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

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Outline

Trends in average vehicle emissions in France

- Significant reduction of average CO_2 emissions of new vehicles sold in France: from 156g/km (01/2003) to 136g/km (12/2008)
- How can we explain this decrease?
  - Usual suspects: fuel price evolution, technological progress (supply-side changes), macroeconomic shocks...
  - But also two policies introduced during the period: the introduction of the energy label (November 2005) and of a feebate, the "Bonus/Malus environnemental" (January 2008)
- Why do we care?
  - Transport represents a large part of CO_2 emissions (19.5% in EU for 2008), efficiency of environmental policies is crucial
  - More generally, to understand the different aspects of public policy effects

Effects of public policies on consumers

E.g. tax, subsidy

Standard incentive effects, through usual channels:

- Prices

Additional effects through "non-standard" channels:

- Individual information set
- Social norms

"Crowding in": when it reinforces standard effects

"Crowding out": opposite effects

A famous example

Gneezy & Rustichini, 2000 (Journal of Legal Studies): "A fine is a Price "

Experiment: introduce a fine for late-coming parents at the day care

Main (surprising) findings :

- Rate of delay significantly increased
- This rate remained stable after the fine is removed

An interpretation: parents acquired information on (uncertain) consequences of delay and permanently affected their behavior

Evidence of "crowding out"

This Paper

Disentangle non-standard effects of the two policies from traditional demand and supply side effects

- Energy label (November 2005)
- Feebate scheme: tax/rebate on purchase (January 2008)

Methodology:

- Estimate demand for new cars
  - Use aggregate data on cars sales between 2003 and 2008
  - Structural model of demand with individual heterogeneity
  - Allow valuation for environmental quality to change over time
- Use structural model to predict CO_2 emissions without the change of preferences

This paper

- Main results:
  - Evidence of increase in consumers' valuation of environmental quality in 2003-2008, timing consistent with policies
  - "Crowding in": the "non-standard" effects reinforced the feebate policy effects
  - This explains 43% of the decrease of average CO_2 emissions in 2003-2008
- Several potential explanations:
  - The policies have improved the information on CO_2 emissions of new vehicles
  - The policies have improved the information on the effect of these CO_2 emissions
  - This may have been reinforced by peer effects/social norms

Link with the literature

Effects of environmental policies in the automobile market

- CAFE standard in the US (Goldberg [98], Anderson & Slemrod [2012], Langer & Miller [2012])
- Feebate (Huse & Lucinda [2014] for Sweden, Adamou & al [2014] for Germany)
- Valuation of fuel efficiency by consumers (Allcott [2011], Anderson et al [2013], Busse et al. [2013], Grigolon et al. [2014])

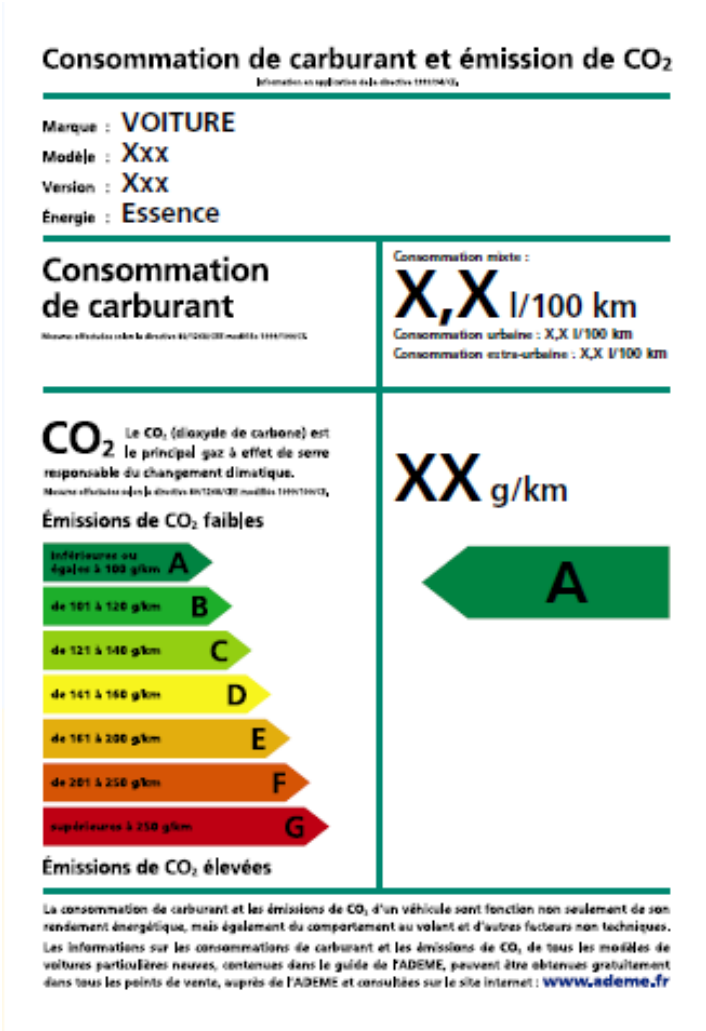
Understanding trends in the automobile market (Miravete et al. [2013] for the evolution of diesel vehicles in Spain)

Literature on energy labels (Houde [2014] for the EnergyStar label for refrigerator)

