.207**	−0.221**	−0.274**	−0.307**	−0.254**	−0.202**
	(0.011)	(0.01)	(0.011)	(0.011)	(0.012)	(0.012)	(0.013)	(0.014)

Notes: Estimation with the market shares of cars owned instead of standard market shares, with different assumption on the lifetime of cars. Specification (4) is our main specification, Specification (15) assumes a lifetime of 18 years, Specification (16) assumes a lifetime of 15 years and Specification (17) assumes a lifetime of 12 years. The depreciation rate and the discount factor are both set to 5% per year. (18): Fuel cost is the sum of discounted future fuel costs based on consumers anticipation about gas prices. (19): Anticipated resell price is deducted from the purchase price. Resell price computed using average depreciation rate from Esteban & Shum (2007). (20): Same as (18) except that resell values increase by 10% for cars with CO_2 emissions $\leq$ 130 g/km in 2008. (21): Same as (18) except that resell values increase by 20% for cars with CO_2 emissions $\leq$ 130 g/km in 2008.

Finally, another concern is that the large drop that occurred in 2008 may have been due to temporary effects. First, consumers may have anticipated the feebate to be temporary, and thus they took advantage of the rebates quickly after the introduction. This kind of reaction would, however, be completely at odds with the government announcement. The feebate was supposed to be permanent, with only a decrease of the cutoffs by 5g every year beginning in 2010, to account for technological progress. In practice, a change in the rebate amounts did occur in 2010, from 1,000, 700 and 200 euros for classes A, B and C+ to 700, 500 and 0 euros, respectively. However, it seems unlikely that a rush in small car purchases in 2008 could be due to the anticipation of this cut in the rebates. We would rather expect such a rush to occur by the end of 2009. Second, price changes may imply a decrease in the optimal lifetime of smaller cars and an increase in the optimal lifetime of bigger ones. In this case, some individuals with small cars find it optimal to replace their cars at the beginning of the period, while individuals with bigger cars postpone their replacement (see, e.g., Adda & Cooper, 2000, for evidence of such effects). If this effect is large, the decrease in average CO_2 emissions should be quickly followed by a rise. We do not observe such a rise in 2008. On the contrary, the trend in the decrease of CO_2 emissions is significantly higher after the beginning of 2008. Similarly, the market share of class B vehicles increases more quickly after this point. Even though we do not have monthly data in 2009, Table 13 shows, using aggregate data also from the CCFA, that this evolution continues in 2009.[21] The market share of class A vehicles increased threefold between 2008 and 2009, while that of class B increased by 36%. On the contrary, the market shares of classes E+ and G decreased by about 50%. Even though other phenomena are probably in play in 2009, these evolutions suggest that the sharp changes following the introduction of the feebate are not temporary.[22]

Table 13: Change in market shares for each class of emissions after 2008

Class of emission	Market shares 2008	Market shares 2009	Evolution of shares
A	0.08%	0.29%	+259%
B	35.18%	47.8%	+35.9%
C+	9.46%	7.99%	-15.6%
C-	18.56%	17.1%	-7.8%
D	22.71%	17.94%	-21.0%
E+	2.01%	1.07%	-47,0%
E-	8.98%	5.97%	-33.6%
F	2.27%	1.51%	-33.6%
G	0.74%	0.34%	-54.5%

Sources: 2008: detailed dataset on registrations of new cars (CCFA). 2009: aggregated data on registrations of new cars (CCFA).

[21] For the sake of comparison, the 2008 figures include car fleets and some exotic cars that are otherwise excluded from our analysis.

[22] This year indeed corresponds to the peak of the economic crisis. The government also introduced a scrapping subsidy of 1,000 euros for cars more than 10 years old that were replaced by vehicles emitting less than 160g/km.

5 Conclusion

We have shown evidence that, in the French automobile market, consumers shifted their preferences for CO_2 emissions between 2003 and 2008. This shift seems to be related to two environmental policies that were implemented during this period, the obligation to display energy labels by the end of 2005 and the introduction of a feebate system in 2008. The shift is substantial, as the willingness to pay for a reduction of 10g of CO_2 emissions increased by 568 euros on average between 2003-2005 and 2008. This amount is more than the rebate offered to buy a car emitting between 121g/km and 130g/km. Without any change in preferences, we also find that the reduction of average CO_2 emissions over the period would have been 43% smaller. On the other hand, it seems difficult, given our data, to identify exactly the channel through which the policies affected consumers' preferences. Such a shift may be due to the informational value of the energy label, which would make it easier for the consumers to compare different vehicles in terms of CO_2 emissions. It is also possible that the feebate introduces a new signal to consumers about how important it is to choose low-CO_2-emitting vehicles.

