The Informational Effect of Public Policies on consumers' preferences: Lessons from the French Automobile Market*

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January 17, 2014

Abstract

In this paper, we investigate whether French consumers have modified their preferences towards environmentally-friendly vehicles between 2003 and 2008. We estimate a model of demand for automobiles incorporating both consumers' heterogeneity and CO_2 emissions of the vehicles. Our results show that there has been a shift in preferences towards low-emitting cars, with an average increase of 367 euros of the willingness to pay for a reduction of 10 grams of carbon dioxide per kilometer. We also stress a large heterogeneity in the evolution of preferences between consumers. Rich and young people are more sensitive to environmental issues, and our results are in line with votes for the green party at the presidential elections. We relate these changes with the informational content of two environmental policies that were introduced at these times, namely the obligation of indicating energy labels by the end of 2005 and a feebate based on CO_2 emissions of new vehicles in 2008. Our results suggest that in addition to incentive effects, both policies have been efficient tools to inform consumers and shift consumers' utility towards environmentally-friendly goods. Finally, we find that this informational effect is non-negligible and account for 20% of the overall decrease in average CO_2 emissions of new cars on the period.

Keywords: environmental policy, consumers' preferences, CO_2 emissions, automobiles.

JEL codes: D12, H23, L62, Q51.

*We would like to thank Pierre-Louis Debar and Julien Mollet from the CCFA for providing us with the data. We also thank Sylvain Chabé-Ferret, Pierre Dubois, Philippe Gagnepain, Christian Huse, Iris Kesternich, Joshua Linn, Laurent Linnemer, Frank Verboven, Philipp Schmidt-Dengler, Katheline Schubert and participants of the various seminars and conferences for their remarks. Isis Durrmeyer acknowledges financial support from the Deutsche Forschungsgemeinschaft through SFB-TR 15.

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1 Introduction

In this paper, we study how people reacted to two French environmental policies that aim at mitigating automobiles carbon dioxide (CO_2) emissions. The first is the implementation, at the end of 2005, of a European directive compelling manufacturers to indicate CO_2 emissions for every car. The second is the introduction, in January 2008, of a green taxation called the "bonus/malus" system (referred to as feebate hereafter), which provides a financial reward for low CO_2 emitting vehicles (less than 130 grams per kilometer) and a penalty for the most polluting ones (more than 160 grams per kilometer).

More precisely, we investigate whether French consumers have modified their preferences towards environmentally-friendly vehicles between 2003 and 2008. The first reason for this interest is an environmental concern. In the last two decades, environment, and in particular global warming, has become a major issue. Policy initiatives are launched in many countries to reduce the human contribution to greenhouse gas emissions, especially CO_2. Cutting vehicle emissions is a crucial objective, as the transportation sector accounts for a third of the CO_2 emissions in developed countries. In April 2010, 17 European countries have implemented a taxation related to the average CO_2 emissions of the vehicles.[1] The California Clean Cars Law, introduced by the State of California and followed by 13 other States, is another example. This program has the ambition to reduce overall greenhouse gas emissions from passenger cars by 18% in 2020 and 27% in 2030.

However, it is unclear how this growing concern for global warming at the society level translates at the individual one, both in terms of utilities and choices. First, global warming is a very slow phenomenon that will impact consumers in the long run only. Second, it is somehow immaterial and individuals may not know exactly what is their true individual impact on it. Finally, even if it enters in the utility function of the consumers, environment is a public good with a very large number of individuals contributing to it. Because of this classic free riding problem, people may not modify their choices, even if global warming and environmental issues are more and more discussed. At the end, we may thus wonder if the evolutions observed at an aggregate level correspond to better information and a true change in preferences, or just standard reactions to supply shocks stemming from environmentally-friendly technical changes and to new incentives created by public policies.

The second reason to investigate the effect of these policies is related to the more general issue of how consumers react to public policies. Beyond incentive effects, public policies may affect social preferences, which in turn modify 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 recent survey). Public policies may also modify the information set of bounded rational consumers, which, in turn, may affect their choices. One goal of the paper is thus to investigate whether

[1] For recent analyzes of the environmental effect of such policies, see for instance D'Haultfoeuille et al. (2013) and Huse & Lucinda (2013).

such effects are at stake here, and, if so, to assess their importance with respect to more standard price and supply-side effects.

To answer these questions, 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 individual characteristics of the purchasers. 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, it is instructive to see whether environmental concerns matter in carefully thought purchases that represent a large share of consumers' budget. 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. We also study whether this evolution is heterogeneous among consumers. We estimate a nested logit incorporating observed heterogeneity through 18 demographic groups of consumers based on age, income and urban area.

Our findings are the following. We observe that the introduction of both policies coincides with a significant decrease of respectively 1.8 and 7.3 grams in the average CO_2 emissions of new vehicles, the average CO_2 emissions being around 155 grams per kilometer in 2003. An analysis of the market shares of each class of energy confirms these results. The market share of cars emitting between 100 and 120 grams of CO_2 per kilometer (class B), for instance, increased from 19.9% in 2007 to 38.4% in 2008, following the introduction of the feebate. Conversely, the market share of cars emitting between 160 and 200 grams of CO_2 per kilometer (class E) has sharply decreased from 18.0% to 9.9%. Disentangling between pure price effects of the feebate, changes in preferences of the consumers and other effects,[2] we find a coincidence between the evolution of the consumers' utility and the timing of the implementation of both policies. Our results thus suggest that environmental policies have been efficient tools to shift consumers' utility towards environmental friendly goods. We obtain that between 2003 and 2008, CO_2 emissions have been reduced by more than 10%. 20% of this decrease are related to the evolution of consumers' preferences, 51% stem from the price effect of the feebate while 29% account for supply-side and other effects.

We thus find evidence that consumers value environment and the reduction of global warming, and that their valuations has increased over time. This is true for all the consumers we are considering, though we find a substantial heterogeneity in this evolution. It differs in particular along age and income, the youngest and the richest being those who value the most the environment. Between 2003 and 2008, young consumers increased their valuation of the reduction of global warming twice more than old ones, while rich consumers increased their valuation around 1.5 times more than poor ones. In line with this interpretation, we observe a positive correlation between the average evolution of the willingness

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

to pay at thex town level and the result of the green party candidate at the 2007 presidential election. 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 raised on average by 367 euros in 2008 compared to 2003-2006. These results are consistent with Brownstone et al. (2000) and the results of the MIT Survey of Public Attitudes on Energy and the Environment.

The paper is organized as follows. Section 2 presents the environmental policies , the evolution of average CO_2 emissions on the period and potential explanations for this evolution. Section 3 presents the demand model and the results. Section 4 concludes.

2 Environmental policies and evolution of CO_2 emissions

2.1 Energy labels and the feebate system

By the end of 2005, the European Commission compels manufacturers to place an energy label on each new car. The French decree applying this European directive was published in November 2005 and manufacturers were given six month, 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 fuel consumption (in liter 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 are aware of the impact of each car on global warming. They may thus take it into account in their purchase decision, whereas it was more difficult to do so before the policy. 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 them what a "good" purchase for environment is.