Outline

Energy labels and the feebate system

Compulsory energy label, end of 2005

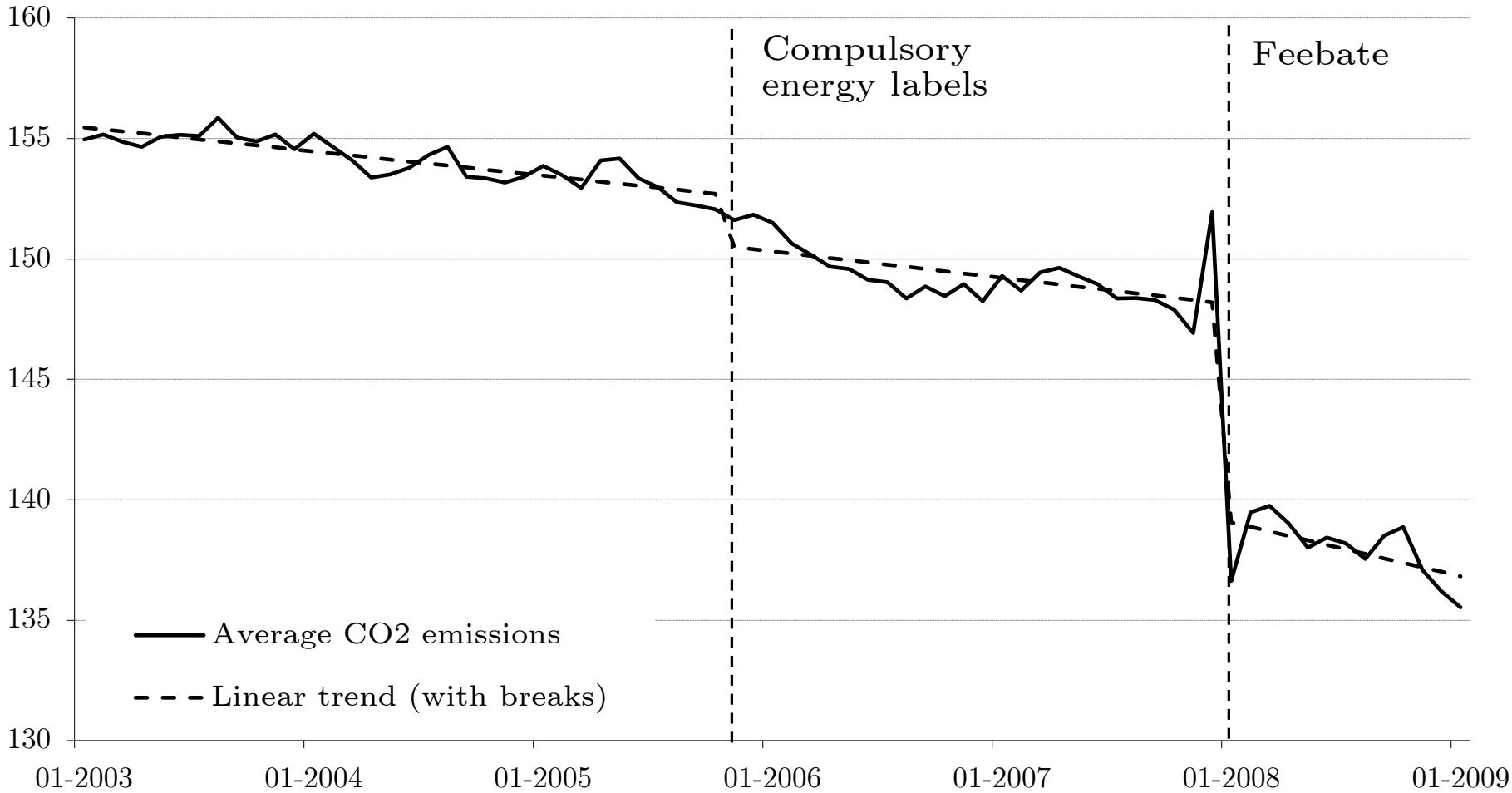


Feebate policy, 2008:

Class of emissions	Emissions (in g/km)	Rebate
A	(60-100]	+1000€
B	(100-120]	+700€
C+	(120-130]	+200€
C-	(130-140]	0€
D	(140-160]	0€
E+	(160-165]	-200€
E-	(165-200]	-750€
F	(200-250]	-1600€
G	> 250	-2600€

Classes related to a new tax/rebate

Evolution of CO_2 emissions



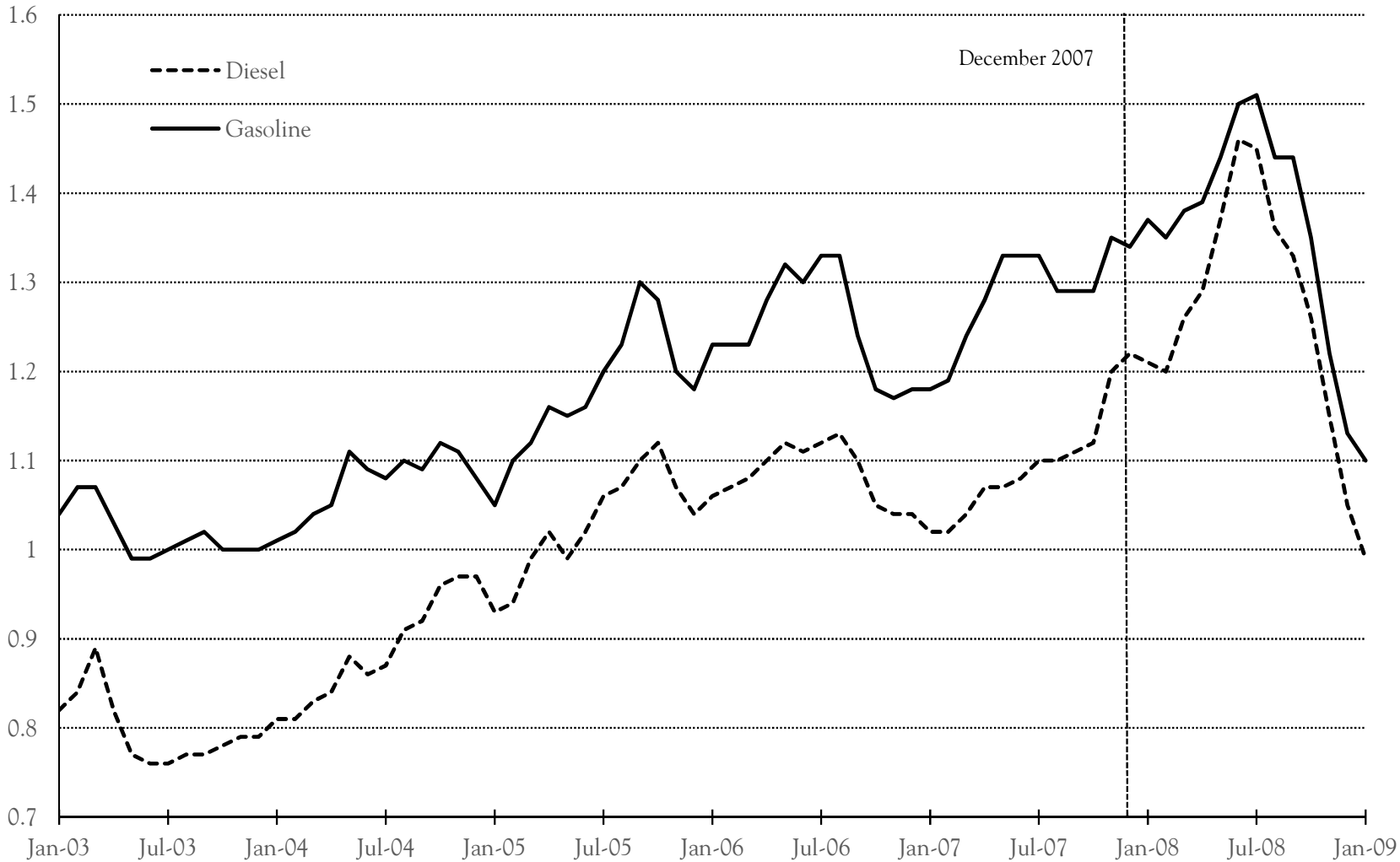
(Seasonally adjusted series)

Price effect of the feebate

Difficult to rationalize evolution of shares between 2007 and 2008 with a price effect of the feebate only:

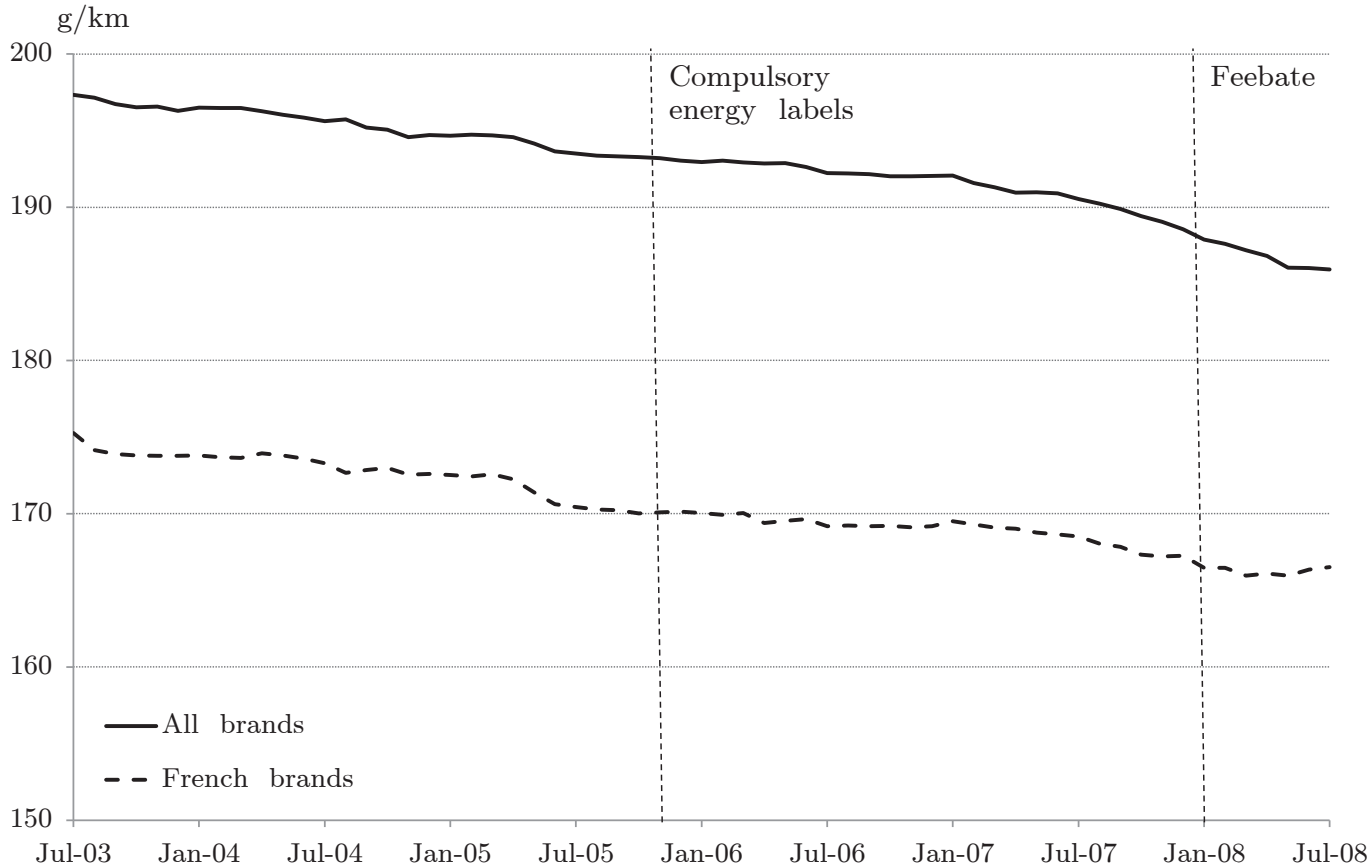
Class of emissions	Evolution of market shares	Rebate	Average price	Average ratio |rebate|/price
B	99.9%	+700	15,647	4.7%
E+	-36.5%	-200	20,172	1.2%
E-	-49.0%	-750	29,910	2.8%