Our analysis suggests that the introduction of the feebate generated crowding-in effects beyond the price effects of the policy. Such phenomena have important consequences. They can of course make the policy very effective at achieving its initial goals. This also implies that the optimal level of rebates and taxes for the different classes, in terms of social welfare, are lower than if individual's preferences are not affected by the policy. On the other hand, the analysis we conduct in the paper is not sufficient to determine precisely this optimal level. We estimate changes in consumers' preferences corresponding to the actual feebate introduced in 2008, but we remain silent on how consumers would have reacted to another feebate scheme. This would nevertheless be needed to compute the optimal level of the feebate. Note also that such crowding-in effects can come at a cost for the state. In this particular example, while the measure was designed to be neutral for the state budget, it ended up costing 285 million euros in 2008. We show in another paper (see D'Haultfœuille et al., 2011) that such a cost was difficult to anticipate. More generally, such crowding-in effects could be a challenge for computing reliable counterfactuals in ex ante analysis.

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A Details on data

A.1 Market definition

We define a market as the set of households sharing the same demographic characteristics in a given year. To exclude the effects of the anticipation of the feebate policy in December 2007 and post-anticipation effects in January 2008, we only consider, within a given year, the sales from February to November. Note that there is a trade-off in the choice of demographic groups between being realistic, which pushes for a large number of groups, and reducing statistical bias stemming from observed market shares equal to zero. When the number of groups is large, many observed market shares are equal to zero. To avoid the selection bias resulting from the exclusion of the zero market share products from the choice set, we use the following corrected market shares which minimizes the bias:[23]:

$$\tilde{s}_j^d = \frac{n_j^d + 0.5}{M^d}$$

where n_j^d is the sales of product j for the demographic group d and M^d the number of potential buyers in group d. This correction is very similar to the one suggested by Gandhi et al. (2013).

This is why we choose a moderate number of groups, namely 18, corresponding to three age classes (18-39, 40-59 and 60 and more), two geographical areas (cities of less than 20,000 inhabitants, called rural areas, and larger cities, called urban areas) and three income classes (0-22,000 euros, 22,000-32,000 euros and more than 32,000 euros). The value of 22,000 euros corresponds to the fiscal income of a two-person household paid at the minimum wage. The purchaser's income is not observed directly in our dataset, and we approximate it using the median income of his age class in his town, using publicly available data from the National Institute of Statistics and Economic Analysis (INSEE). When age is missing or the area of residence too small, the median income of the whole population is attributed since the median income by age class is only available for cities of more than 10,000 inhabitants.

[23]See D'Haultfœuille et al. (2015) for more detail on this correction.

Table 14: Frequency of demographic characteristics among the population

Demographics	Frequency
Rural area	41.7%
Urban area	58.3%
Age $\in$ 18-39	25.8%
Age $\in$ 40-59	40.4%
Age $\in$ 60-100	33.9%
Income $<$ 22,000	21.5%
Income $\in$ 22,000-32,000	50.8%
Income $>$ 32,000	27.8%

The computation of market shares s_j^d involves computing the market potential, i.e, the number of households sharing characteristics d. We assume that the market potential is one fourth of the total number of households, or equivalently that every four years, a household has to decide whether or not to buy a new car. Of course, the major part of consumers decides not to buy a new car and prefer to hold their old car. Since we only observe the quartiles of the income distribution that do not necessary correspond to our threshold values of 22,000 and 32,000 euros we have to estimate the fraction of households in each income class. Similarly to Berry et al. (1995), we suppose that the income distribution is log-normal within each group d. We then estimate the parameters of this log-normal distribution using the quantiles of the income distribution by age and type of residence area stemming from INSEE data. Finally, using the log-normal form, the probability of belonging to each income class is estimated in order to recover the number of households. The share of the outside option is variable across demographic groups and years (see Table 15), reflecting heterogeneity in consumers' preferences across our demographic groups.