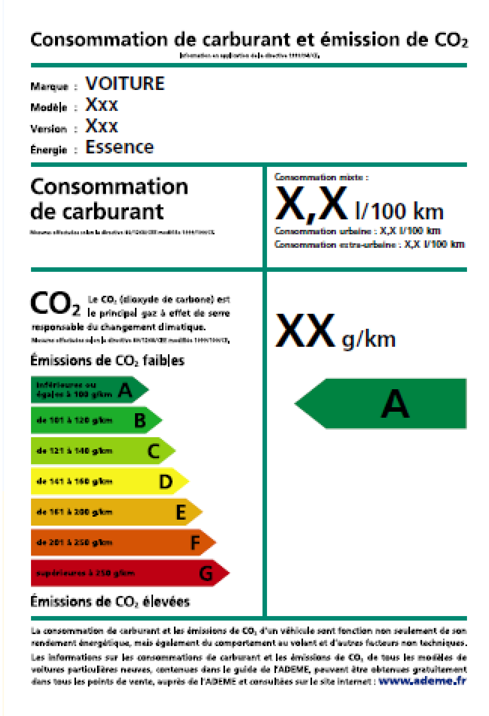


Figure 1: A model of French energy label.

The second institutional change is the introduction, in January 2008, of a green taxation called the "bonus/malus" system, referred to as feebate hereafter. This new policy was announced on October 25, 2007. It was one of the main measures of an environmental roundtable called the "Grenelle de l'environnement" that took place in France in 2007. Its purpose, among others, was to lower average CO_2 emissions stemming from cars from 176g to 130g of CO_2 per kilometer in 2020, and the feebate was chosen as an incentive to purchase environmentally-friendly new vehicles.

To this end, a financial rebate, from 200 and 1,000 euros, was given to consumers who buy low CO_2 emissions 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 class of emissions the vehicle belongs to and 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.[3] This feebate is received or paid once, at the time of the sale of the vehicle. It applies to all new cars, including those

[3] We do not indicate in this table the class of emissions A+, which corresponds to emissions lower than 60g per kilometer. A rebate of 5000€ was associated to this class, but in 2008 no vehicle belonging to this class was sold in France. Note also that for the replacement of more than 15-year old vehicles by new vehicles, the rebates were increased by an amount 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 purchaser received this extra rebate.

purchased abroad. On the other hand, second-hand vehicles were not in the scope of the policy.

Class of emissions	Emissions (in g/km)	Feebate	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%

Table 1: Details of the feebate

Contrary to the first policy, which only aims at modifying the information given to the 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 decomposing finely the effects, we provide a broad picture on 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.[4] Figure 2 displays the evolution of average CO_2 emissions of cars purchased on that period. Overall, there was an important reduction of 13% (from 156 to 136 grams per kilometer) on average CO_2 emissions of new cars between January 2003 and January 2009. This reduction can be decomposed in three parts. Between January 2003 and October 2005, before the introduction of the compulsory energy label policy, average CO_2 emissions dropped from 156g to 152g. This negative trend indicates that there was already, before the policies, a tendency to reduce CO_2 emissions. Between the two policies, from November 2005 to October 2007, the decrease was slightly more important, the CO_2 emissions falling from 152 to 147. This is reinforced by the fact

[4] 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.

that this decrease took place in a shorter period of time (24 months instead of 34). We finally observe a large drop after the introduction of the feebate. In February 2008, CO_2 emissions were equal to 138 grams and reached 136 grams in December 2008. The feebate policy seems thus to have had 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 by the end of October 2007, so that some households who planned to buy a high CO_2 emitting vehicle were able to anticipate their purchase in order to avoid the penalty.

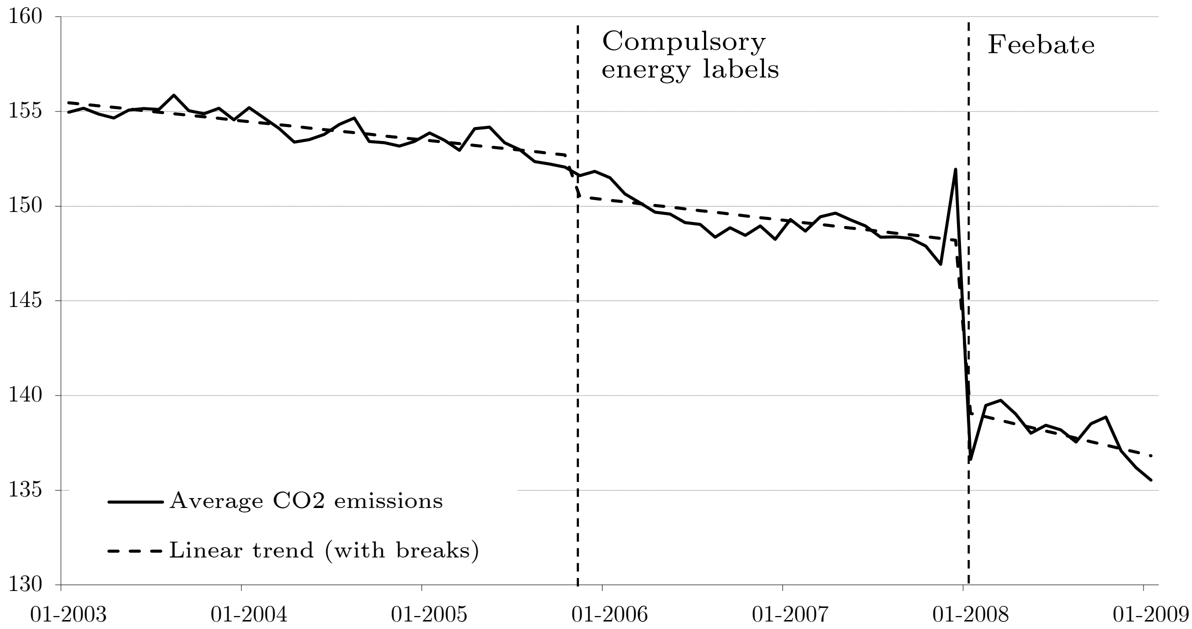


Figure 2: Seasonally adjusted monthly average CO_2 emissions of new cars.

To further analyze these patterns and measure the impact of the introduction of both policies, we regress the CO_2 emissions on three trends (corresponding to the three periods previously described) and on two dummies indicating if each policy was active or not at this time, controlling for monthly seasonal effects. The results are given in Table 2 and represented in dashed lines in Figure 2. The econometric analysis confirms that the feebate policy had a significant and negative impact on CO_2 emissions but also indicates that the introduction of compulsory energy labels negatively and significantly decreased the level of emissions. Even if the effect of the first policy was smaller than the one of the feebate (-1.81 versus -7.27 grams of CO_2), it seems that both informational and financial incentives are important to modify consumers' choices. We also see that not only the level but also the trend in the decrease of CO_2 emission have been affected and strengthened by both policies.

Parameters	Estimate
Intercept	156.6** (0.370)
Time trend	−0.083** (0.011)
Dummy of being after 11/2005	−1.81** (0.430)
Additional trend after 11/2005	−0.046† (0.024)
Dummy of being after 01/2008	−7.27** (0.535)
Additional trend after 01/2008	−0.174* (0.069)
Nb of observations	71

Notes: monthly effects are included. December 2007 and January 2008 are dropped because of anticipation effects. Standard errors are heteroskedasticity-autocorrelation robust. Significance levels: ** 1%, * 5%, † 10%.

Table 2: Regression of CO_2 emissions on time

Given that both policies are based on the classes of emissions of new cars, similar patterns should be observed in the market shares of each class of emissions between 2003 and 2008. We display their evolutions in Table 3. Overall, the results are in line with the effects depicted in Figure 2. The market shares of low-emitting classes increase sharply during the period, while those of high-emitting classes fall drastically. Considering for instance class B, we observe in 2006 a first jump from 13.2% to approximately 18.7% in its market shares, and then an even larger increase, from around 20% to 38.4%, in 2008. Conversely, considering class E-, we observe in 2006 a first fall from around 17% to approximately 15.2% in its market shares, and then an even larger decrease, from 15.1% to 7.8%, in 2008. This is confirmed by the econometric analysis on classes B and E (see Figure 6 and Table 18 in Appendix B).