Gasoline prices



Supply Side Effects

Evolution of average CO_2 emissions of the choice set



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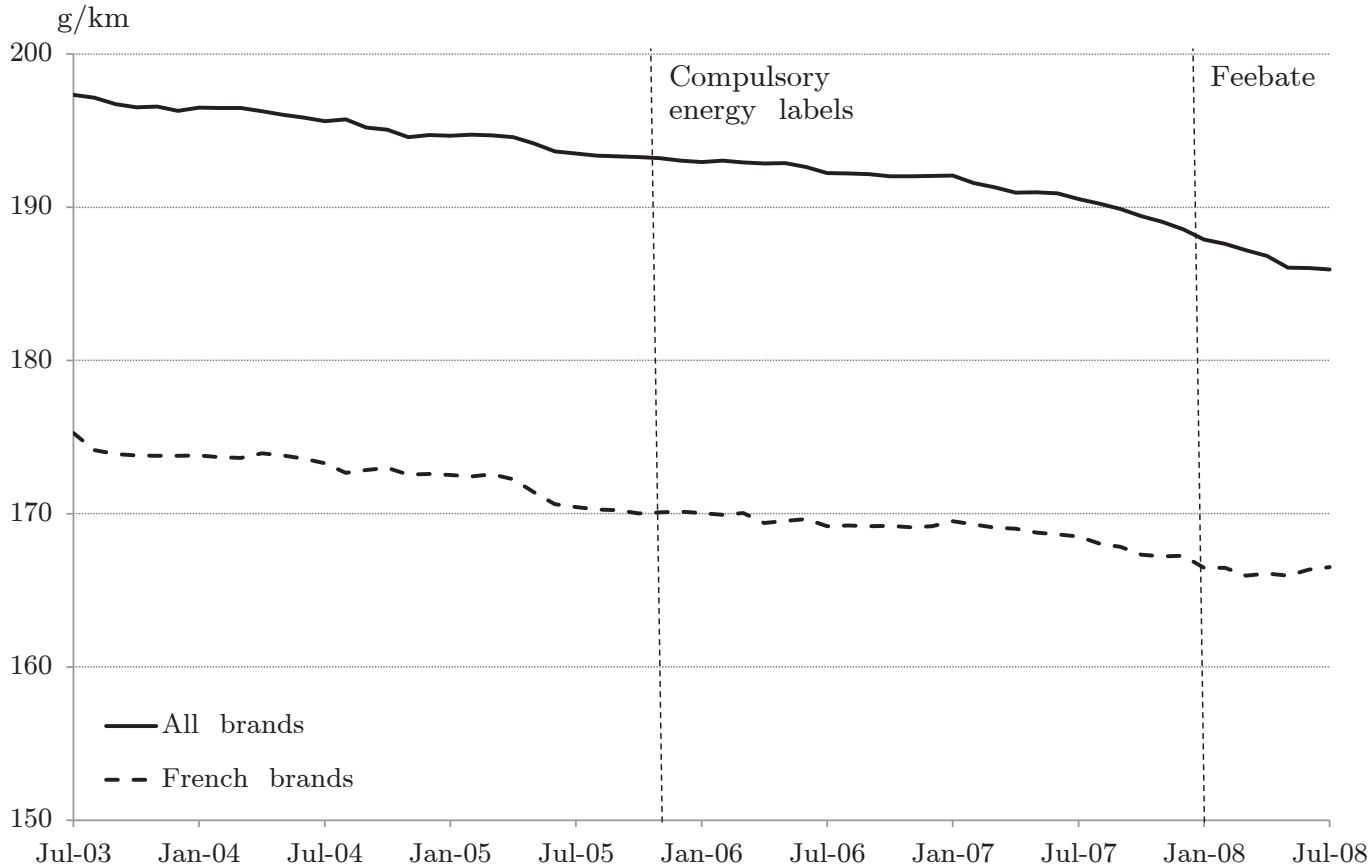
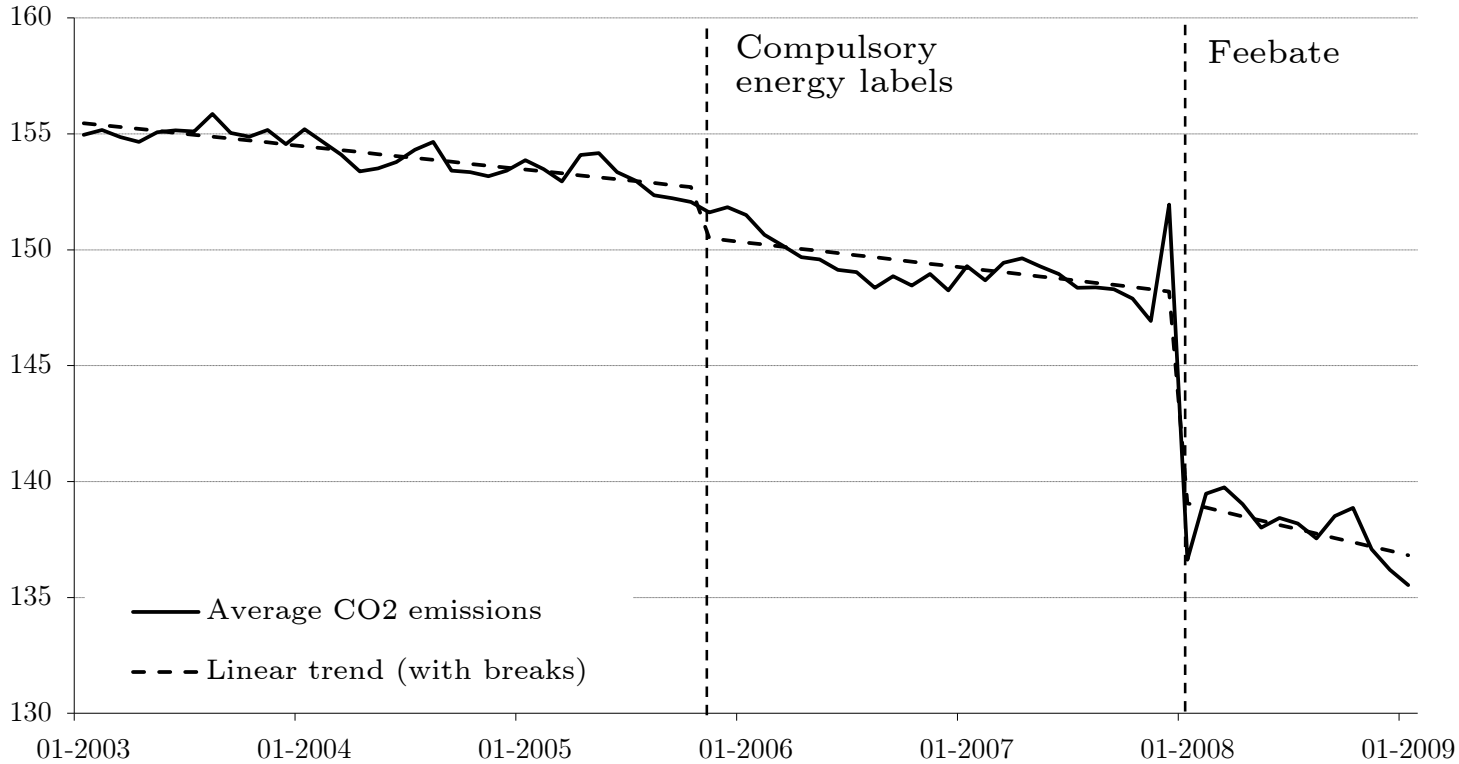


- Measure conducted at the French level only
- Feebate announced two months before its application
- Certification of new vehicles is not immediate

Rationalize the evolution of the market



- Supply-side effects, technological progress
- Preference for fuel efficiency, reaction to the increase in gasoline prices
- Macroeconomic shocks on the car market
- Monetary incentive effect of the feebate
- **Change in consumers' valuation of environmental quality**

Outline

Data

Dataset: monthly registrations of new cars by French households between Jan. 2003 and Jan. 2009

Characteristics of the cars:

- Brand, model, CO_2 emissions, horsepower, weight, number of seats, type of gas, number of doors
- Prices: retail prices

Individual characteristics :

- Precise town
- Age
- Expected income = median income of the town, according to age class

Discrete-choice model of demand

Berry [94], BLP [95]

Main features:

Each consumer purchases one car within the available set or chooses not to buy any (outside option)

Consumers have preferences for vehicles attributes *and* environmental quality

Our strategy = Nested logit with observed heterogeneity:

- Assume consumers make a sequential choice: 1st the segment (urban car, family car or allroad), and 2nd the car inside the segment
- Unobserved terms of preferences allowed to be correlated inside segments
- Heterogeneity of preferences according to observed demographic characteristics

Model of demand

Utility of consumer i at date t, with demographic characteristics d for vehicle k belonging to segment g:

$$U_{ikt}^d = \beta^d p_{kt} + X_{kt}\gamma^d + f_t^d(\mathrm{CO}_{2kt}) + \xi_{kt}^d + \zeta_{igt}^d + (1-\sigma^d)\varepsilon_{ikt}^d$$

X_{kt} are observed vehicle characteristics (horsepower, fuel cost...), model and time fixed effects

$f_t^d(\mathrm{CO}_{2kt})$ represents the valuation of environmental quality, allowed to vary across time

ξ_{kt}^d are (time-varying) unobservable car characteristics / demand shocks
ζ_{igt}^d and ε_{ikt}^d are individual error terms:

- ζ_{igt}^d captures the within segment correlation
- ε_{ikt}^d are iid following an E.V. distribution
- $\zeta_{igt}^d + (1-\sigma)\varepsilon_{ikt}^d \sim$ E.V.