Table 15: Share of the outside good in 2003, 2007 and 2008 according to the group of consumers

		Rural area			Urban area		
Income/Age	Year	18-39	40-59	$\geq$ 60	18-39	40-59	$\geq$ 60
0-22,000	2003	90.5%	88.8%	92.5%	89.0%	96.6%	91.7%
	2007	95.4%	95.0%	95.8%	92.9%	98.1%	96.3%
	2008	95.6%	95.8%	96.5%	92.7%	98.4%	97.1%
22,000-32 000	2003	70.9%	69.2%	72.3%	79.1%	59.8%	74.4%
	2007	75.8%	73.5%	69.1%	80.8%	69.7%	69.3%
	2008	74.9%	73.7%	68.7%	79.4%	70.6%	69.2%
$\geq$ 32,000	2003	92.0%	94.0%	92.4%	92.4%	88.9%	93.4%
	2007	90.7%	92.5%	89.1%	92.7%	89.3%	90.8%
	2008	89.1%	91.5%	87.3%	92.1%	88.7%	90.0%

A.2 Segmentation of the automobile market

The nested logit approach requires the definition of a segmentation of the market in homogenous groups of products. Our segmentation, based on the main use of the vehicle, is close to that of The European New Car Assessment Program (Euro NCAP). Table 16 displays the eight segments we consider and their market shares in 2007 and 2008. Note that small multi-purpose vehicles (MPV) include small vans such as the *Renault Kangoo*. The entire classification is presented in Table 17.

Table 16: Frequency of purchase per segment in 2007 and 2008

	2007		2008	
	Number	Freq.	Number	Freq.
Urban	330,607	47.2%	404,122	55.3%
Small Family	122,771	17.5%	124,190	17.0%
Large Family	57,877	8.3%	52,042	7.1%
Executive	9,213	1.3%	5,678	0.78%
Sports	3,590	0.5%	2,043	0.28%
Small MPV	130,833	18.7%	114,008	15.6%
Large MPV	6,393	0.9%	3,216	0.44%
Allroad/SUV	38,539	5.5%	26,054	3.6%

