Welfare Implications of CO_2-Based Feebates for Automobiles: A Simulation Analysis for Germany

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Background

- Transportation is globally the largest final energy consuming sector
  [23% of global energy-related CO_2 emissions (30% in OECD countries), 15% of total global GHG emissions]
- Share in energy use and GHG emissions projected to increase in the future (mainly in non-OECD)
- Deep transport CO_2 reductions required in order to meet the global 2-degrees stabilization target
- It may take time for biofuels and new technologies (hybrids, fuel cells etc.) to be effective fleet-wide
- Basic policies discussed:
  - Fuel economy / CO_2 emission standards
  - Fuel taxes

Vehicle Taxes

- Very different across European countries; taxation is considered a matter of national sovereignty; in most countries vehicle taxes are not fuel-neutral
- But currently most countries base vehicle taxes – at least partly – on CO_2 emissions
- Current taxation schemes in many European countries imply very high costs per ton of carbon
- Company car taxation is different; may compromise the effectiveness of such policy instruments

Feebates – A promising type of vehicle tax?

- Cars emitting CO_2 above a threshold (e.g. 130 g/km) pay a fee; those emitting less than the threshold receive a rebate
- If tax rate is constant (for each g/km) then marginal compliance costs are equalized across all car models; probably the economically efficient outcome
  - But most current systems do not apply constant tax rates
- If threshold decreases over the years, feebates provide a credible long-term price signal that can stimulate innovation – technology-neutrally
  - Can convince economists because the cost of carbon emissions increases over the years

Features of Feebates

- Market-based instrument
- Equivalent to a flexible fuel economy / CO_2 standard
- Oriented to consumers because they directly affect car prices, in contrast to standards that impose an obligation on the supply side
- Can be designed to be revenue-neutral
  - But current real-world applications (e.g. Netherlands, France, Ireland) turned out to be costly for governments
- Not detrimental to consumer ‘welfare’: consumers can shift to low-carbon cars in the same segment
- Impressive results from implementation in France & Norway: significant drop in new-car CO_2 emissions

Our Modelling Approach – 1

- Discrete-choice consumer demand model for differentiated products (automobiles)
- Structural estimation of demand by heterogeneous consumers with Nested Multinomial Logit model (Berry S., *Rand Journal of Economics* 25, 242–262)
- NML model relatively simple, allows for linear estimation techniques for multiple policy simulations without large computational burden (compared to random coefficients model of Berry, Levinsohn & Pakes, *Econometrica* 63, 841–889)
- We use two levels of nests to allow for more consumer heterogeneity – and estimate several variants of the NML model to be more confident that policy conclusions are not specification-dependent

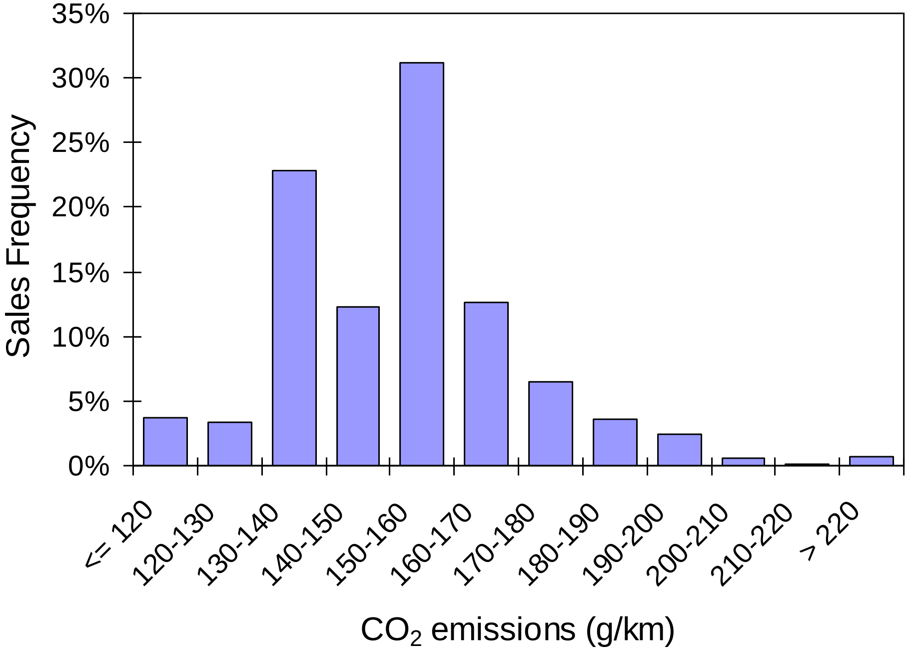
Data

- Automotive data obtained from ‘JATO Dynamics’ after a tender process
- Coverage: 9 EU countries (AT, BE, DE, DK, GR, IT, NL, PT, ES), period: 1998–2008
- Dataset includes following variables:

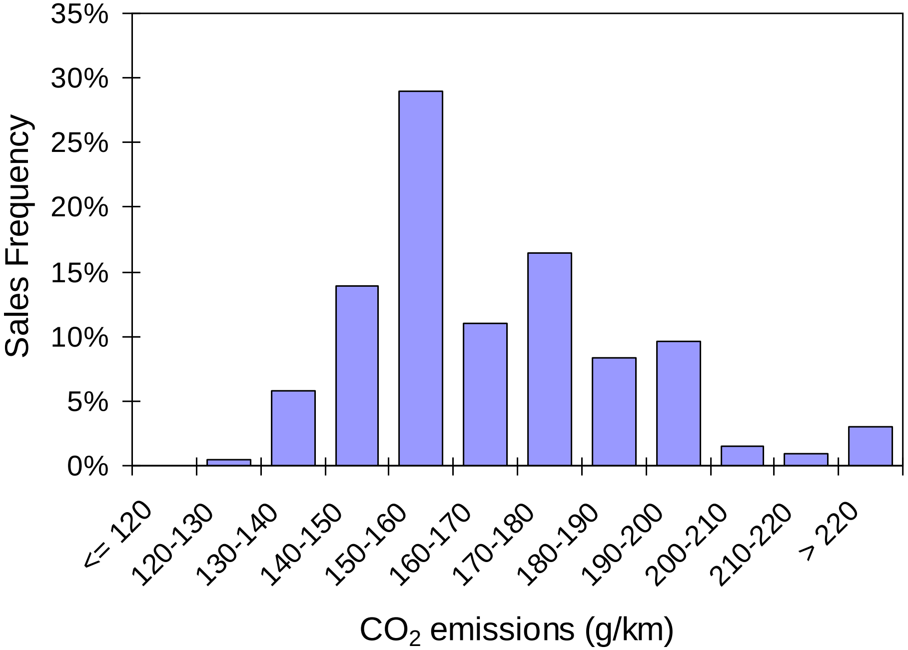
Make
Model
Vehicle length
Vehicle width
Engine size
Max. engine power
Max. torque
Fuel type
Transmission type
Body type
Max. speed
Acceleration 0-100 km/h
Fuel consumption

CO_2 emissions
Airbag for driver seat offered as standard
Airbag for passenger seat offered as standard
Air conditioning system offered as standard
Climate control offered as standard
Segment type
Retail price
Sales volume

CO_2 Emissions Distribution of Cars Sold in Germany in Year 2008



Market segment
'Lower medium-sized cars'



Market segment
'Upper medium-sized cars'

Different model specifications

- Two alternative ways to aggregate observations of the dataset:
  - Cars grouped according to model, engine type (gasoline/diesel) and engine size (e.g. 1151-1250 cc, 1251-1350 cc etc.) (6061 observations)
  - Cars grouped according to model and engine type only (3139 observations)
- Two ways that price enters the demand equation:
  - Linearly (leads to more dispersed elasticities, which are a linear function of price)
  - Logarithmically (produces more dispersed markups; implies constant expenditure)
- IV estimation using standard + alternative approach to select instruments

Descriptive Statistics of Data for Germany
(6061 observations aggregated from > 150,000 individual models in the database)

Class	Obs.	Eng. disp.	CO_2 emis.	Sales	Price
Gasoline engine					
Small	705	1.33	0.149	6466	13.358
Medium	649	1.76	0.182	4660	19.884
Large	749	2.25	0.212	2497	29.496
Luxury	412	3.23	0.258	1179	53.155
SUV	421	2.90	0.268	987	37.229
Sport	408	2.63	0.229	1444	42.667
MPV	669	1.87	0.198	2662	22.654
Diesel engine					
Small	273	1.47	0.122	2227	15.037
Medium	280	1.84	0.143	7139	21.376
Large	378	2.13	0.167	7201	29.315
Luxury	230	2.81	0.213	4757	50.002
SUV	325	2.68	0.244	2849	40.343
Sport	49	2.16	0.164	1211	35.245
MPV	513	1.96	0.172	3508	25.378