Nested logit model

Each consumer chooses the product that maximizes the utility :

$$Y_{it}^d = \arg \max_{k=0...J} U_{ikt}^d$$

Aggregation of individual optimal choices:

$$s_{kt}^d = \frac{\exp^{\delta_{kt}^d/(1-\sigma^d)}}{D_{gt}^{(\sigma^d)} \times \sum_{gt'=0}^{G} D_{gt'}^{(1-\sigma^d)}} \quad \text{with: } D_{gt} = \sum_{j \in \mathcal{J}_{gt}} \exp^{\delta_{jt}^d/(1-\sigma^d)}$$

Normalisation of outside option mean utility to 0:

$$\ln s_{kt}^d - \ln s_{0t}^d = \beta^d p_{kt} + X_{kt}\gamma^d + f_t^d(CO_{2kt}) + \sigma^d \ln \bar{s}_{kt/g}^d + \xi_{kt}^d,$$

- Linear equation, estimated by 2SLS
- Endogenous variables: prices and intra-group market shares
- Identification strategy: instruments correlated with $\bar{s}_{kt/g}^d$ and p_{kt} but not with ξ_{kt}^d
- Traditional instruments (BLP): functions of other products characteristics

Specification

Definition of 18 demographic groups:

- Age class ([18-29], [30-59], [$\geq$60])
- Income class ([0-22 000], [22 000-32 000], [$\geq$ 32 000])
- Rural area (-20 000 inhabitants) vs. urban area

Observable characteristics (X_{kt}) include:

- Price (**net feebate**), horsepower, weight, fuel cost
- Car body style, number of doors
- Time fixed effects
- Model fixed effects (constrained to be identical for all demographic groups)

Separately identify valuation of CO_2 emissions and valuation of fuel cost :

- Fuel prices change over time
- Relation between fuel cost and CO_2 emissions differ whether the car uses gas or diesel

Outline

Preferences for standard attributes

Variable	Estimate	Std err
Price ($\bar{\beta}$)	-0.057**	0.004
ln($\bar{s}$) (σ)	0.708**	0.006
Fuel cost	-0.076**	0.005
Weight	0.101**	0.006
Horsepower	0.105**	0.008
Station wagon car-body	-0.224**	0.007
Coupe/convertible	-0.123**	0.016
Three doors	-0.219**	0.006

Average of parameters across groups

▸ Heterogeneity in preferences

Price elasticities

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

Population mean $\simeq -4.5$

Comparison with previous analysis of the automobile market:

- Berry & al. (1995): $\eta \in$ [-6.5;-3.5]
- Train & Winston (2007): $\eta =$ -2.37

Preferences for environmental Quality

Variable	(1)	(2)	(3)
CO_2 emissions	-0.013	-0.198^{**}	-0.187^{**}
	(0.030)	(0.028)	(0.028)
CO_2 emissions$\times$Trend	-0.058^{**}		
	(0.002)		
CO_2 emissions$\times$2006		-0.078^{**}	
		(0.009)	
CO_2 emissions$\times$2007		-0.084^{**}	
		(0.01)	
CO_2 emissions$\times$2008		-0.287^{**}	-0.284^{**}
		(0.011)	(0.011)
CO_2 emissions$\times$(2006-2007)			-0.082^{**}
			(0.008)

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(2): Significant evolution of environmental preference from 2006

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(1): Trend significant

(2): Significant evolution of environmental preference from 2006

(3): Two shifts in environmental preference, 2006-2007 and 2008

Evolution of CO_2 emissions

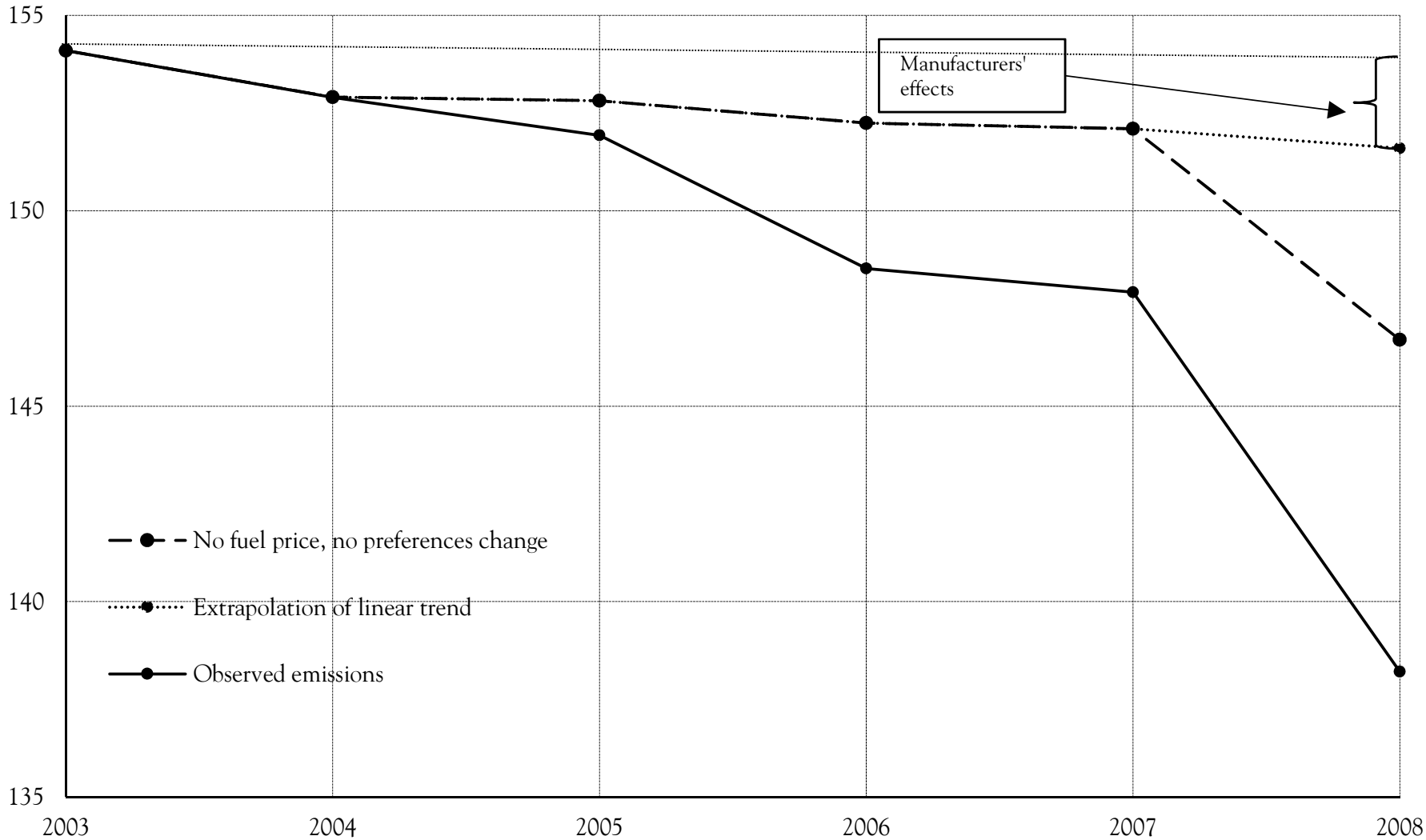
Decomposition of the evolution of average CO_2 emissions between 2003 and 2008:

- Manufacturers' effect
- Fuel prices
- Monetary effect of the feebate
- Preferences change effect

Methodology:

- Simulate counter-factual average CO_2 emissions:
  - Without increase in gas prices
  - Without change in preferences
- Use structural model of demand to compute market shares
- Compute average CO_2 emissions

Evolution of CO_2 emissions



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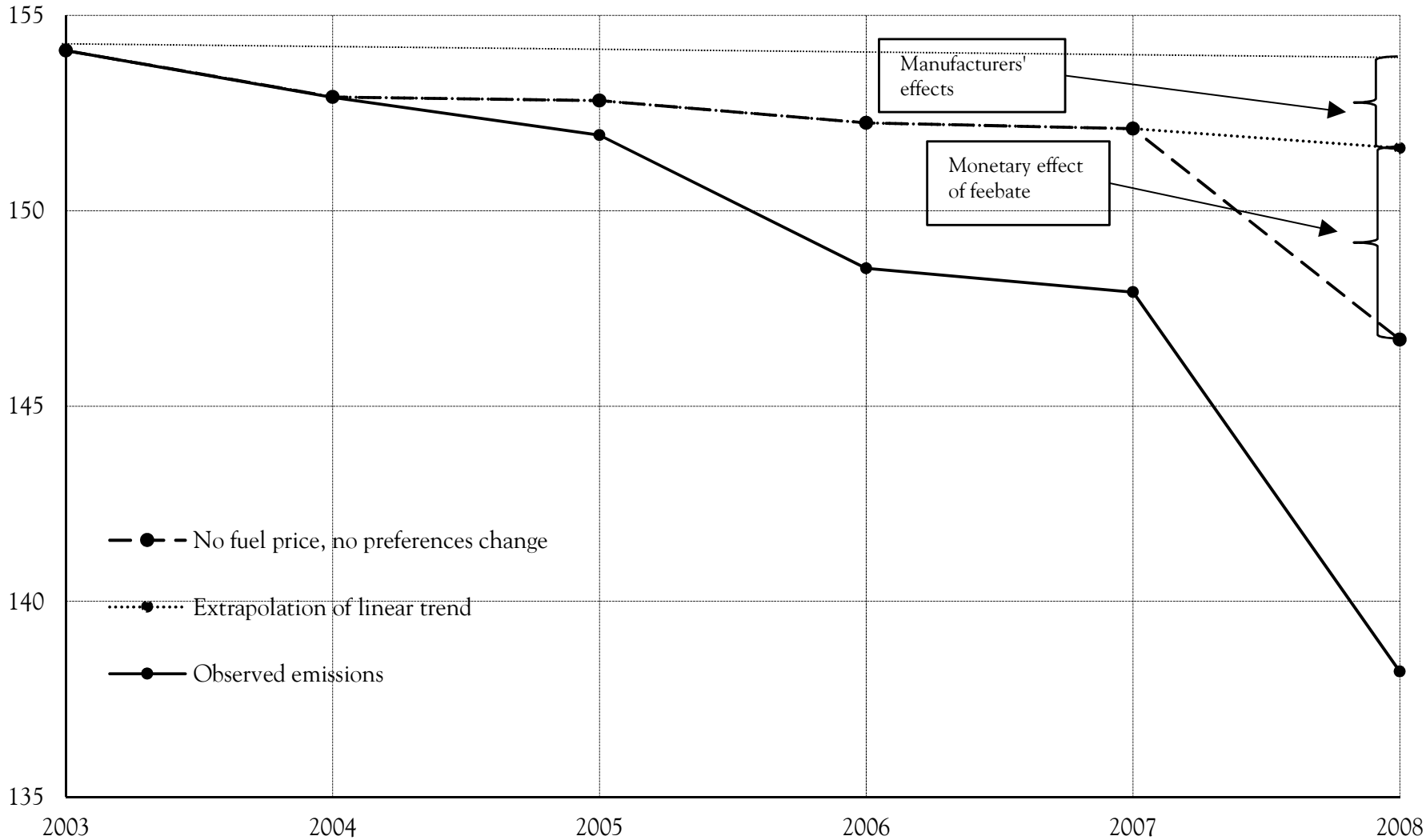

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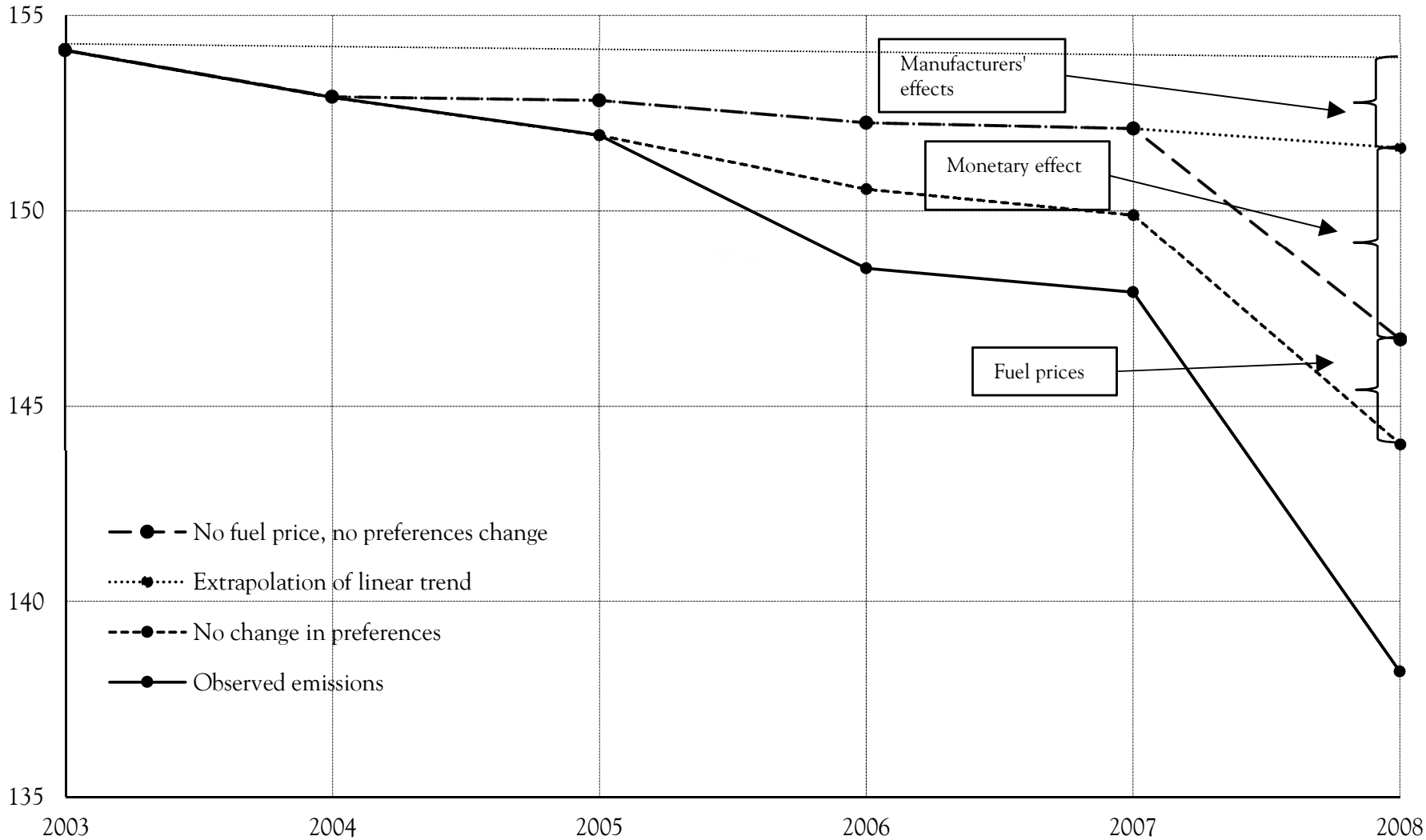