Class of emissions	2003	2004	2005	2006	2007	2008	Evolution 2003-2008
	Market shares						
A	0.03%	0.02%	0.01%	0%	0.02%	0.06%	100%
B	13.58%	13.22%	13.17%	18.72%	19.89%	38.40%	188%
C+	2.61%	5.20%	10.60%	12.35%	10.33%	9.53%	264%
C-	17.48%	18.55%	14.84%	15.63%	19.74%	18.57%	12%
D	36.04%	34.16%	32.66%	28.77%	26.93%	21.67%	-38%
E+	4.76%	5.45%	5.31%	3.38%	2.90%	2.04%	-55%
E-	18.88%	16.48%	17.04%	15.20%	15.10%	7.82%	-60%
F	4.80%	5.16%	4.98%	4.63%	3.66%	1.38%	-73%
G	1.82%	1.76%	1.39%	1.30%	1.44%	0.54%	-73%

Notes: market shares exclude the outside option (i.e., not to buy any car) and thus sum to one here.

Table 3: Evolution of market shares according to the emissions class

Finally, we study the evolution of average CO_2 emissions according to some demographic characteristics. This is possible since the French new cars registrations dataset provides information on the car but also on its owner. We observe the age and the city in which the owner lives. Based on these characteristics, we created 18 groups of individuals based on their age classes (18-39, 40-59 or 60 and more), geographical areas (cities of less than 20,000 inhabitants, called rural areas or more, called urban areas) and imputed income classes (0-22,000, 22,000-32,000 or more than 32,000). Details on the income imputation and market definitions are provided in Appendix A.1. These three variables were chosen because they turn out to have a large effect on purchases (see Table 13 in Appendix A.1). The evolution of average CO_2 emissions according to the type of area, age and income are displayed in Table 4. The table emphasizes consumers' heterogeneity in the purchase of new cars. Young people, low-income people, and people living in rural areas tend to buy lower CO_2 emitting cars. Nevertheless, the evolution of CO_2 emissions supports our previous findings and is rather the same for all groups of consumers. In particular, each policy implies a significant decrease in the CO_2 emissions, with, as expected, a larger effect for the feebate.

Demographics	2003	2004	2005	2006	2007	2008	Evolution
Age ∈ [18-39]	149.3	148.4	147.4	144.1	143.7	133.8	-10.4%
Age ∈ [40-59]	156.0	155.1	154.2	150.7	150.3	138.6	-11.2%
Age ∈ [60-100]	155.1	153.8	152.7	149.3	148.4	138.4	-10.8%
Income < 22,000€	150.9	149.5	148.3	144.6	143.6	133.9	-11.3%
Income ∈ [22,000-32,000]	154.0	153.0	151.8	148.3	147.6	136.9	-11.1%
Income > 32,000€	157.9	156.8	155.5	151.6	150.8	139.2	-11.8%
Rural area	152.7	151.7	150.9	147.6	147.2	136.9	-10.3%
Urban area	154.7	153.7	152.7	149.3	148.5	137.6	-11.1%

Table 4: Evolution of average CO_2 emissions according to demographic characteristics

2.3 Potential explanations

The evolution of average CO_2 emissions may be due to several factors that we now examine in details.

2.3.1 Price effects

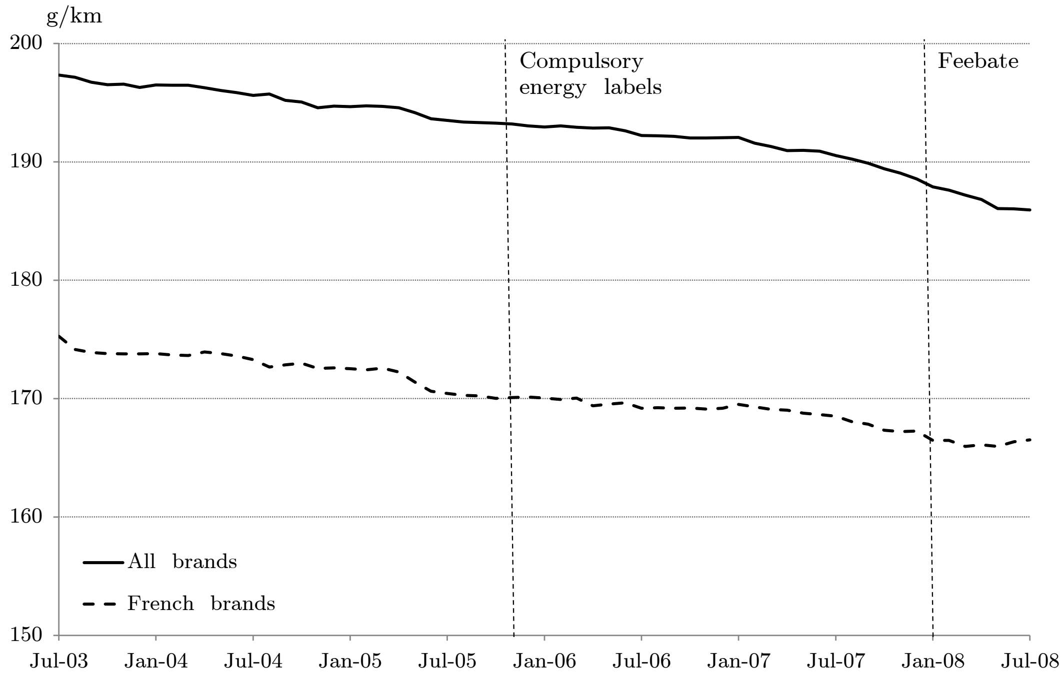
The more natural explanation of the sharp decrease in CO_2 emissions in 2008 is a price effect due to the feebate system. What is peculiar is that the amounts of fees and rebates are relatively low compared to their effect. For instance, a rebate of 700€ given to class B vehicles represents, on average, a 4.8% reduction of price (see Table 1), but implies an increase by almost 100% of the market share of this class. Similarly, the decrease of 50% in the market share of class E- would be due to a 750€ penalty, or a 3.2% raise of their prices. Because manufacturers adjusted their prices in reaction to this policy change, these percentage are actually upper bounds of the true changes in prices. Overall, it thus seems difficult to rationalize such variations of sales with usual price reactions solely.

These important variations may however stem from threshold effects induced by the feebate. If many consumers choosing class C+ vehicles before 2008 were nearly indifferent between them and class B vehicles, they could massively switch to class B following the introduction of the feebate. The extent of this effect can only be assessed through a microeconomic demand model taking into account heterogeneity both of cars' attributes and consumers' preferences. We develop and estimate such a model in the following sections to assess precisely the importance of the price effect.

2.3.2 Supply side effects

The evolution of CO_2 emissions may also be due to supply side effects, such as technical changes or new incentives to market low-emitting vehicles, because of a fuel price increase

for instance. The sharp fall in 2008 could also be due to an immediate adjustment of the supply side. To assess the importance of these effects, we study how the set of vehicles offered by manufacturers evolved through time. Because we do not observe directly this set of vehicles, through brand lists for instance, we assume that a product is proposed to consumers at a given month if it is bought at least once before this month and after this month, or at least once during this month. We then compute average CO_2 emissions of the set of cars offered at each date, for all brands and French brands only. The results are depicted in Figure 3.



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.

Figure 3: Average emissions of supplied vehicles

Overall, there has been a reduction of around 5.5% of the average CO_2 emissions of supplied cars on the period. This decrease is very regular over time and approximately identical for French and other manufacturers. Beyond technical change effects, this 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 90's, automobile manufacturers committed to reducing the level of CO_2 for passenger cars in the European Union, the latest target being an average of 130 g/km for 2015. Finally, the observed decrease may be a reaction to an increasing trend in preferences for

low-emitting cars, leading manufacturers to develop their product line in favor of small and fuel efficient vehicles.