Source: *JATO Dynamics.*

Econometric estimation results

Variables	Aggregate		Disaggregate linear		Disaggregate logarithmic	
	OLS	IV	OLS	IV	OLS	IV
α (price)	-0.0094**	-0.054**	-0.0048**	-0.038**	-0.36**	-2.02**
	(0.00041)	(0.0058)	(0.00029)	(0.0022)	(0.011)	(0.091)
σ_1 (group)	0.999**	0.530**	0.99**	0.95**	0.99**	0.84**
	(0.0015)	(0.170)	(0.012)	(0.016)	(0.0011)	(0.020)
σ_2 (subgroup)			0.99**	0.91**	0.98**	0.71**
			(0.0025)	(0.014)	(0.0024)	(0.020)
Engine capacity	0.045**	0.316**	-0.17**	0.062**	-0.17**	0.046*
	(0.0052)	(0.089)	(0.0061)	(0.017)	(0.0056)	(0.019)
CO_2 emissions	1.86**	-3.52	2.53**	1.57**	2.62**	0.37
	(0.082)	(2.26)	(0.066)	(0.24)	(0.062)	(0.33)
Horsepower	1.25**	4.62**	1.88**	4.69**	2.35**	5.79**
	(0.091)	(1.32)	(0.068)	(0.27)	(0.065)	(0.30)
Frame	-0.062**	0.058†	-0.047**	0.025**	-0.0025	0.28**
	(0.0033)	(0.032)	(0.0024)	(0.0057)	(0.0028)	(0.015)
Manual gearbox	0.011	-0.15*	-0.015**	-0.16**	-0.020**	-0.14**
	(0.0076)	(0.062)	(0.0053)	(0.013)	(0.0049)	(0.016)
Climate control	0.0043	0.020	0.0028	0.051**	0.027**	0.15**
	(0.0056)	(0.039)	(0.0041)	(0.0098)	(0.0040)	(0.015)
Constant	-3.04**	-5.82**	-3.00**	-3.59**	-0.0027	12.90**
	(0.025)	(0.98)	(0.019)	(0.083)	(0.091)	(0.77)
F-test	24,727.15**	262.35**	36,826.02**	3,134.33**	41,526.77**	1,428.98**
Wald test, null: $\sigma_1 = \sigma_2$				29.71**		137.86**
Underidentification test		8.70*		102.07**		164.11**
Overidentification test		7.84*		821.47**		6.16*

Significance levels: † : 10%, * : 5%, ** : 1%. $N = 3,139$ for the aggregate model and $N = 6,061$ for the disaggregate. Standard errors are reported in parentheses. Time and country dummies are included but not reported for brevity.

Distribution of own price elasticities from the three models

	1%	10%	25%	50%	75%	90%	99%
Aggregate	9.6	5.3	3.8	2.7	1.9	1.5	1.0
Disaggregate linear	67.5	38.3	27.7	19.5	14.1	11.1	7.3
Disaggregate logarithmic	12.6	12.6	12.5	12.5	12.5	12.3	11.6

- Different demand elasticities depending on the model variant used

➢ Every econometric model imposes restrictions

- **But** our policy conclusions are robust because they are supported by simulations with all three variants

'Feebate' Policy Simulations for Germany

- Fee/rebate per vehicle sold according to formula:
  $A = t \times (CO2 - PP)$
- A *in* € , t in € per g/km
- Cars emitting above *PP* pay a fee; those emitting less than *PP* receive a rebate
- Scenarios for t = 15, 30, 45, 60 (corresponding to carbon taxes of 75–300 € / t CO_2), and for pivot points *PP* = 120, 140, 160 g CO_2 / km
- Additional scenarios for revenue-neutral policies, asymmetric feebates and welfare-improving feebates
- Feebate levied at consumer/producer level, passes through (not by 100%) to car price