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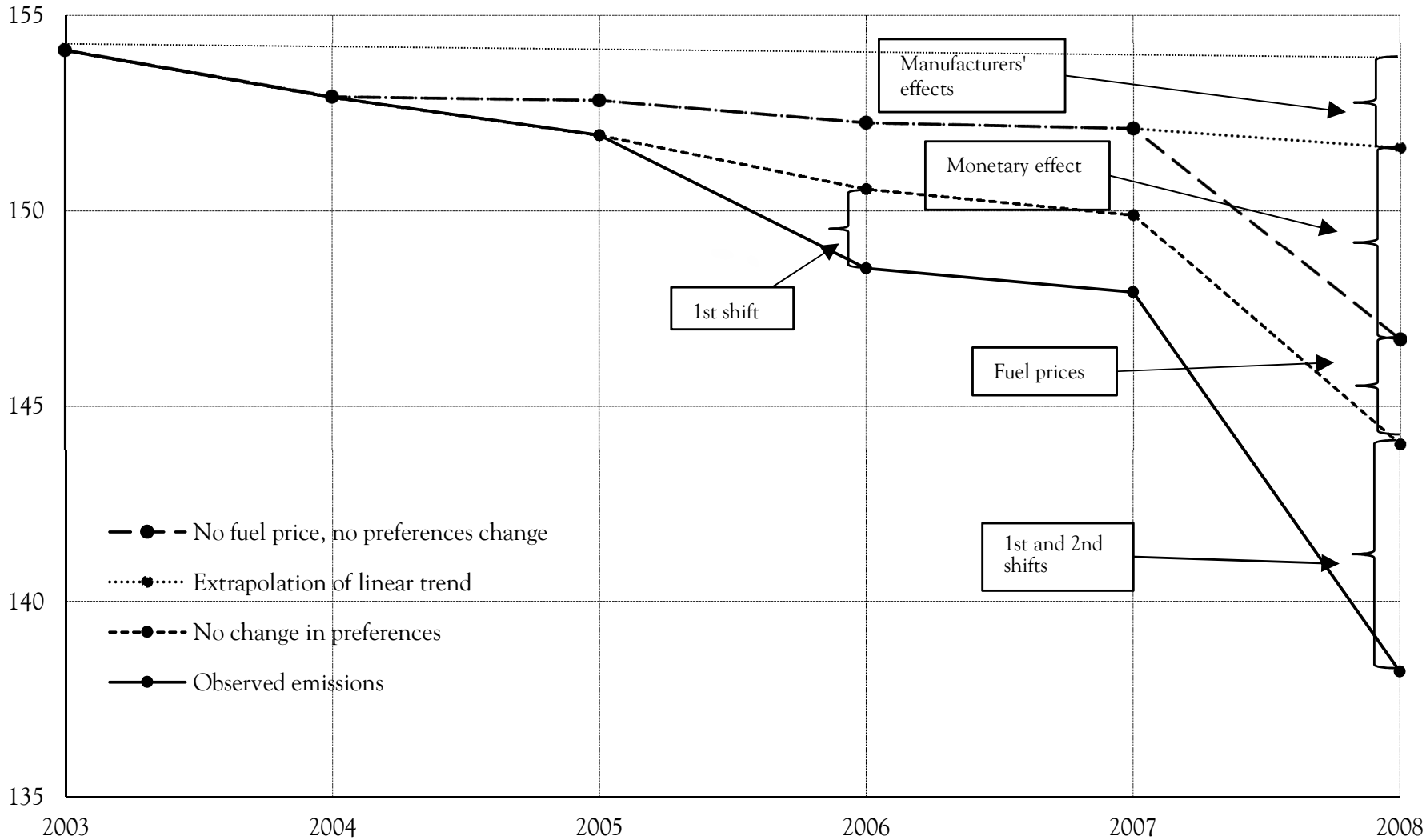

Evolution of CO_2 emissions

Factor	Amount (in g/km)	Percent
Changes in preferences	6.77	43%
2006-2007	2.24	14%
2008	4.53	29%
Fuel price	1.72	11%
Supply side	2.50	16%
Monetary (feebate)	4.90	31%
Overall decrease	15.89	100%

▸ Detail of the simulation

Heterogeneity in Changes of Preferences

Evolution of willingness to pay for a 10g reduction of CO_2 emissions: 2006-2007 and 2008 compared to 2003-2005

Average ΔWTP:

- 2006-2007: 151 €
- 2008: 562 €

		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)

Previous study (Brownstone et al, 2000): WTP = \$500-\$600 for alternative-fuel vehicles in California

Environmental Concern?

Correlation between average Δ WTP and electoral preferences in French towns (votes for 2007 presidential election)

	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)
Bayrou (center)	Ref.	Ref.
Sarkozy (right)	−13.6 (11.6)	2.2 (26.6)
Extreme right	−201.4** (10.9)	−632** (25.1)
Nb. obs	31,373	

Outline

Specification Tests

Variable	**(1)**	(2)	(3)	(4)
Fuel cost	−0.094**	−0.123**	−0.173**	−0.155**
	(0.005)	(0.005)	(0.006)	(0.006)
CO_2 emissions	−0.013	0.165**	0.291**	0.259**
	(0.03)	(0.033)	(0.031)	(0.031)
CO_2 × Trend	−0.058**	−0.115**	−0.049**	−0.057**
	(0.002)	(0.005)	(0.002)	(0.003)
Fuel cost×Trend		0.010**		
		(0.001)		
Diesel			−0.250**	−0.137**
			(0.015)	(0.022)
Diesel×Trend				−0.016**
				(0.002)

(1) Base specification

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(1) Base specification

(2) Fuel cost × trend

(3) With diesel

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(1) Base specification

(2) Fuel cost × trend

(3) With diesel

(4) With diesel and diesel × trend

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(2) Fuel cost × trend

(3) With diesel

(4) With diesel and diesel × trend

Specification Tests

Variable	(1)	(5)	(6)	(7)
Fuel cost	-0.094^{**}		-0.135^{**}	-0.090^{**}
	(0.005)		(0.007)	(0.005)
Fuel cost^2			0.002^{**}	
			(0.000)	
CO_2 emissions	-0.013	-0.465^{**}	0.021	-0.652^{**}
	(0.03)	(0.025)	(0.031)	(0.048)
$CO_2 \times$ Trend	-0.058^{**}	-0.078^{**}	-0.063^{**}	-0.046^{**}
	(0.002)	(0.003)	(0.002)	(0.002)
km/euro		0.002^{**}		
		(0.002)		
CO_2 emissions^2				0.156^{**}
				(0.011)