Table 17: Segmentation of the automobile market

Manufacturer	**Brand**	Supermini	Small family	Large family	Executive	Sports car	Small MPV	Large MPV	Allroad/SUV
PSA	*Citroen*	C1, C2, C3, Saxo	Xsara	C5	C6	-	Berlingo, C4, Nemo, Xsara	C8	C-Crosser
	Peugeot	106, 107,1007,206, 207	306, 307, 308	406, 407	607	-	Bipper, Partner	807	4007
Renault	*Renault*	Clio, Modus, Twingo	Megane	Laguna	Vel Satis	-	Kangoo, Megane	Espace	Koleos
	Dacia	Sandero	Logan	-	-	-	-	-	-
B.M.W	*B.M.W*	-	1-Series	3-Series	5, 6, 7-Series	Z4	-	-	X3, X5, X6
	Mini	Mini	-	-	-	-	-	-	-
Chrysler	*Chrysler*	-	-	Sebring	300C, 300M, Crossfire	-	PT Cruiser	Voyager, G.Voyager	-
	Jeep	-	-	-	-	-	-	-	Compass, Cherokee, Commander, G.Cherokee, Wrangler
	Dodge	-	Caliber	Journey	Viper	-	-	-	Durango, Nitro
Daihatsu	*Daihatsu*	Cuore, Sirion, YRV	-	-	-	Copen	-	-	Terios
Daimler	*Mercedes*	-	A-Class	C, CLK-Class	E, CL, R, S, SL, CLS, SLR-Class	SLK-Class	B-Class, Vaneo	Viano	G, GL, GLK, ML-Class
	Smart	Fortwo, Forfour	-	-	-	Coupe, Roadster	-	-	-
Fiat	*Alfa Romeo*	Mito	147	156, 159, GT	166, Brera	GTV, Spider	-	-	-
	Fiat	500, Palio, Panda, Punto, Seicento	Bravo, Stilo	Croma	-	Barchetta	Doblo, Fiorino, Idea, Multipla	Ulysse	Sedici
	Lancia	Y	-	Lybra	Thesis	-	Musa	Phedra	-
Ford	*Ford*	Fiesta, Ka,	-	Mondeo	-	Puma	Focus, Fusion, T.Connect, Tourneo	Galaxy, S-Max	Kuga
	Jaguar	-	-	X-Type	S-Type, XJ, XK	-	-	-	-
	Land Rover	-	-	-	-	-	-	-	Freelander, Defender, Discovery, R.Rover
	Volvo	-	C30, V50	C70, S40, S60, V70	V40, S80	-	-	-	XC60, XC70, XC90
GM Europe	*Chevrolet/ Daewoo*	Kalos, Matiz	Aveo, Lacetti, Lanos, Nubira	Epica, Evanda	-	Corvette	Rezzo, Tacuma	-	Captiva, Tahoe, Korando, Rexton
	Opel	Corsa	Astra	Insignia, Signum, Vectra	Omega	Tigra, Speedster	Agila, Combo, Meriva, Zafira	-	Antara, Frontera
	Saab	-	-	9-3	9-5	-	-	-	-
Honda	*Honda*	Jazz	Civic	Accord	-	S2000	FR-V, Stream	-	CR-V, HR-V
Hyundai	*Hyundai*	Atos, Getz, I10	Accent, Coupe, I30	Elantra, Sonata	-	-	Matrix	Trajet	Tucson, Santafe, Terracan
	Kia	Picanto, Rio	Cee-d, Cerato	Magentis	-	-	Carens, Soul	Carnival	Sorento, Sportage
Lada	*Lada*	-	111, 112	-	-	-	-	-	Niva
Mazda	*Mazda*	2	3	6	RX8	MX5	5, Premacy	MPV	-
Mitsubishi	*Mitsubishi*	Colt	Lancer	Carisma	-	-	Spacestar	Grandis	Outlander, Pajero
Nissan	*Nissan*	Micra, Note	Almera, Qashqai	Primera	350Z, Maxima-Q	-	Almera	-	X-Trail, Murano, Pathfinder, Patrol, Terrano
Porsche	*Porsche*	-	-	-	911, Boxter, Cayman	-	-	-	Cayenne
Rover	*Rover*	25, Streetwise	45	75	-	-	-	-	-
Ssangyong	*Ssangyong*	-	-	-	-	-	-	Rodius, Stavic	Actyon, Korando, Kyron, Rexton
Subaru	*Subaru*	Justy	Impreza	Legacy	-	-	-	-	Forester, B9Tribeca
Suzuki	*Suzuki*	Alto, Ignis, Splash, Swift, SX4	Liana	-	-	-	Wagon-R	-	G. Vitara, Jimny, Samurai, Vitara
Toyota	*Toyota*	Aygo, IQ, Yaris	Auris	Avensis, Prius	-	Celica, MR	Corolla	Previa	RAV4, L.Cruiser
	Lexus	-	-	IS	GS, LS	-	-	-	RX
VW Group	*Audi*	A2	A3	A4, A5	A6, A8, R8	S3, S4, S6, S8 TT	-	-	Allroad, Q5, Q7
	Seat	Arosa, Ibiza	Cordoba, Leon	Toledo	-	-	Altea	Alhambra	-
	Skoda	Fabia	-	Octavia, Superb	-	-	Roomster	-	-
	Volkswagen	Fox, Lupo, Polo	Eos, Golf, Jetta, Newbeetle	Scirocco, Passat	-	Phaeton	Caddy, Touran	Sharan	Tiguan, Touareg

A.3 Definition of the products

Using the common practice in this literature, we define a product by a set of characteristics. In choosing this set of characteristics, we face a similar trade-off as previously mentioned. A rather large set is necessary to avoid aggregating products that are too dissimilar, but defining products too precisely increases the number of zero market shares, raising the sample selection issue mentioned above. We define a product by its brand, model, body style, type of fuel, CO_2 emissions class and number of doors. To keep the number of zeros moderate, we exclude price, horsepower, fuel consumption, weight and exact CO_2 emissions from this definition. On the other hand, we can still introduce these characteristics into the utility functions by considering their value for the most frequently purchased version of the product (in case of multiple versions with the same frequency of purchase, we select the cheapest one). Table 18 represents the number of products and the number of zeros obtained with our product definition. The number of products increases over time, reflecting the differentiation strategy of manufacturers. As a consequence, the average number of null market shares also increases across time. A maximum of 749 zeros is observed in 2008 for young purchasers who have low incomes and live in rural areas.