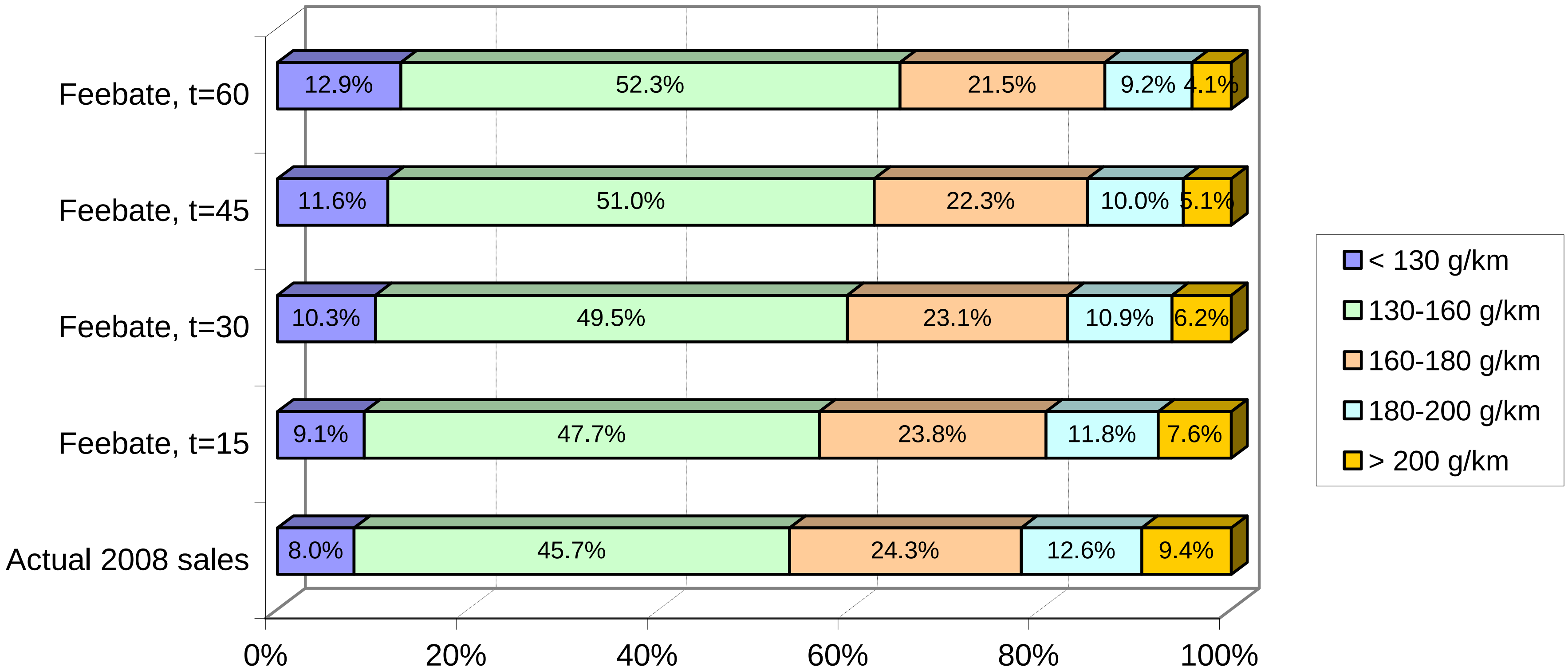
Change in new car prices, sales & revenues by car size & emissions class

	Prices				Sales				Revenues per car			
	S	M	L	All	S	M	L	All	S	M	L	All
Lenient scheme ($t = 10$, $PP = 135.2$)												
<130	-1.2	-0.4	-0.3	-1.0	25.1	19.1	24.1	22.9	-11.5	-4.2	-1.9	-8.4
130-160	0.7	0.7	0.7	0.7	3.5	4.6	8.1	5.8	3.7	4.7	3.0	4.5
160-180	2.1	1.8	1.3	1.6	-14.3	-6.9	-10.1	-6.7	14.4	12.4	8.3	9.7
180-200	2.7	2.5	2.0	2.2	-28.9	-21.0	-17.0	-16.2	19.0	16.3	13.1	14.3
>200		3.0	2.8	2.6		-37.1	-39.3	-36.4		20.3	12.4	12.3
All	0.2	1.3	1.8	1.6	10.6	2.9	-3.0	-0.8	-2.3	4.8	4.9	0.8
Stringent scheme ($t = 40$, $PP = 127.7$)												
<130	-2.7	0.04	0.2	-2.0	118.8	72.6	98.0	101.9	-35.1	-7.1	1.6	-24.3
130-160	5.3	4.3	4.0	4.3	1.0	6.1	18.6	9.4	28.8	27.5	17.2	26.6
160-180	10.2	8.6	6.5	7.8	-53.0	-33.4	-44.4	-34.8	70.5	60.1	39.3	45.7
180-200	12.2	11.2	9.3	10.0	-77.7	-65.7	-60.3	-59.1	85.8	73.8	59.3	63.4
>200		13.0	11.8	11.3		-85.6	-87.0	-84.2		85.9	56.0	50.5
All	3.0	6.6	8.6	7.7	41.0	5.4	-15.9	-3.3	-6.3	21.6	21.1	3.4

