Distributional and Environmental Effects of an Emissions-Differentiated Car Sales Tax

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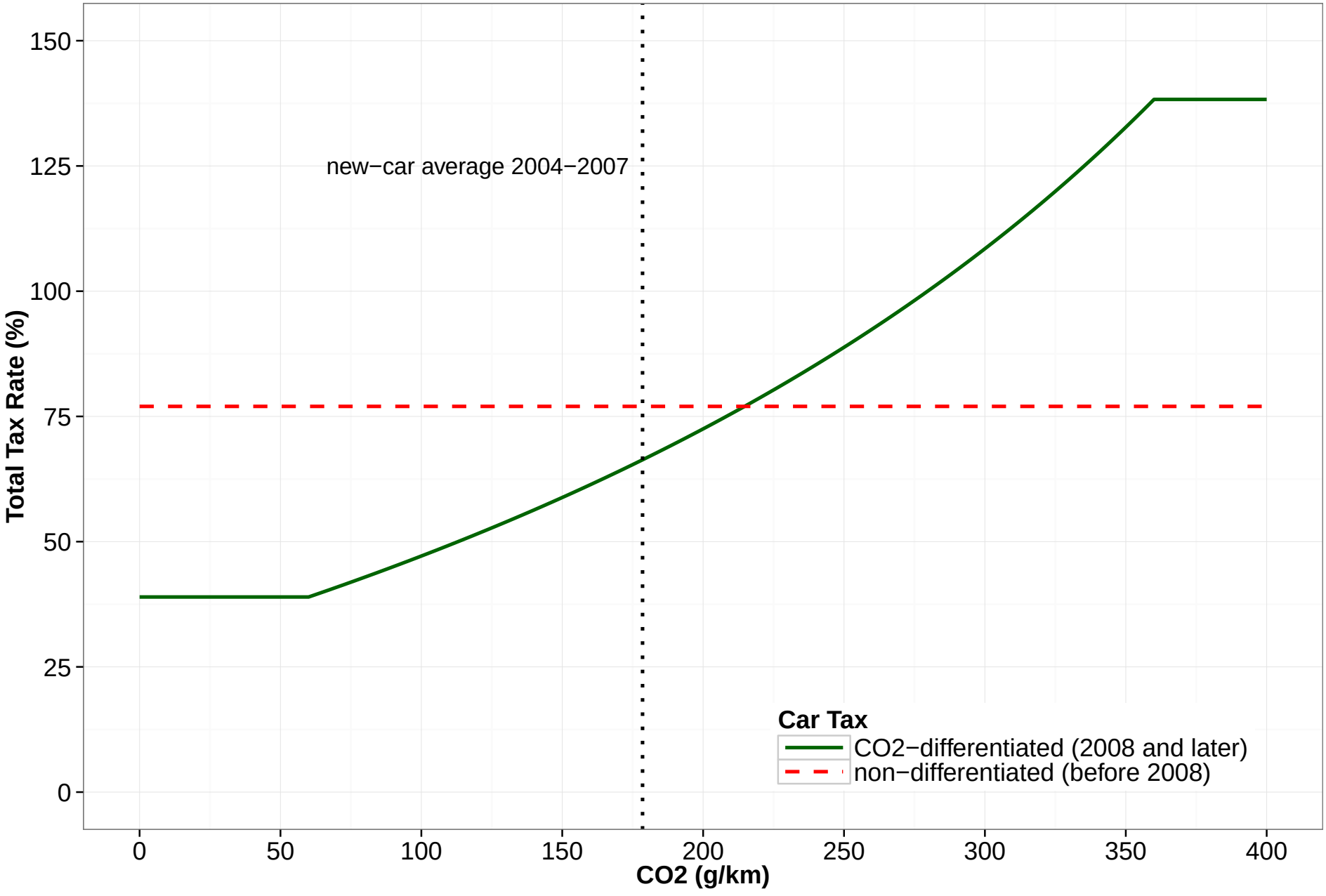
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125
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75
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Total Tax Rate (%)
new−car average 2004−2007
0
50
100
150
200
250
300
350
400
CO2 (g/km)
Car Tax
CO2−differentiated (2008 and later)
non−differentiated (before 2008)

Reseach Questions

How did the Car Tax Reform Affect the Market for New Cars?