On the other hand, it seems that there is no immediate change in the products offered in response to both policies. This may seem surprising, especially for the feebate, given the sharp changes observed in market shares of the different classes of emissions. However, there are several reasons for not observing an immediate adjustment of the supply side. First, the manufacturers incentives may not be 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 classes level. The advantage of exploiting these thresholds for the French market only may thus not overcome the costs of developing specific models, especially for non French manufacturers.[5] Second, the feebate policy was announced only two months before its application, 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 shift between the increase in the fuel price following the first oil crisis and the corresponding technical innovations. Similarly, we do not observe any particular acceleration or changes between 2003 and 2008 in the number of patents on domains related with CO_2 emissions. Finally, even if horsepower, and thus CO_2 emissions, can be adjusted quickly, the modified vehicle must be certified before appearing on the market. This certification, together with the distribution of the new vehicles, typically takes several months.

2.3.3 Macroeconomic effects

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). Negative economic conditions may lead people to buy smaller, low-emitting cars. It seems unlikely, however, that the drop in January 2008 stems from such an effect. Figure 4 shows that the economic distress mainly appears at the fourth quarter of 2008. Similarly, the unemployment was at a historically low level in January 2008 (7.5%), and the sharp increase (from 8.1% to 9%) only occurs by the fourth quarter of 2008. Thus, consumers' economic situation seems very unlikely to explain the pattern of CO_2 evolution. Yet, we do take into account possible wealth effects hereafter by stratifying our demand model along income classes and introducing year dummies to capture some of these effects.

Fuel price is also known to be an important determinant of automobile choices (see, e.g., Berry et al., 1993). The increase after 2005 may be responsible for the change in the trend of average CO_2 emissions that we document before. It is very unlikely to explain the drop

[5]Note also that within countries tax systems evolve rapidly. The feebate cutoffs, for instance, were modified in 2010 and in 2011. This further limits the incentive to adapt the products line.

at the beginning of 2008, on the other hand, as the fuel price increase started at the end of 2006. Nonetheless, we take into account this evolution by including kilometers per euro in the attributes of the vehicles when estimating our demand model.

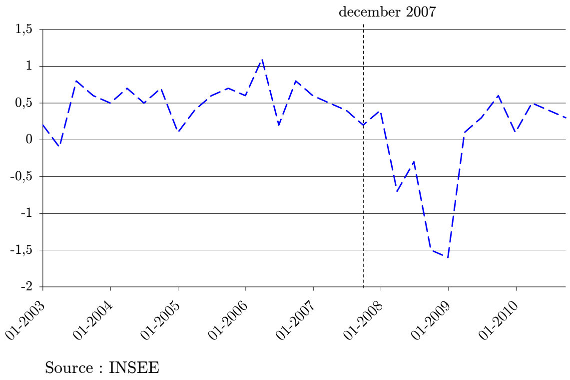


Figure 4: Quarterly GDP Growth

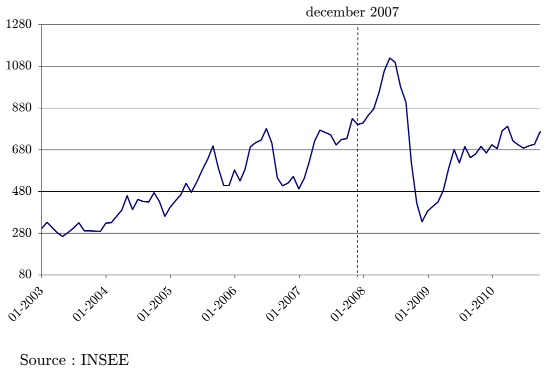


Figure 5: Gasoline Prices evolution

2.3.4 Temporary effects

Another possibility is that the large fall that occurred in 2008 may be due to temporary effects. First, consumers may anticipate the feebate to be temporary, and thus take advantage of the rebates quickly after the introduction. This kind of reactions 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 from 2010, to induce technical 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 respectively 700, 500 and 0 euros. However, it seems unlikely that a rush in small cars purchase 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 car 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 was large, the fall in average CO_2 emissions should be quickly followed by a rise in these emissions. 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 increases more quickly after this point. Even though we do not have monthly data in 2009, Table 5 shows, using aggregate data also from the CCFA, that this evolution continues in 2009.[6] The market share of class A was multiplied by three between 2008 and 2009, while the one of class B increased by 36%. On the opposite, the market shares of classes E+ and G decreased by around 50%. Even

[6] For the sake of comparison, the 2008 figures include car fleets and some exotic cars that are excluded otherwise from our analysis. This explains why the market shares by classes differ from Table 3.

though other phenomena are probably at stake in 2009,[7] these evolutions suggest that the sharp changes following the introduction of the feebate were not temporary.

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).

Table 5: Market shares according to the class of emission after 2008 (aggregated data)

2.3.5 Changes in consumers' information and preferences

Finally, additional non-price effects may be at stake. It is documented that people value environment *per se*, and are thus ready to pay for environmentally-friendly goods (on 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 both drops at the end of 2005 and at the beginning of 2008.

These policies may have modified the information set of consumers, by putting forward the CO_2 emissions levels of automobiles. The information being easier to incorporate in their choices, consumers may have taken it more easily into account. In the model developed by Gabaix (2012), consumers face too much characteristics and only select part 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

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

credible signal that environmental issues really matter, in a world where consumers may have trouble to make up their mind about the negative impact of CO_2 emissions. The introduction by the state of a tax, or a feebate as here, is a way to convince consumers that CO_2 emissions constitute a first order problem.

Though we do not model this hereafter, the change in preferences may also be reinforced by peer effects. If people tend to conform to others in their purchasing decisions (see e.g. Bollinger & Gillingham, 2012, for such evidence), and anticipate that environmental policies will induce a shift towards environmentally-friendly cars, this shift will be reinforced through a social multiplier.

All these effects will be captured in our model by a change in the valuations for CO_2 emissions. With a slight abuse of language, we will refer to them as changes in consumers' preferences, keeping in mind that they could also be informational or peer effects.

3 Distinguishing the effects

3.1 The demand model

To disentangle between the explanations detailed above, we rely hereafter on a structural demand model, using the CCFA registration dataset. CO_2 emissions, the brand, model, type of fuel, number of doors, type of car-body, horsepower, weight and cylinder capacity are reported for each registration. These characteristics have been complemented with list prices[8] and fuel prices, allowing us to compute the number of kilometers per euro. We estimate a nested logit with observed heterogeneity, taking advantage of the availability of consumers' characteristics in our database. In other words, we estimate structural parameters that are group-specific. This amounts to supposing that among each of the 18 groups of individuals defined by their age class, income class and type of area, preferences are homogenous.

Formally, we suppose that each year, consumers can choose to buy one of the J different products proposed on the market. To avoid the aforementioned anticipation and post-anticipation effects of 2007 and 2008, the year we consider actually excludes January and December. We define a product by its brand, model, car-body style, type of fuel, CO_2 emissions class and number of doors. As usually in the literature, we consider the characteristics of the base version of the car model, which is considered to be the cheapest one. Product 0 corresponds to the outside option, namely not purchasing a new car during the year. The automobile market is supposed to be segmented according to the main use of the car and we have created several nests accordingly.[9] The utility of consumer i, belonging

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

[9]Our segmentation is close to the one of the European New Car Assessment Program (Euro NCAP), see Appendix A.3 for details. For more details on the construction of products, see also Appendix A.2.

to the demographic group d, for purchasing car j at year t is then given by

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

p_{jt} denotes the price of vehicle j at t. X_{jt} denotes other standard attributes: weight, horsepower, number of kilometers per euro (computed using the average price of fuel each year), engine capacity, number of doors and car-body style. X_{jt} also includes time and model fixed effects, to control for macroeconomic shocks and unobserved heterogeneity of products, respectively. Thanks in particular to the introduction of the feebate, we still have sufficient variations within models, in particular in prices, to allow for such fixed effects.