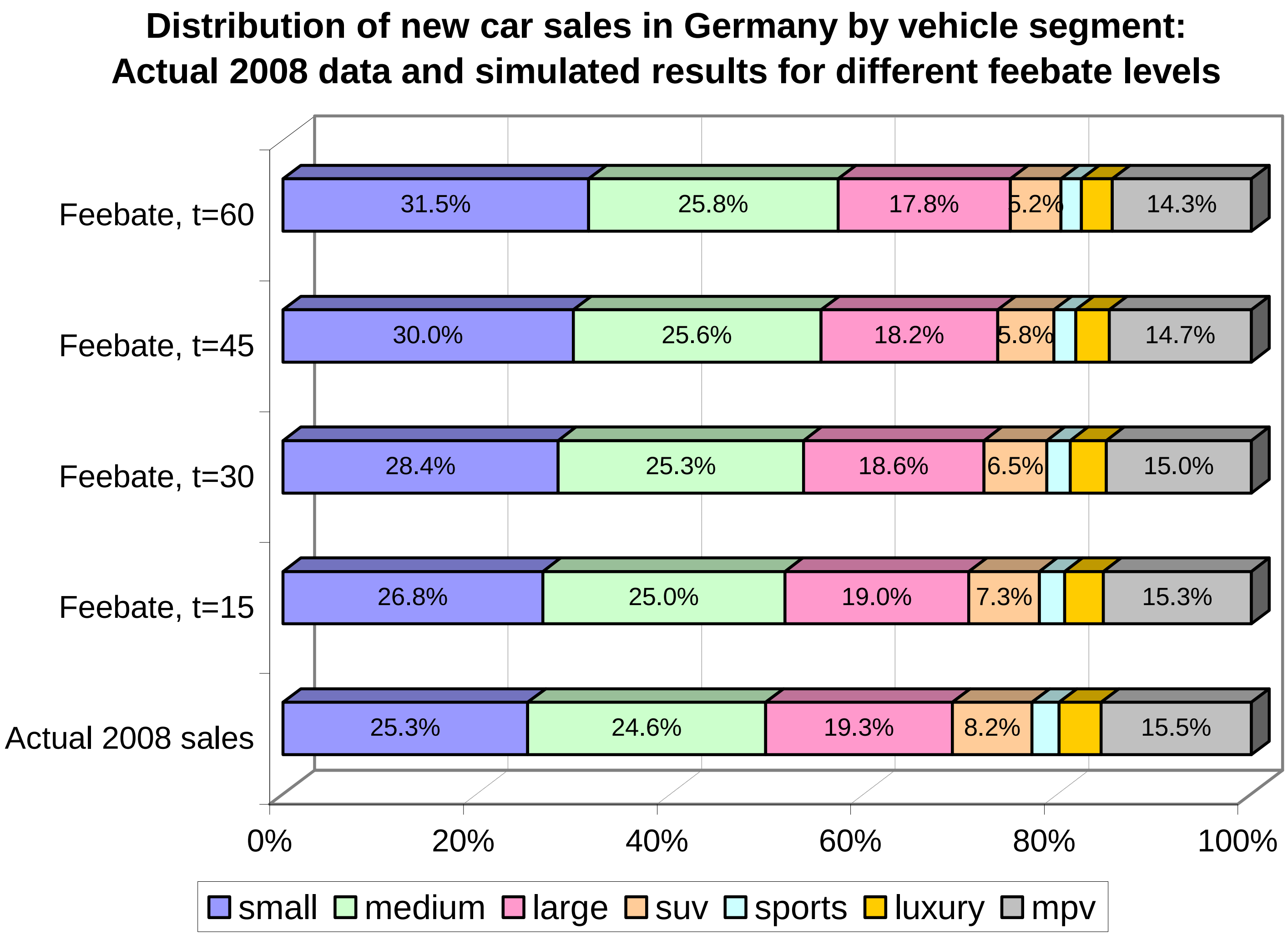
Both schemes are revenue-neutral. Reported numbers are percentage changes. S=Small, M=Medium, L=Large.