- Environmental Effects
  - What are the environmental effects?
  - What is driving the observed decline of new-car CO_2 emissions rates?
- Distributional Effects
  - Who are the winners and losers of this environmental policy?

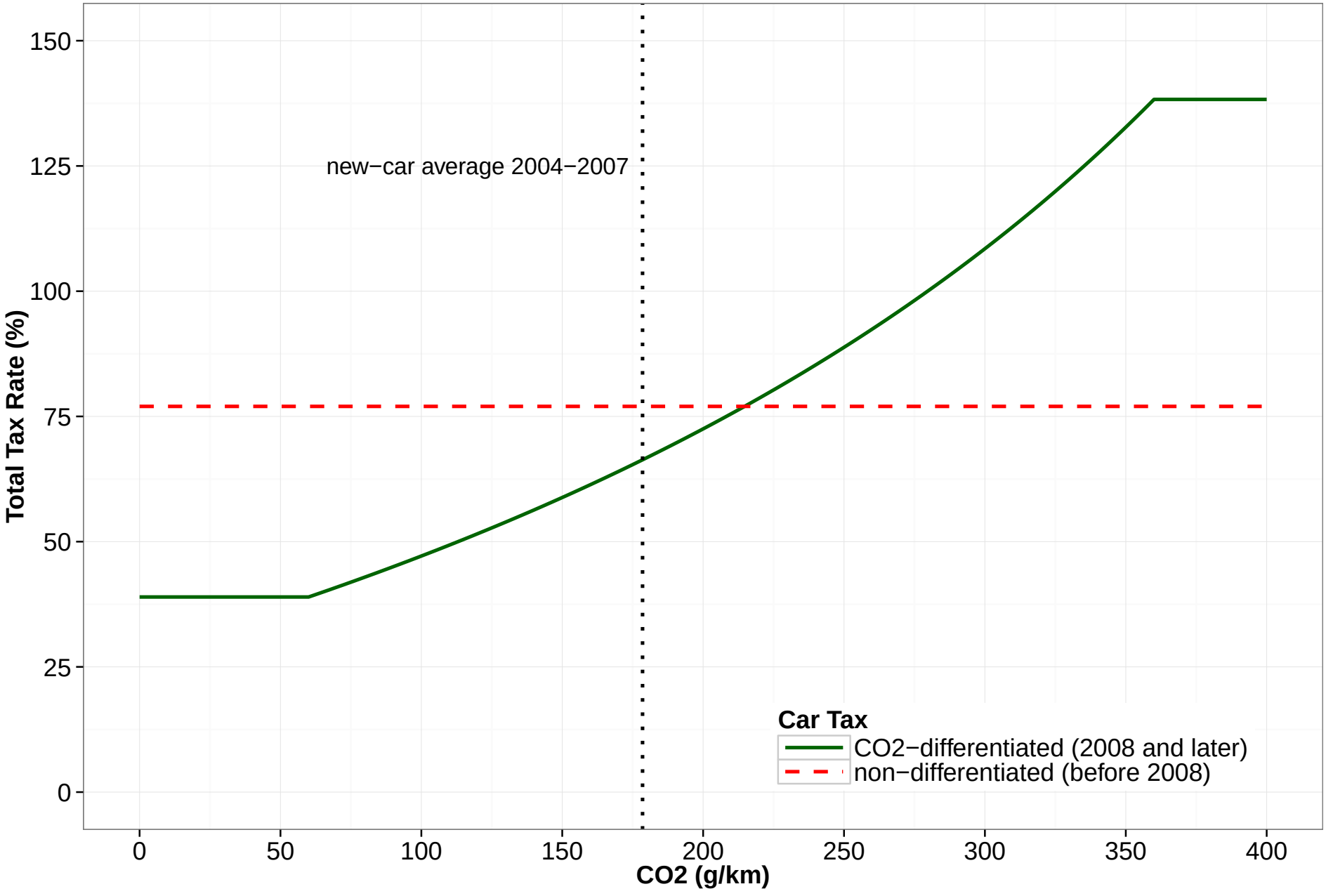
This Paper

Differentiated-product oligopoly model

- based on Berry et al. (1995, "BLP") & Petrin (2002)
- Random-coefficient logit demand w. heterogeneous consumers
- Nash-Betrand price competition w. strategic price-setting