To capture potential time-varying environmental concerns of the consumers, we also include CO_2 emissions through the term $f_t^d(\mathrm{CO}_{2jt})$, where we consider several specifications for f_t^d hereafter. CO_{2jt} is not collinear with the number of kilometers per euro because first, this cost varies with the fuel type and second, gasoline and diesel prices differ.[10] Its specific effect can therefore be identified. If the environmental policies affects 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. As explained above, the interpretation of the term $f_t^d(\mathrm{CO}_{2jt})$ is complex. It may capture both a negative valuation of CO_2 emissions *per se* and an information effect, people becoming more aware of the true CO_2 emissions of the cars and its impact on pollution level.

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-product-specific error term. In the nested logit model, 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, executives, sports car...).

The nested logit specification, together with the normalization to zero of the mean utility level of the outside option,[11] yields (see, e.g., Rust & Berkovec, 1985)

$$\ln(s_{jt}^{d}) - \ln(s_{0t}^{d}) = p_{jt}\beta^{d} + X_{jt}\gamma^{d} + f_{t}^{d}(\mathrm{CO}_{2jt}) + \sigma\ln(\bar{s}_{j/gt}^{d}) + \xi_{jt}^{d}\ , \tag{1}$$

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 represents the correlation of consumers' utility across automobiles of the same nest and lies between 0 (no correlation) and 1 (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

[10] CO_2 emissions and kilometers per euro are related through the formula $\mathrm{km}/€ = \frac{k}{\mathrm{CO}_2 \times p_g}$, where p_g stands for the gasoline price and k depends on the fuel type only ($k = 22.866$ if the motor uses gasoline, $k = 26.86$ if the motor uses diesel).

[11] The mean utility of the outside option may evolve through time, especially if the feebate policy has discouraged consumers to purchase cars on the second hand market. This is accounted for by the year dummies.

consumers heterogeneity through the dependence in d of β^d, γ^d, f_t^d and ξ_{jt}^d. Hereafter we impose a linear decomposition in d, so that for the price parameter for instance:

$$\beta^d = \beta^0 + \beta^u \mathbb{1}_{\text{urban}} + \beta^{a_1} \mathbb{1}_{\text{age}\in[40,59]} + \beta^{a_2} \mathbb{1}_{\text{age}\geq 60} + \beta^{i_1} \mathbb{1}_{\text{income}\in[22,000;32,000]} + \beta^{i_2} \mathbb{1}_{\text{income}\geq 32,000}.$$

As usually (see, e.g., Berry et al., 1995, Nevo, 2000, and Nevo, 2001), we suppose that, except 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.[12] By construction, conditional market shares $\bar{s}_{j/gt}$ are also endogenous, so that 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' products. 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 by the sums of characteristics of other models of the brand in the same segment.

3.2 Consumers preferences

We estimate Model (1) as explained above but with slight variations in the way the price and CO_2 affect the model. In Specification (1), price is not instrumented, whereas all other specifications allow for price endogeneity. Specifications (2) to (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 periods (2006-2007 and 2008) dummies in Specification (4). Results are displayed in Table 6. For the sake of concision, we only present the estimates of σ and $(\bar{\beta}, \bar{\gamma})$, the average of the preferences parameters $(\beta^d, \gamma^d)_{d=1\ldots18}$ among the population of purchasers. Table 19 in Appendix B displays the estimates of the preference parameters according to demographic characteristics.

[12] Another source of endogeneity is measurement error since, as mentioned before, we observe list prices rather than transaction prices.

Variable	(1)	(2)	(3)	(4)
Price ($\bar{\beta}$)	-0.026^{**} (0.001)	-0.171^{**} (0.012)	-0.094^{**} (0.013)	-0.109^{**} (0.013)
$\ln(\bar{s})$ (σ)	0.279^{**} (0.008)	0.285^{**} (0.009)	0.283^{**} (0.008)	0.284^{**} (0.008)
Characteristics ($\bar{\gamma}$)				
Weight	0.087^{**} (0.006)	0.286^{**} (0.017)	0.181^{**} (0.019)	0.202^{**} (0.019)
Horsepower	-0.104^{**} (0.004)	0.096^{**} (0.017)	-0.014 (0.018)	0.007 (0.018)
Km/€	0.019^{**} (0.002)	0.054^{**} (0.004)	0.034^{**} (0.004)	0.038^{**} (0.004)
Cylinder capacity	0.041^{**} (0.002)	0.06^{**} (0.002)	0.051^{**} (0.002)	0.053^{**} (0.003)
Station wagon car-body	-0.494^{**} (0.012)	-0.440^{**} (0.014)	-0.467^{**} (0.013)	-0.462^{**} (0.013)
Coupe/convertible	-0.583^{**} (0.017)	-0.164^{**} (0.039)	-0.39^{**} (0.041)	-0.347^{**} (0.042)
Three doors	-0.436^{**} (0.01)	-0.468^{**} (0.011)	-0.449^{**} (0.011)	-0.452^{**} (0.011)
Nb. of observations	100 876	100 876	100 876	100 876

Notes: Column (1): price not instrumented, (2): evolution of CO_2 preferences captured through a temporal trend. (3): CO_2 interacted with year dummies. (4): CO_2 interacted with three periods (2003-2005, 2006-2007 and 2008). All specifications include model and years fixed effects. Standard errors are in parentheses. Significance levels: ** 1%, * 5%, † 10%.

Table 6: Estimates of average preferences for vehicle characteristics.

Before studying the way consumers value CO_2, we describe results on their preferences for standard attributes. When not instrumented, the price coefficient has the correct sign but is very small, leading to price elasticities between -1 and 0. Horsepower is also significantly negative in this case. Apart from that, all mean parameters are globally stable from one specification to another. Weight, fuel economy and cylinder capacity are positively valuated. On average, households dislike coupe/convertible, station-wagon cars and three-door vehicles.[13] We obtain estimates around 0.3 for σ, reflecting the fact that products inside segments are moderate substitutes. This result stems from the fact that in our estimation, we have controlled for model fixed effects. A large part of the correlation on fixed unobservable characteristics of models in the same segment is thus already taken into account. Without model fixed effects, we obtain $\widehat{\sigma} \simeq 0.6$.

All the previous estimates correspond to the average parameters of preferences of purchasers. Table 19 in Appendix B shows there is a substantial heterogeneity across them. Households are in particular less sensitive to price when they live in urban area than in

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

rural area. The effect of price also decreases with income and age. Hence, unsurprisingly, the more price-sensitive consumers are the young and poor ones, living in rural areas.

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 $-\beta^d p_j(1-\sigma\bar{s}^d_{j/g}-(1-\sigma)s^d_j)/(1-\sigma))$. Sales-weighted average price elasticities are reported in Table 7. These elasticities lie between -4.49 and -1.54, the mean being -2.9. These orders of magnitude are similar to those found in the literature. They are below those of Berry et al. (1995), who report price elasticities between -6.5 and -3.5 (see their Table 4) but in the same range as those of Train & Winston (2007), who obtain -2.37 on average. Moreover, as expected, the most elastic demand comes from young, poor and rural consumers, whereas the less elastic one arises from rich, old and urban individuals.