(1) Base specification

Specification Tests

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km/euro		0.002**		
		(0.002)		
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(1) Base specification

(5) km/euro instead of fuel cost (euro/km)

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		(0.002)		
CO_2 emissions^2				0.156**
				(0.011)

(1) Base specification

(5) km/euro instead of fuel cost (euro/km)

(6) With fuel cost^2

Specification Tests

Variable	(1)	(5)	(6)	**(7)**
Fuel cost	−0.094**		−0.135**	−0.090**
	(0.005)		(0.007)	(0.005)
Fuel cost^2			0.002**	
			(0.000)	
CO_2 emissions	−0.013	−0.465**	0.021	−0.652**
	(0.03)	(0.025)	(0.031)	(0.048)
CO_2 × Trend	−0.058**	−0.078**	−0.063**	−0.046**
	(0.002)	(0.003)	(0.002)	(0.002)
km/euro		0.002**		
		(0.002)		
CO_2 emissions^2				0.156**
				(0.011)

(1) Base specification

(5) km/euro instead of fuel cost (euro/km)

(6) With fuel cost^2

(4) With CO_2 emissions^2

Using classes of CO_2 emissions

Another variable to measure environmental quality

"Positive classes"		"Negative classes"	
A ×(2006-2007)	0.025	E ×(2006-2007)	-0.026**
A ×(2008)	0.36**	E+ ×(2008)	-0.033*
B ×(2006-2007)	0.177**	E- ×(2008)	-0.103**
B ×(2008)	0.602**	F ×(2006-2007)	-0.028*
C ×(2006-2007)	0.115**	F ×(2008)	-0.209**
C+ ×(2008)	0.19**	G ×(2006-2007)	0.007
C- ×(2008)	0.173**	G ×(2008)	-0.051**

Increase in valuation of "positive classes"

Decrease in valuation of "negative classes"

Conclusion

Main results:

- Evidence of change in consumers' valuation of environmental quality
- Timing in line with the two policies
- Energy label efficient to provide information
- "Crowding in" seems at stake for the feebate policy

- Our results are consistent with growing environmental concern
- Measure of WTP for environmental quality using revealed preferences

Consequence for policy design and evaluation:

- Government could not anticipate these effects when the feebate scheme was designed
- Initially designed to be cost neutral eventually cost 285M€ in 2008!
- See companion paper about unpredictability of the cost of the policy (*Revue Économique, 2011*)

Heterogeneity in valuation

	Rural	Urban
Price	-0.062^{**}	-0.054^{**}
	(0.004)	(0.004)
$\ln(\bar{s})$	0.718^{**}	0.701^{**}
	(0.006)	(0.006)
Fuel cost	-0.103^{**}	-0.057^{**}
	(0.005)	(0.005)
Weight	0.113^{**}	0.093^{**}
	(0.006)	(0.006)
HP	0.113^{**}	0.099^{**}
	(0.008)	(0.008)
Break	-0.185^{**}	-0.252^{**}
	(0.008)	(0.008)
Coupe	-0.116^{**}	-0.129^{**}
	(0.016)	(0.017)
Three doors	-0.223^{**}	-0.215^{**}
	(0.007)	(0.008)
CO_2 emissions	-0.014	-0.311^{**}
	(0.03)	(0.033)
$CO_2 \times$ 2006-07	-0.067^{**}	-0.094^{**}
	(0.01)	(0.011)
$CO_2 \times$ 2008	-0.273^{**}	-0.292^{**}
	(0.014)	(0.015)

▸ go back

Heterogeneity in valuation

	[18;39]	[40;59]	≥ 60
Price	-0.084^{**} (0.004)	-0.054^{**} (0.004)	-0.039^{**} (0.004)
$\ln(\bar{s})$	0.743^{**} (0.007)	0.769^{**} (0.007)	0.616^{**} (0.006)
Fuel cost	-0.116^{**} (0.005)	-0.089^{**} (0.005)	-0.032^{**} (0.005)
Weight	0.109^{**} (0.006)	0.107^{**} (0.006)	0.089^{**} (0.006)
HP	0.189^{**} (0.008)	0.091^{**} (0.008)	0.056^{**} (0.008)
Break	-0.185^{**} (0.009)	-0.165^{**} (0.008)	-0.318^{**} (0.009)
Coupe	0.148^{**} (0.018)	-0.065^{**} (0.016)	-0.392^{**} (0.019)
Three doors	-0.077^{**} (0.008)	-0.168^{**} (0.007)	-0.381^{**} (0.01)
CO_2 emissions	-0.202^{**} (0.037)	0.071^{*} (0.031)	-0.456^{**} (0.037)
$CO_2 \times$ 2006-07	-0.148^{**} (0.014)	-0.078^{**} (0.01)	-0.037^{**} (0.014)
$CO_2 \times$ 2008	-0.338^{**} (0.021)	-0.289^{**} (0.015)	-0.239^{**} (0.018)

go back

Heterogeneity in valuation

	Low	Medium	High
Price	−0.039**	−0.061**	−0.064**
	(0.004)	(0.004)	(0.004)
ln(s)	0.616**	0.687**	0.707**
	(0.006)	(0.006)	(0.006)
Fuel cost	−0.032**	−0.09**	−0.091**
	(0.005)	(0.005)	(0.005)
Weight	0.089**	0.084**	0.115**
	(0.006)	(0.006)	(0.006)
HP	0.056**	0.118**	0.121**
	(0.008)	(0.008)	(0.008)
Break	−0.318**	−0.233**	−0.225**
	(0.009)	(0.009)	(0.009)
Coupe	−0.392**	−0.109**	−0.112**
	(0.019)	(0.018)	(0.018)
Three doors	−0.381**	−0.193**	−0.23**
	(0.01)	(0.009)	(0.009)
CO_2 emissions	−0.456**	−0.196**	−0.2**
	(0.037)	(0.035)	(0.035)
$CO_2 \times$ 2006-07	−0.037**	−0.03*	−0.106**
	(0.014)	(0.013)	(0.013)
$CO_2 \times$ 2008	−0.239**	−0.147**	−0.359**
	(0.018)	(0.018)	(0.018)

▸ go back

Simulation of average CO_2 emissions

Year	Observed	No fuel price increase	No preferences changes No fuel price increase
2003	154.1	154.1	154.1
2004	152.91	152.91 (0.004)	152.91 (0.004)
2005	151.93	152.82 (0.025)	152.82 (0.025)
2006	148.53	150.00 (0.045)	152.24 (0.227)
2007	147.92	149.84 (0.061)	152.10 (0.232)
2008	138.20	139.92 (0.055)	146.70 (0.33)

go back