Benefits of Institutional Setup

- Small market size $\rightarrow$ exogenous product characteristics
- Novel, reliable register data
- New IV based on tax rate differentiation by CO2 emissions rating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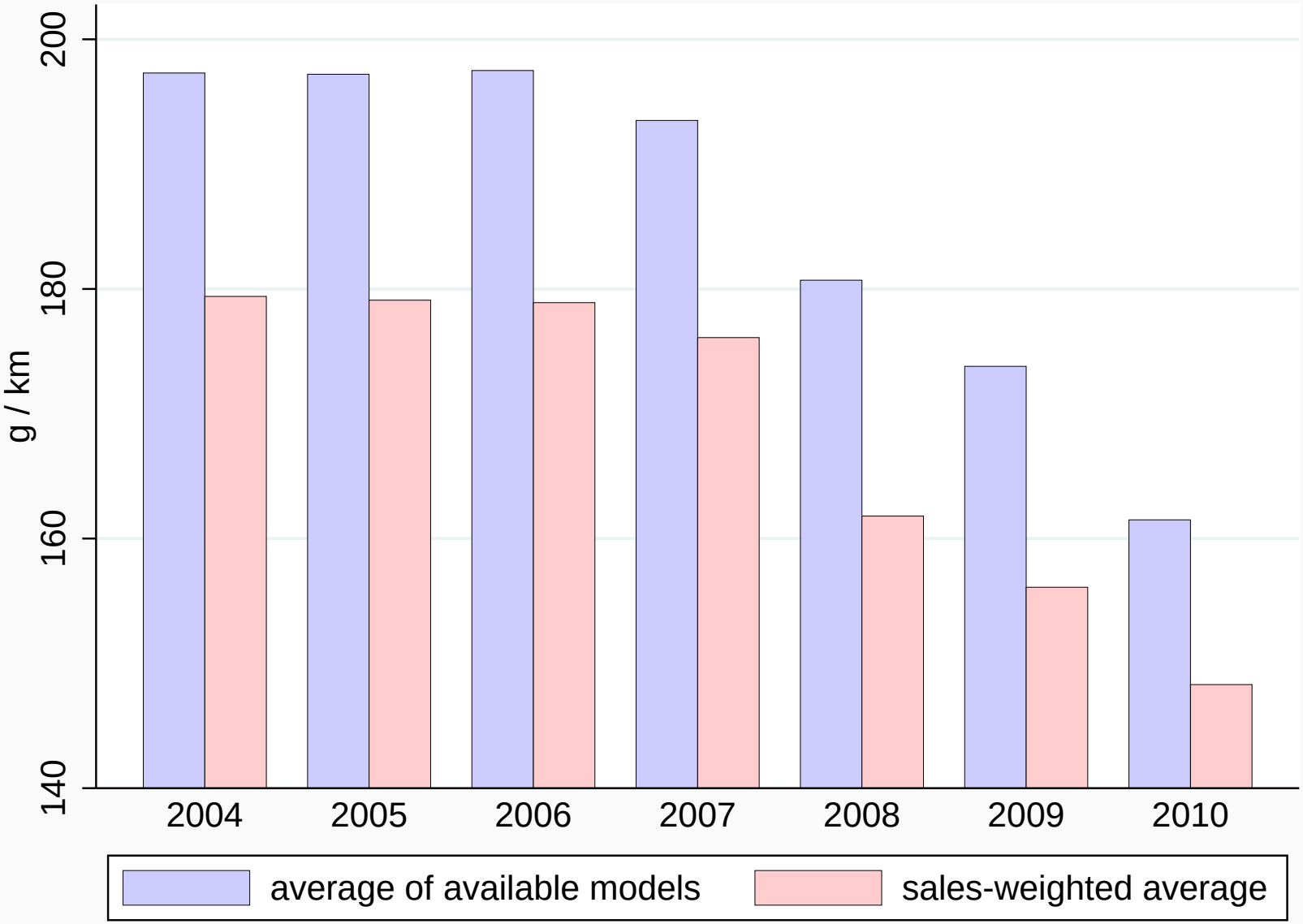
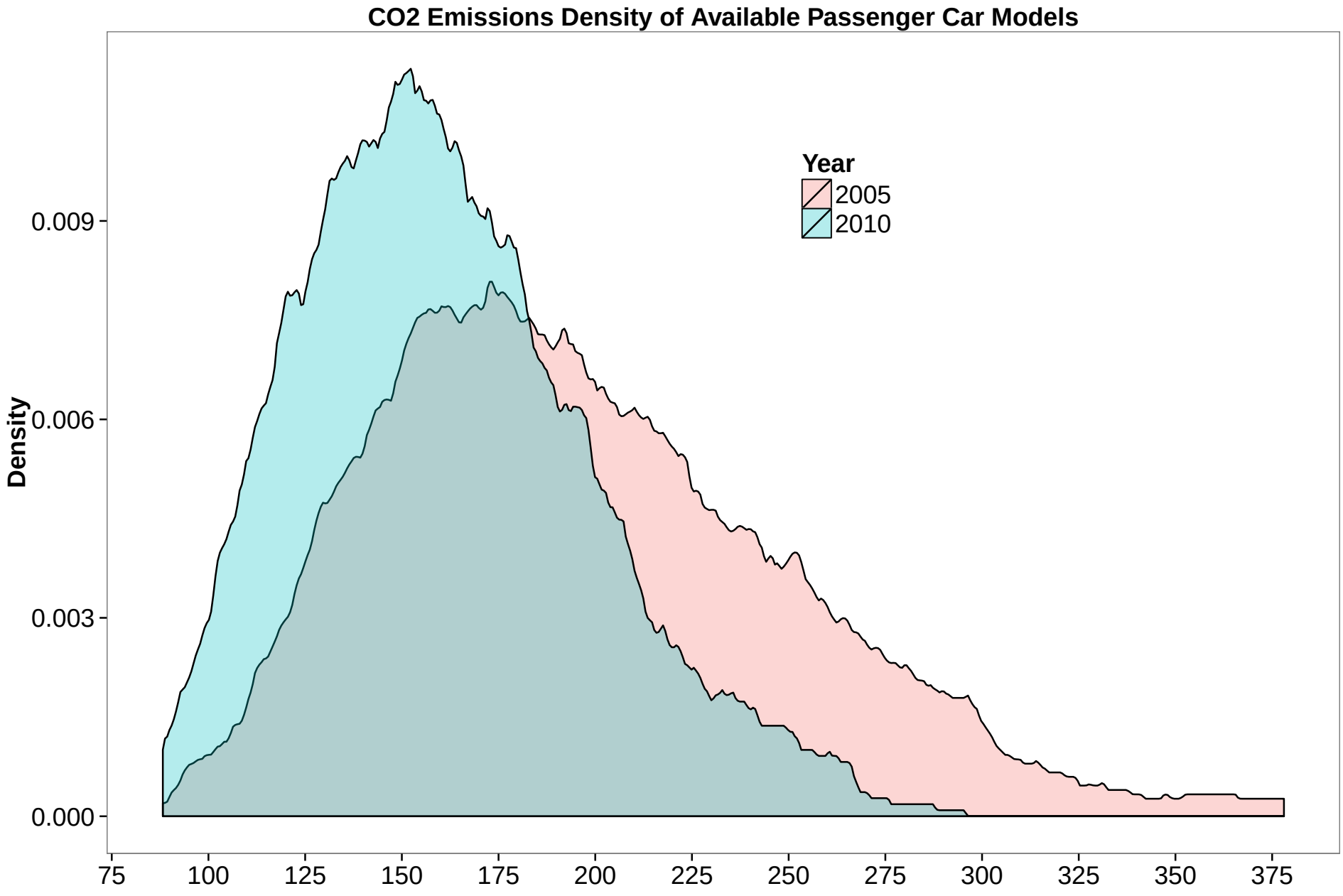
CO2 Emissions Rates of New Cars