	Rural area			Urban area		
Income/Age	18-39	40-59	≥ 60	18-39	40-59	≥ 60
0-22,000	-4.49 (0.361)	-3.68 (0.388)	-2.72 (0.362)	-3.93 (0.348)	-3.15 (0.380)	-2.24 (0.352)
22,000-32,000	-4.21 (0.366)	-3.31 (0.384)	-2.39 (0,y365)	-3.82 (0.367)	-2.81 (0.376)	-1.97 (0.362)
$\geq$ 32,000	-3.77 (0.366)	-2.80 (0.38)	-1.93 (0.367)	-3.46 (0.374)	-2.35 (0.376)	-1.54 (0.369)

Notes: the standard errors, in parentheses, are computed by bootstrap.

Table 7: Average price elasticity (sales-weighted) according to demographic characteristics.

Overall, the previous results on consumers' preferences for standard attributes are reassuring and give credit to the model and the estimations. We can thus turn our attention to the estimates of the valuations of CO_2 emissions.

3.3 Evidence of environmental valuation changes

Table 8 displays the estimates of the evolution of CO_2 emissions valuation corresponding to Specifications (1) to (4) considered above.[14]

[14] The parameters presented correspond to the average in the population, parameters of heterogeneity are presented in Table 20 in Appendix B.

Variable	(1)	(2)	(3)	(4)
CO_2 emissions	-0.904^{**} (0.038)	-0.794^{**} (0.042)	-0.947^{**} (0.039)	-0.947^{**} (0.039)
CO_2 emissions×Trend	-0.067^{**} (0.005)	-0.127^{**} (0.007)		
CO_2 emissions×2006			-0.241^{**} (0.026)	
CO_2 emissions×2007			-0.182^{**} (0.03)	
CO_2 emissions×2008			-0.383^{**} (0.022)	-0.382^{**} (0.023)
CO_2 emissions×(2006-2007)				-0.234^{**} (0.025)

Notes: Column (1): price not instrumented, (2): evolution of CO_2 preferences captured through a temporal trend. (3): CO_2 interacted with year dummies. (4): CO_2 interacted with three periods (2003-2005, 2006-2007 and 2008). Significance levels: ** 1%, * 5%, † 10%.

Table 8: Estimates of CO_2 emissions valuation (mean parameters)

The negative and significant sign of CO_2 emissions captures the idea that consumers have a preference for low CO_2 emitting cars, all things being equal. We also observe a quite clear pattern on evolutions. All specifications indicate a growing concern on 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' concern on global warming, has decreased by around 0.38 according to Specifications (3) or (4).

Moreover, while the trend is quite large, Specification (3) indicates that actually, there have been two main steps in this evolution: a first one in 2006, and a second one in 2008 whereas 2007 resembles much to 2006. Column (4), which summarizes these results, indicates that both effects have a similar magnitude with a first decrease of -0.234 in the years 2006-2007 compared to the years 2003-2005 and a second decrease of -0.148 (-0.382+0.234) in 2008 compared to the period 2006-2007. Because the compulsory energy label policy took place at the end of 2005 and the feebate was introduced at the beginning of 2008, this timing suggests that the shift in preferences is related to the policies introduced during this period.

Up to now, we have estimated preferences for CO_2 emissions. It is possible, however, given that both the energy label and the feebate policies are based on classes of emissions, that consumers focus on such classes rather than directly on CO_2 emissions. This may especially be 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.

Class of emissions	Parameter	Class of emission	Parameter
A ×(2006-2007)	0.168 (0.179)	E+ ×(2006-2007)	−0.119** (0.028)
A ×(2008)	1.005** (0.15)	E+ ×(2008)	−0.260** (0.034)
B ×(2006-2007)	0.448** (0.033)	E- ×(2006-2007)	−0.164** (0.020)
B ×(2008)	1.106** (0.037)	E- ×(2008)	−0.156** (0.025)
C+ ×(2006-2007)	0.425** (0.03)	F ×(2006-2007)	−0.108** (0.025)
C+ ×(2008)	0.499** (0.035)	F ×(2008)	−0.125** (0.031)
C- ×(2006-2007)	−0.029 (0.027)	G ×(2006-2007)	0.015 (0.035)
C- ×(2008)	0.092** (0.031)	G ×(2008)	0.201** (0.043)

Notes: the parameters are obtained with the same model as in Column (4) of Table 6, except that we replace CO_2 by the class of emissions dummies.

Table 9: Evolution of valuation for classes of emissions (mean parameters)

The results, displayed in Table 9, are in line with those on CO_2 emissions. We observe a sharp evolution of consumers' preferences towards environmentally-friendly goods during this period. The results are also consistent with the previous interpretation. The raise in the valuation of low-emitting classes (namely, A to C) contrasts with the fall in the high-emitting ones (E to F). Only class G, which represents less than 1% of total sales in 2008, has a profile that does not fit with our other results.[15] The raise is especially striking in 2008 for classes A and B. Similarly, the fall for E+ cars is larger in 2008 than in 2006-2007. For other polluting cars (classes E- and F), the shift appears to be similar in 2006-2007 and in 2008, suggesting that consumers were more attracted by the rebates than discouraged by the fees. In the end, the signals given by these policies, first with colorful labels, then with both labels and prices, seem to have been successful to shift consumers preferences towards environmentally-friendly cars and to align the preferences of the consumers with the classes promoted by the French government.

With the previous estimates in hand, we can compute the willingness to pay for a 10g reduction of CO_2 emissions. Because $\hat{\beta}$ is the valuation of price in thousands of euros and $\hat{\gamma}$ is the valuation of CO_2 emissions for 100 grams, this willingness to pay corresponds to 100 times the ratio between the CO_2 coefficient and the price coefficient in the demand model. The average evolution on the whole population is substantial. With Specification (4) described above, we obtain an average increase of 213 euros in 2006-2007 compared to 2003-2005, and 367 euros in 2008 (all in 2008 euros). This corresponds to an increase in the willingness to pay of approximately 700 euros for going from the lower threshold of

[15]The results are consistent with the fact that these cars are luxury goods, with an inelastic demand.

class C+ (121g per kilometer) to the lower threshold of class B (101g per kilometer), an amount of the same magnitude 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 around \$500-600 to reduce CO_2 emissions by 10%.[16] Our results are also in line with the results 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 ten years, we obtain an increase in the willingness to pay of around \$600, broadly consistent with our estimates.

This overall shift mixes however important differences among consumers (see Table 10). While the willingness to pay has increased in 2008 by only 211 euros for old and poor people living in rural area, this increase reaches 675 euros for old and rich 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 have thus 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 environment but high price elasticities whereas old ones do not strongly care about global warming but have small price elasticities. In 2006-2007, the effect of environmental preferences dominates the price elasticities and young people usually have a higher willingness to pay to reduce global warming than their elder. The situation is more contrasted in 2008.

[16] Few other papers have studied the automobile market but do not give precise estimate of the willingness to pay for the reduction of global warming. Potoglou & Kanaroglou (2007) analyse the factors of 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.