Table 18: Number of products and number of zeros per market

	2003	2004	2005	2006	2007	2008
Number of products	1082	1160	1215	1263	1325	1429
Number of zeros						
Mean	289	314	319	372	393	464
Minimum	130	156	148	188	193	215
Maximum	451	452	498	569	642	749

B Additional results and checks

B.1 Alternative definition of the products

We check in this subsection that our results are robust to the definition of products we use. Recall that we define a product by its brand, model name, body style, type of fuel and CO_2 emissions class. One concern with this definition is that we may wrongly define two distinct products for the same one, in case the CO_2 emissions slightly evolve over time in a way that the CO_2 emissions class switches. This should not be too much a concern here, given that we do not impose in the estimation of the model any intertemporal restrictions on ξ_{jt}^d. Still, we test that our results are robust to the segmentation of CO_2 emissions we use. We consider alternative classes of CO_2 emissions defined as 2 grams below the real classes and 2 grams above the real classes. The results, displayed in Table 19, are very close to those we obtain with our initial definition.

Table 19: Robustness of the main specification with respect to the definition of classes of CO_2 emissions

	(1)	(2)	(3)
Price (β)	-0.057^{**}	-0.063^{**}	-0.072^{**}
	(0.004)	(0.004)	(0.004)
$\ln(\bar{s})$ ($\bar{\sigma}$)	0.708^{**}	0.733^{**}	0.72^{**}
	(0.006)	(0.006)	(0.006)
Fuel cost	-0.076^{**}	-0.083^{**}	-0.086^{**}
	(0.005)	(0.005)	(0.005)
Weight	0.101^{**}	0.103^{**}	0.11^{**}
	(0.006)	(0.006)	(0.006)
Horsepower	0.105^{**}	0.114^{**}	0.13^{**}
	(0.008)	(0.007)	(0.008)
Station wagon car-body	-0.224^{**}	-0.195^{**}	-0.205^{**}
	(0.007)	(0.007)	(0.007)
Coupe/convertible	-0.123^{**}	-0.058^{**}	-0.057^{**}
	(0.016)	(0.015)	(0.016)
Three-door	-0.219^{**}	-0.212^{**}	-0.22^{**}
	(0.006)	(0.006)	(0.006)
CO_2 emissions	-0.187^{**}	-0.109^{**}	-0.156^{**}
	(0.028)	(0.027)	(0.029)
CO_2 emissions×(2006-2007)	-0.082^{**}	-0.076^{**}	-0.093^{**}
	(0.008)	(0.008)	(0.008)
CO_2 emissions×2008	-0.284^{**}	-0.287^{**}	-0.278^{**}
	(0.011)	(0.011)	(0.012)

Column (1) corresponds to the main definition, Column (2) uses the hypothetical classes of CO_2 emissions moving the thresholds downwards by 2 grams and Column (3) hypothetical classes of CO_2 emissions moving the thresholds upwards by 2 grams.

Second, we may wonder to what extent our results are sensitive to the choice we have to make regarding the value of other characteristics (price, horsepower, weight, fuel cost and CO_2 emissions) that are not included in the definition of the products. Recall that when these characteristics vary, we use those of the most frequently purchased version. First, we note that our definition of products is actually very precise. On average, we only have two different levels of CO_2 emissions within a given product. Furthermore, the intra-products variance of CO_2 emissions is only 1.23% of the total variance of CO_2 emissions in 2007 and 1% in 2008, which corresponds to 0.3 gram per kilometer.

Nevertheless, we consider alternative ways to fix the other characteristics, and in particular CO_2 emissions. First, instead of considering the most frequently purchased version, we use the versions of the product for which the CO_2 emissions lie at the first, second or third quartile of the distribution (within each product). Second, we consider the characteristics of the most frequently purchased version, as we do in the rest of the paper, except for the

CO_2 emissions, which are fixed once more at either the first, second or third quartile of the within distribution. Once again, the results are very similar to those of our benchmark specification (see Table 20).