CO2 Emissions Density of Available Passenger Car Models
Year
2005
2010
Density
0.009
0.006
0.003
0.000
75
100
125
150
175
200
225
250
275
300
325
350
375

Key Results

Decline of CO_2 emissions rates not driven by tax policy

- Effect on 2008-2010 CO_2 emissions rate: - **1.9 g/km**
- Compared to **27.8 g/km** decline from 2007 to 2010

Increased local pollution

- CO_2-based taxation favors diesel engines
- **9.5%** more new cars and **11.3%** higher diesel market share

Positive net welfare effect but regressive policy

- Loss of tax revenue
- Disproportional benefit to high-income consumers

Supply: Multi-Product Oligopoly Pricing

- F multi-product firms engage in pure-strategy **Nash-Betrand price competition**
- Operating profits of firm f:

$$\pi_f(\boldsymbol{p^f}) = \sum_{j \in f} \left(\frac{p_j}{1 + \underbrace{\tau_j(CO2_j)}_{\text{tax rate}}} - mc_j(C_j; \boldsymbol{\theta}) \right) \times \underbrace{s_j(\boldsymbol{p}; \boldsymbol{X}; \boldsymbol{\theta})\, M}_{\text{demand for car } j}$$

- C_j: cost characteristics of car j
- $CO2_j$: CO_2 emissions rating of car j

Demand: Indirect Utility

- Conditional indirect utility of household i:

$$u_{i,j} = \alpha_i \, p_j + \beta_i \, X_j + \xi_j + \epsilon_{i,j}$$

where

  - p_j: consumer price (including tax)
  - X_j: observed non-price product characteristics
  - ξ_j: Unobserved product quality / demand shock
  - $\epsilon_{i,j}$: idiosyncratic logit taste shock

Data & Estimation

Sources: Government Register Data 2004-2010

- **Cars:** vehicle registration database + car tax database
- **Households:** Finnish Linked Employee-Employer Data
  - Distribution of net household income
  - Net household income of car-buying households

Estimation

- **GMM estimation:** **Berry et al. (1995,1999)** & **Petrin (2002)**
- **Micro moments:** income group probabilities conditional on car purchase
- **New IV:** CO_2 tax IV to complement BLP instruments

Equilibrium Effects of 2008 Car Tax Reform

2008-2010 Percentage Change of

	CO2 emissions level (g/km)				
	< 130	130-159	160-199	200-249	≥ 250
Mean price*	-10.8	-8.3	-5.9	-0.3	5.6
Mean markup*	12.3	11.1	9.5	6.8	-2.0
Mean tax*	-29.6	-22.5	-15.3	-0.8	11.1
Sales	20.8	12.8	6.3	-14.2	-35.2

* weighted by sales under non-differentiated tax system

- Firms have (limited) market power
- Strategic pricing mitigates intended pass-through to consumer prices

Distributional Effects of 2008 Car Tax Reform

Aggregate Welfare Effects 2008-2010

Variable (Mio. €)	Change
Tax revenue	- 352
Firms' profits	234
Consumer welfare	572
CO_2	- 5
Other externalities	- 188
Net welfare	260

Distribution of consumer welfare change (2010)

Net HH Income	Δ CW	Δ CW | purchase*
$< 25.303\,€$	10 €	1,200€
$25.303\,€ - 42.899\,€$	34 €	1,388 €
$> 42.899\,€$	71 €	1,877 €

Concluding Remarks

This paper

- estimates differentiated-product oligopoly model
- evaluates fiscal policy using counterfactual simulations

Implications for optimal policy

- **Tax design:** tax incidence and market structure matter
- **CO_2-Based Car Taxation:**
  - little effect on CO_2 emissions rates given concurrent supply-side standards
  - local vs. global pollution trade-off due to Diesel fuel
- **Coordination** between different levels of government crucial

Environmental Effects of 2008 Car Tax Reform

2008-2010

Variable	Change	percent
Market size (sales)	27,833	9.5 %
Diesel mkt share (%)	4.8	11.3 %
CO_2 (g/km)	-1.9	-1.2 %

- Negative CO_2 trend not driven by domestic tax policy
- Effect on total lifetime emissions economically unimportant
- Preferable tax treatment of diesel cars
  $\rightarrow$ **local pollution problem**

Demand: Random Coefficients

- **Price Coefficient:**

$$\alpha_i(y_i) = \begin{cases} \alpha_1/y_i & \text{if } y_i < \bar{y}_1 \\ \alpha_2/y_i & \text{if } \bar{y}_1 \leq y_i < \bar{y}_2 \\ \alpha_3/y_i & \text{if } y_i > \bar{y}_2, \end{cases} \tag{1}$$

  y_i: net household income
  $\rightarrow$ poorer households more price sensitive than richer ones

- Random coefficients on non-price product characteristics normally distributed

Mean Effects of 2008 Car Tax Reform

2008-2010

Variable	Change	Percent
Price*	-2,046	-7.3 %
Markup*	307	8.1 %
Tax*	-2,335	-19.4 %