Income	Age	Rural area 18-39	Rural area 40-59	Rural area ≥ 60	Urban area 18-39	Urban area 40-59	Urban area ≥ 60
0-22,000	2006-07	205 (25)	176 (30)	131 (39)	204 (27)	171 (35)	117 (46)
	2008	249 (41)	203 (49)	211 (62)	268 (44)	224 (56)	239 (74)
22,000-32,000	2006-07	230 (26)	206 (32)	162 (43)	231 (28)	205 (35)	152 (50)
	2008	322 (48)	298 (58)	335 (83)	351 (50)	335 (65)	391 (101)
≥ 32,000	2006-07	289 (32)	285 (42)	260 (65)	297 (34)	298 (49)	272 (88)
	2008	427 (62)	442 (86)	544 (145)	472 (67)	514 (105)	675 (226)

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

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

These results are consistent with a governmental French report on environmental consciousness between 1995 and 2011.[17] This report highlights an increase in environmental concerns over the period, 46.1% of French people being sensitive to environment against 35% in 2002. It also concludes that rich consumers are more willing to pay to fight against the environmental degradation.

To assess the credibility of the differences we estimate between demographic groups, we also relate the willingness to pay to the general environmental preoccupation using data on electoral vote 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.[18] We use the electoral votes during the first ballot of 2007 presidential elections, and look in particular at the relationship between the average willingness to pay and votes for the green party. The rate of green voters is considered to be the number of votes in favor of Dominique Voynet, the candidate of the green party, divided by the total number of valid votes. 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 environment. As expected, the voters of the green party are

[17] 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

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

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 right party, have higher willingness to pay for environment.

	2006-07	2008
Constant	252.46^{**} (3.49)	439.66^{**} (7.50)
Voynet (Green politics)	508.56^{**} (21.9)	1037.3^{**} (47.22
Extreme left	-175.66^{**} (6.77)	-422.06^{**} (14.56)
Royal (left)	-111.86^{**} (5.05)	-216.47^{**} (10.85)
Bayrou (center)	Reference	
Sarkozy (right)	25.30^{**} (5.00)	46.79^{**} (10.77)
Extreme right	-129.88^{**} (4.72)	-307.64^{**} (10.16)
Nb. obs	31,373	

Notes: we regress the evolution in the willingness to pay on results of the presidential elections, at a municipal level.

Table 11: Link between the evolution of average willingness to pay and political preferences at the town level

Overall, these results suggest that environmental policies may impact consumers' utility and increase their preference for environmentally-friendly cars. However, it seems difficult, given our data, to identify exactly the channel through which they modify consumers preferences. A first channel would be the signalling effect mentioned earlier. In particular, the existence of the feebate signal to consumers how important it is to choose low CO_2 emitting vehicles. Such a shift may also 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. Finally, these policies may have also affected the manufacturers marketing strategy, more advertising being put on low-emitting vehicles after the introduction of the policies.

3.4 Importance of preference changes

While our estimates suggest that preferences evolve over time, we now measure the importance of the evolutions. For that purpose, we compute, using the structural parameter estimates, what would have been the evolution of the average CO_2 emissions of new vehicles

without any evolution in environmental preferences. More precisely, we compute counterfactual market shares and the average CO_2 emissions of new vehicles by dropping from the utilities the interactions between CO_2 emissions and the time dummies (2006-2007) and 2008. The results are displayed in Table 12.[19]

Year	Observed	Predicted
2003	152.8	152.8
2004	151.4	151.4
2005	150.5	150.5
2006	146.9	149.6 (0.349)
2007	146.6	149.1 (0.321)
2008	137.0	140.3 (0.242)

Notes: for predicted values, the standard errors are computed by bootstrap.

Table 12: Evolution of average CO_2 emissions with and without the variation in the environmental preferences.

Without any shift, we would have observed average CO_2 emissions around 140.3g per kilometer instead of 137g at the end of 2008. Put it another way, the shift in preferences explain 20% (3.3g of the total 15.8g decrease) of the decrease observed between 2003 and 2008. 75% (2.5g) of this shift are due to the energy label policy, measured by the difference between observed and predicted CO_2 in 2007. The 25% left (0.8g) is due to non-price effects of the feebate system.

Manufacturers effects (i.e., improvements in the fuel efficiency of vehicles and a marketing of more low-emitting cars), excluding the price effect resulting from the feebate, explains around 29% of the overall decrease of 15.8g. Predicted values shows indeed that without any shift in preferences in 2006-2007, the annual decrease in average CO_2 emissions between 2003 and 2007 is $(152.8 - 149.1)/4 \simeq 0.93$g. If we extrapolate the same trend on 2008 and thus neglect, in line with what is suggested by Figure 3, any reaction of manufacturers to the feebate in 2008, we obtain a total decrease due to manufacturers of 4.7g between 2003 and 2008, corresponding to 29%. Finally, the rest, i.e. 51%, can be attributed to the price

[19] The observed average CO_2 emissions displayed in the table do not match those of Figure 2 for two reasons. First, and as discussed previously, the sample excludes December and January. Second, to remain consistent with the rest of the econometric analysis, we use the CO_2 emissions of the cheapest version of each product. In general these versions are the lowest CO_2-emitting cars within a given product, resulting in smaller average emissions than in Figure 2.

effect resulting from the feebate. If this effect is the largest one, non-price effects appear to be quite substantial.

4 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, namely the obligation of indicating 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 has increased by 367 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 the preferences, we also find that the reduction of average CO_2 emissions over the period would have been 20% smaller.

Our analysis suggests that the shift in preferences is related to environmental concerns. It is in line with the idea that public policies may not only change the incentives given to consumers, but also their preferences. Changes in consumers' preferences should be interpreted here in a broad sense, including informational or peer effects. Our analysis also shows that preferences may evolve across time. Not taking this evolution into account may thus lead to erroneous conclusions and biased predictions. The estimation of demand using structural models traditionally rely on the assumption that parameters of preferences are constant across time. Our paper suggests that caution should thus be taken when a large time series is considered or when public policies have been introduced during the period.

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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 on 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 and are not used in the estimation because we take the logarithm of market shares. This results in general in a selection bias. 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 the others, called urban areas) and three income classes (0-22,000, 22,000-32,000 and more than 32,000). 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 town 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.

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%

Table 13: Frequency of demographic characteristics among purchasers

The computation of market shares s_j^d involves computing the number of households sharing characteristics d. 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 distribution stemming from INSEE data. Finally, using the log-normal form, the probability to belong to each income class is estimated

in order to recover the number of households. The share of the outside option is variable across markets (see Table 14), reflecting heterogeneity in consumers' preferences across our demographic groups.

	Rural area			Urban area		
Income/Age	18-39	40-59	≥ 60	18-39	40-59	≥ 60
0-22,000	99.0%	99.0%	99.2%	98.2%	99.6%	99.3%
22 000-32 000	93.9%	93.5%	92.3%	94.9%	92.7%	92.4%
≥ 32,000	97.3%	97.9%	96.9%	98.1%	97.2%	97.5%

Table 14: Share of the outside good in 2008 according to the group of consumers

A.2 Definition of the products

As usually 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. A rather large set is necessary to avoid aggregating too different products, 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, car-body style, type of fuel, CO_2 emissions class and number of doors. We do not use horsepower and weight in this definition to keep the number of zeros moderate. On the other hand, we can still introduce them in utility functions by considering their value for the base model, i.e. the cheapest vehicle within the same product. Table 15 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 821 zeros is observed in 2008 for young purchasers with a low income and living in a rural area.

	2003	2004	2005	2006	2007	2008
Number of products	1163	1249	1307	1374	1438	1522
Number of zeros						
Mean	332	359	365	428	449	516
Minimum	150	174	175	225	228	243
Maximum	505	513	559	649	722	821

Table 15: Number of products and number of zeros per market

A.3 Segmentation of the automobile market

The nested logit approach requires to define a segmentation of the market in homogenous groups of products. Our segmentation, based on the main use of the vehicle, is close to the one of The European New Car Assessment Program one (Euro NCAP). Table 16 displays the 8 segments we consider and their market shares in 2007 and 2008. Note in particular that sport cars include all convertible cars as well as vehicles with a high horsepower/weight ratio, while small multi-purpose vehicles (MPV) include small vans such as the *Renault Kangoo*. The entire classification is presented in Table 17.