Table 20: Robustness of the main specification to alternative product definitions

		Change in all characteristics			Change in CO_2 emissions only		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Price ($\bar{\beta}$)	−0.057** (0.004)	−0.101** (0.005)	−0.115** (0.006)	−0.077** (0.005)	−0.061** (0.004)	−0.055** (0.004)	−0.048** (0.004)
ln($\bar{s}$) ($\bar{\sigma}$)	0.708 ** (0.006)	0.721 ** (0.006)	0.718 ** (0.007)	0.713 ** (0.006)	0.709 ** (0.006)	0.708 ** (0.006)	0.708 ** (0.006)
Fuel cost	−0.076** (0.005)	−0.095** (0.005)	−0.12** (0.006)	−0.107** (0.006)	−0.034** (0.004)	−0.069** (0.004)	−0.102** (0.004)
Weight	0.101 ** (0.006)	0.157 ** (0.008)	0.161 ** (0.008)	0.101 ** (0.006)	0.142 ** (0.006)	0.102 ** (0.006)	0.063 ** (0.006)
Horsepower	0.105 ** (0.008)	0.168 ** (0.009)	0.199 ** (0.011)	0.14 ** (0.01)	0.113 ** (0.008)	0.099 ** (0.008)	0.084 ** (0.008)
Station wagon	−0.224** (0.007)	−0.185** (0.008)	−0.189** (0.008)	−0.214** (0.008)	−0.232** (0.007)	−0.227** (0.007)	−0.22** (0.007)
Coupe/convertible	−0.123** (0.016)	0.023 (0.019)	0.067 ** (0.021)	−0.06** (0.02)	−0.129** (0.015)	−0.13** (0.015)	−0.131** (0.015)
Three-door	−0.219** (0.006)	−0.219** (0.006)	−0.234** (0.007)	−0.226** (0.007)	−0.209** (0.006)	−0.217** (0.006)	−0.221** (0.006)
CO_2 emissions	−0.187** (0.028)	−0.136** (0.033)	0.065 * (0.032)	0.118 ** (0.031)	−0.632** (0.025)	−0.238** (0.02)	0.122 ** (0.015)
CO_2 × (2006-07)	−0.082** (0.008)	−0.15** (0.01)	−0.188** (0.012)	−0.126** (0.01)	−0.125** (0.008)	−0.09** (0.008)	−0.054** (0.008)
CO_2 × 2008	−0.284** (0.011)	−0.277** (0.014)	−0.306** (0.013)	−0.312** (0.012)	−0.331** (0.011)	−0.3 ** (0.011)	−0.26** (0.01)

Column (1) corresponds to our imputation, Columns (2)-(4) consider different product imputation schemes and Columns (5)-(7) keep the same car characteristics but impute different levels of CO_2 emissions. Specifically, in Column (2) we use the version located at the first quartile of the CO_2 emissions distribution, in Column (3) we use the median version and in Column (4) we use the third quartile version. In Column (5), we impute the second quartile level of CO_2 emissions, in Column (6), the median level of CO_2 emissions and in Column (7) we impute the third quartile.

B.2 Further results on the nested logit model

We first present the estimates of the parameters affecting price elasticities, that is to say the price sensitivities α^d and the intra-group correlations σ^d. Economic theory and the nested logit model imply that $\alpha^d < 0$ and $\sigma^d \in [0, 1]$. These restrictions are not imposed in the estimation and can therefore be used to test the model. As Table 21 shows, the 36 corresponding estimates satisfy these constraints, so that we do not reject the model on this basis.

Table 21: Price parameters for each demographic group.

		Rural area			Urban area		
Income/Age		18-39	40-59	≥ 60	18-39	40-59	≥ 60
0-22,000	α^d	-0.085	-0.063	-0.051	-0.088	-0.056	-0.035
		(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.005)
	σ^d	0.73	0.773	0.655	0.686	0.77	0.58
		(0.009)	(0.008)	(0.008)	(0.011)	(0.009)	(0.009)
22,000-32,000	α^d	-0.1	-0.065	-0.053	-0.085	-0.057	-0.041
		(0.005)	(0.004)	(0.005)	(0.005)	(0.004)	(0.005)
	σ^d	0.74	0.77	0.644	0.759	0.763	0.597
		(0.01)	(0.008)	(0.008)	(0.01)	(0.008)	(0.009)
$\geq$ 32,000	α^d	-0.082	-0.056	-0.036	-0.075	-0.044	-0.024
		(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.005)
	σ^d	0.765	0.771	0.635	0.803	0.768	0.597
		(0.009)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)

Table 22 shows the average valuations for vehicle attributes with respect to demographic characteristics associated to Specification (4) of Table 4. We observe a substantial heterogeneity across the groups of households we consider. Horsepower is more valued by younger consumers and seems to be less important for older purchasers. Station wagons are more popular among the medium age households and in rural areas. It is indeed more inconvenient to have a larger vehicle in large cities. Older people value less weight and station wagons. Because they live on average in smaller households, this probably reflects that they do not value size as much as other groups (these two attributes being very good proxies for size). They also value less convertibles than standard car-body style vehicles and three-door vehicles than four or five doors vehicles, probably because they care more about comfort. The heterogeneity along the income is less pronounced but it can be noted that rich people value horsepower, convertibles and three-door vehicles slightly less highly than other consumers.