* weighted by sales under non-differentiated tax system

in 2005 Euros

Supply: Marginal Costs

- Firms produce at constant marginal cost mc_j
- Log marginal costs linear in cost components:

$$\log(\text{mc}_j) = rC_j + \omega_j$$

where

  - C_j: observed cost component
  - ω_j: unobserved cost component

Supply: Multi-Product Oligopoly Pricing

- F firms engage in pure-strategy **Nash-Betrand price competition**

- Operating profits of firm f:

$$\pi_f = \sum_{j \in f} \Big(\overbrace{\frac{p_j}{1 + \underbrace{tr_j}_{\text{model-specific tax rate}}}}^{\text{producer price}} - mc_j \Big) \underbrace{s_j(\boldsymbol{p}; \boldsymbol{X}; \boldsymbol{\theta})\, M}_{\text{demand for car model } j}$$

- J FOCs for static price competition:

$$s_j(\boldsymbol{p}; \boldsymbol{X}; \boldsymbol{\theta}) + \sum_{r \in \mathcal{F}_f} \Big(\frac{p_r}{1 + tr_r} - mc_r \Big) \frac{\partial s_r(\boldsymbol{p}; \boldsymbol{X}; \boldsymbol{\theta})}{\partial p_j} = 0 \quad \forall j \in \mathcal{F}_f.$$

Estimation via 2-Step GMM

Moment Sets

- Market shares: $s - s(\boldsymbol{\theta}) = 0$
  $\rightarrow$ predicted market shares equal observed shares
- Demand: $E\left[\xi(\boldsymbol{\theta})' Z\right] = 0$
  $\rightarrow$ demand shocks orthogonal to instrument vector Z
- Supply: $E\left[\omega(\boldsymbol{\theta})' Z\right] = 0$
  $\rightarrow$ supply shocks orthogonal to instrument vector Z
- Micro: income tercile probabilities conditional on purchase

$$E\left[I^i_{FLEED}\ \{y_i < \bar{y}_1 | \text{purchase}\} - \bar{P}_{model}\ (y < \bar{y}_1 |\ \text{purchase};\ \theta)\right] = 0$$

$$E\left[I^i_{FLEED}\ \{y_1 \leq y_i \leq \bar{y}_2 | \text{purchase}\} - \bar{P}_{model}\ (\bar{y}_1 \leq y_i \leq \bar{y}_2 |\ \text{purchase};\ \theta)\right] = 0$$

$$E\left[I^i_{FLEED}\ \{\bar{y}_1 \leq y_i \leq \bar{y}_2 | \text{purchase}\} - \bar{P}_{model}\ (y_i > \bar{y}_2 |\ \text{purchase};\ \theta)\right] = 0$$

Instrumental Variables

Intuition

- Price: function of attributes of cars produced by other firms.
- Consumer valuation of car j independent of rival cars
- Multi-product extension: characteristics of other cars by same firm

Standard Breshnahan et al.(1997)/ BLP(1995) instruments

- sum of characteristics over firms' other products
- sum of characteristics over products of competing firms
- also by fuel-type segment

Demand Parameter Estimates

Demand Variable	Mean	Standard Deviation
Constant	-18.470**	6.292**
	(2.587)	(1.731)
Curb weight (100kg)	5.615**	1.463**
	(1.263)	(0.568)
Power / weight	4.849**	2.417**
	(1.115)	(1.083)
Fuel cost (EUR / 100km)	-0.276**	
	(0.066)	
Diesel engine	-1.342**	** z-statistics > 2
	(0.346)	* z-statistics > 1
- Price / Income α_1	5.956**	Not shown:
	(1.453)	Market segment, time,
- Price / Income α_2	6.592**	brand-level fixed-effects
	(1.355)	
- Price / Income α_3	8.255**	N = 2,156
	(2.424)	

Cost Parameter Estimates

Cost Variable	Mean
Constant	2.574**
	(0.237)
Log engine power	0.611**
	(0.063)
Log curb weight	1.338**
	(0.160)
Log fuel consumption	-0.202
	(0.103)
Diesel engine	0.034*
	(0.0034)

Robust standard errors in parentheses.

* z-statistics > 1, ** z-statistics > 2

Number of observations used in estimation = 2,156

Not shown: Market segment, time, and brand-level fixed-effects