	2007		2008	
	Number	Freq.	Number	Freq.
Urban	310 228	44.3%	390 557	53.4%
Small Family	109 211	15.6%	115 011	15.7%
Large Family	50 841	7.3%	46 749	6.4%
Executive	6 919	1.0%	4 394	0.6%
Sports	47 877	6.8%	31 648	3.8%
Small MPV	130 068	18.6%	113 732	15.6%
Large MPV	6 393	0.9%	3 216	0.4%
Allroad/SUV	38 286	5.5%	26 046	3.6%

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

Group	**Make**	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	Insigna, 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

Table 17: Segmentation of the automobile market

B Additional tables and figures

B.1 Evolution of market shares

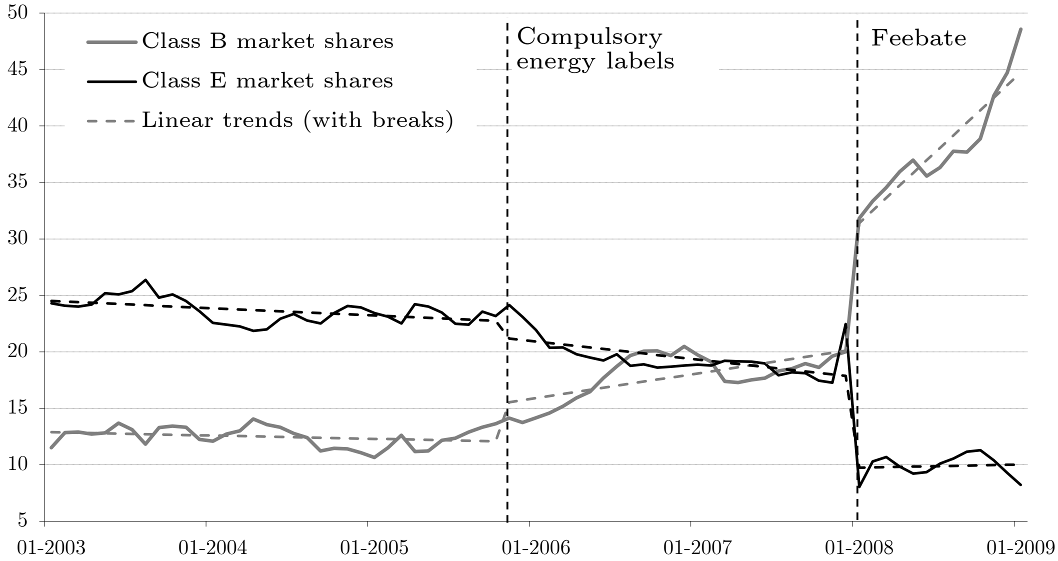

Figure 6: Evolution of market shares for classes B and E

	Estimates	
Parameters	Class B	Class E
Intercept	12.7** (0.576)	24.7** (0.527)
Time trend	−0.02 (0.019)	−0.06** (0.015)
Dummy of being after 11/2005	3.30** (0.87)	−0.82 (0.614)
Additional trend after 11/2005	0.21** (0.044)	−0.13** (0.033)
Dummy of being after 01/2008	10.1** (1.46)	−6.0** (0.673)
Additional trend after 01/2008	0.94** (0.206)	0.07 (0.067)

Notes: monthly effects are included. December 2007 and January 2008 are dropped because of anticipation effects. Standard errors are heteroskedasticity-autocorrelation robust. Significance levels: ** 1%, * 5%, † 10%.

Table 18: Regression of market shares of classes B and E on time

B.2 Further results on the nested logit model

As Tables 19 and 20 show, we observe a substantial heterogeneity across the groups of households we consider. Purchasers living in large agglomerations value less fuel efficiency and station-wagon cars than consumers in rural areas. This is probably related to the fact that people drive less in urban areas and it is more convenient to have a smaller vehicle in large cities. Older people value less weight and station-wagon cars, which may stem from the fact that older people live on average in smaller households, so that they do not value much these attributes (these attributes being very good proxies for size). They also value less convertible and three-door vehicles, probably because they care more about comfort. Finally, as may be expected, they hardly value horsepower. Rich people also value less horsepower, convertible and three-door vehicles. The results also indicate that both the price and the cost per kilometer are less an issue for this population.

	Base	Urban	Age∈[40;59]	Age≥ 60	Medium income	High income
Price	-0.175^{**} (0.014)	0.015^{**} (0.004)	0.042^{**} (0.004)	0.070^{**} (0.004)	0.014^{**} (0.005)	0.034^{**} (0.005)
Weight	0.283^{**} (0.022)	-0.036^{**} (0.008)	-0.025^{**} (0.009)	-0.134^{**} (0.009)	0.003 (0.010)	-0.021^{*} (0.010)
Horsepower	0.174^{**} (0.022)	-0.007 (0.011)	-0.133^{**} (0.012)	-0.232^{**} (0.013)	-0.029^{*} (0.014)	-0.058^{**} (0.014)
Km/€	0.111^{**} (0.005)	-0.046^{**} (0.003)	-0.023^{**} (0.004)	-0.090^{**} (0.004)	0.001 (0.004)	-0.025^{**} (0.004)
Cylinder capacity	0.059^{**} (0.004)	-0.008^{**} (0.003)	-0.002 (0.004)	0.013^{**} (0.004)	-0.004 (0.004)	-0.012^{**} (0.004)
Station-wagon	-0.415^{**} (0.022)	-0.060^{**} (0.015)	-0.006 (0.018)	-0.085^{**} (0.019)	0.014 (0.019)	0.043^{*} (0.019)
Convertible	0.114^{*} (0.051)	0.0130 (0.027)	-0.283^{**} (0.032)	-0.895^{**} (0.033)	$-0.060^{\dagger}$ (0.033)	-0.075^{*} (0.034)
3 doors	-0.190^{**} (0.020)	-0.006 (0.016)	-0.131^{**} (0.019)	-0.472^{**} (0.020)	-0.048^{*} (0.019)	-0.079^{**} (0.020)

Notes: the base parameters correspond to the parameters for the reference group, namely young people with low income in rural areas.

Table 19: Decomposition of preference parameters according to demographic characteristics, for Specification (4)

Environmental preferences are heterogeneous, as Table 20 shows. Preference for environmentally-friendly vehicles is higher for young and old purchasers while there is no significant effect of the income. Environmental quality is clearly more valuated in urban areas than in rural towns. The evolution of preferences is also stronger for medium and high income households. Finally, there is a clear negative effect of age on the change of preferences, the group of young purchasers increasing more their valuation than the others in 2006-2007 and 2008.

	Base	Urban	Age∈[40;59]	Age≥ 60	Medium income	High income
CO_2 emissions	-0.844^{**} (0.084)	-0.378^{**} (0.063)	0.250^{**} (0.074)	0.030 (0.076)	-0.013 (0.078)	0.045 (0.079)
CO_2 ×(2006-2007)	-0.359^{**} (0.045)	0.032 (0.031)	0.126^{**} (0.039)	0.221^{**} (0.039)	-0.011 (0.039)	-0.049 (0.040)
CO_2 ×2008	-0.436^{**} (0.057)	0.006 (0.042)	0.166^{**} (0.051)	0.213^{**} (0.053)	-0.084 (0.054)	-0.168^{**} (0.055)

Notes: the base parameters correspond to the parameters for the reference group, namely young people with low income in rural areas.

Table 20: Decomposition of environmental preferences according to demographic characteristics, for Specification (4)