Table 22: Average parameters for each demographic characteristic, from Specification (4)

	Type of town		Age			Income		
	Rural	Urban	[18;39]	[40;59]	≥ 60	Low	Medium	High
Price	−0.062** (0.004)	−0.054** (0.004)	−0.084** (0.004)	−0.054** (0.004)	−0.039** (0.004)	−0.061** (0.004)	−0.064** (0.004)	−0.05** (0.004)
$\ln(\bar{s})$	0.718** (0.006)	0.701** (0.006)	0.743** (0.007)	0.769** (0.007)	0.616** (0.006)	0.687** (0.006)	0.707** (0.006)	0.729** (0.007)
Fuel cost	−0.103** (0.005)	−0.057** (0.005)	−0.116** (0.005)	−0.089** (0.005)	−0.032** (0.005)	−0.09** (0.005)	−0.091** (0.005)	−0.056** (0.005)
Weight	0.113** (0.006)	0.093** (0.006)	0.109** (0.006)	0.107** (0.006)	0.089** (0.006)	0.084** (0.006)	0.115** (0.006)	0.11** (0.006)
Horsepower	0.113** (0.008)	0.099** (0.008)	0.189** (0.008)	0.091** (0.008)	0.056** (0.008)	0.118** (0.008)	0.121** (0.008)	0.084** (0.008)
Station-wagon	−0.185** (0.008)	−0.252** (0.008)	−0.185** (0.009)	−0.165** (0.008)	−0.318** (0.009)	−0.233** (0.009)	−0.225** (0.009)	−0.215** (0.008)
Convertible	−0.116** (0.016)	−0.129** (0.017)	0.148** (0.018)	−0.065** (0.016)	−0.392** (0.019)	−0.109** (0.018)	−0.112** (0.018)	−0.142** (0.017)
Three doors	−0.223** (0.007)	−0.215** (0.008)	−0.077** (0.008)	−0.168** (0.007)	−0.381** (0.01)	−0.193** (0.009)	−0.23** (0.009)	−0.237** (0.008)
CO_2 emissions	−0.014 (0.03)	−0.311** (0.033)	−0.202** (0.037)	0.071* (0.031)	−0.456** (0.037)	−0.196** (0.035)	−0.2** (0.035)	−0.172** (0.034)
$CO_2 \times$ 2006-07	−0.067** (0.01)	−0.094** (0.011)	−0.148** (0.014)	−0.078** (0.01)	−0.037** (0.014)	−0.03* (0.013)	−0.106** (0.013)	−0.12** (0.011)
$CO_2 \times$ 2008	−0.273** (0.014)	−0.292** (0.015)	−0.338** (0.021)	−0.289** (0.015)	−0.239** (0.018)	−0.147** (0.018)	−0.359** (0.018)	−0.376** (0.017)

Notes: the parameters correspond to the average among consumers with the corresponding demographic characteristics. Robust standard-errors are computed using the delta-method.

Environmental preferences are heterogeneous, as Table 22 shows. Preference for environmentally friendly vehicles is higher for young and old purchasers while income does not have a large effect. Environmental quality is clearly valued more highly in urban areas than in rural areas (where the estimated parameter of CO_2 emissions is not significant). This might reflect the fact that in urban areas, households are more exposed to pollution and care more about their car's CO_2 emissions.

B.3 Detail of simulated average CO_2 emissions

Table 23 displays the evolution of average CO_2 emissions under our three counterfactuals.

Table 23: Detail of simulations of CO_2 emissions

Year	Observed	No fuel price increase	No change in preferences	No feebate
2003	154.1	154.1	154.1	154.1
2004	152.9	152.86 (0.093)	152.89	152.9
2005	151.93	152.9 (0.065)	151.93	151.93
2006	148.53	150.2 (0.06)	150.96 (0.213)	148.53
2007	147.92	150.19 (0.072)	150.33 (0.21)	147.92
2008	138.2	140.22 (0.061)	144.53 (0.296)	140.5 (0.137)

Note: Bootstrap standard-errors in parentheses.