Comparison of policies according to feebate stringency for a given pivot point – 1

Distribution of new car sales in Germany by CO_2 emissions class:
Actual 2008 data and simulated results for diffferent feebate levels



Comparison of policies according to feebate stringency for a given pivot point – 2



Results: Impacts on emissions, public revenues & consumer welfare

Scheme		Change in:				
t	PP	Total sales	Consumer surplus	Producer surplus	Emissions cost	Total welfare
Revenue-neutral symmetric schemes						
10	135.2	-23.8 (-0.8)	-96 (-1.7)	-30 (-0.8)	-60 (-4.2)	-66 (-0.3)
20	132.7	-47.6 (-1.6)	-191 (-3.3)	-58 (-1.5)	-110 (-7.7)	-139 (-0.7)
30	130.2	-71.9 (-2.5)	-288 (-4.9)	-84 (-2.1)	-155 (-10.7)	-217 (-1.0)
40	127.7	-97.3 (-3.3)	-388 (-6.7)	-109 (-2.8)	-196 (-13.4)	-300 (-1.4)
30.7	130	-73.7 (-2.5)	-295 (-5.1)	-86 (-2.2)	-158 (-10.9)	-223 (-1.1)
71.6	120	-186.7 (-6.4)	-732 (-12.6)	-175 (-4.4)	-315 (-20.8)	-593 (-2.8)
Revenue-neutral asymmetric schemes						
-10/+20	130.6	-26.3 (-0.9)	-106 (-1.8)	-34 (-0.8)	-66 (-4.6)	-74 (-0.3)
-20/+10	136.7	-43.5 (-1.5)	-175 (-3.0)	-52 (-1.3)	-101 (-7.0)	-127 (-0.6)
-5/+20	127.2	-14.4 (-0.5)	-58 (-1.0)	-19 (-0.5)	-38 (-2.7)	-39 (-0.2)
-20/+5	139.4	-41.0 (-1.4)	-165 (-2.8)	-49 (-1.2)	-95 (-6.6)	-119 (-0.6)
-10/+30	127.3	-28.2 (-1.0)	-114 (-2.0)	-36 (-0.9)	-70 (-4.9)	-80 (-0.4)
-30/+10	136.6	-61.8 (-2.1)	-248 (-4.3)	-72 (-1.8)	-134 (-9.3)	-185 (-0.9)
-5/+30	123.8	-15.4 (-0.5)	-62 (-1.1)	-21 (-0.5)	-41 (-2.9)	-43 (-0.2)
-30/+5	138.8	-58.8 (-2.0)	-236 (-4.1)	-67 (-1.7)	-127 (-8.8)	-176 (-0.8)
Welfare-improving schemes						
10	130	-29.1 (-1.0)	-118 (-2.0)	-37 (-0.9)	-62 (-4.4)	61 (0.3)
20	120	-73.2 (-2.5)	-293 (-5.0)	-92 (-2.3)	-122 (-8.4)	473 (2.2)
-2/+3	130.6	-6.0 (-0.2)	-24 (-0.4)	-8 (-0.2)	-14 (-1.0)	13 (0.06)
-10/+20	123.8	-34.2 (-1.2)	-138 (-2.4)	-44 (-1.1)	-68 (-4.7)	141 (0.7)
Sales-increasing schemes						
0/+10	120	0.6 (0.02)	3 (0.04)	0.3 (0.01)	-1.5 (-0.1)	-31 (-0.15)
0/+10	140	3.8 (0.1)	15 (0.3)	4 (0.1)	-6 (-0.4)	-167 (-0.8)
0/+10	160	12.7 (0.4)	52 (0.9)	15 (0.4)	-13 (-0.9)	-508 (-2.4)

Conclusions & Outlook

- It is possible to design a feebate program for new automobiles that curbs carbon emissions without reducing total welfare
- But needs careful design in order to account for trade-offs between environmental effectiveness, public finances and consumer/producer surplus
- Revenue-neutral tax schemes (politically most attractive) may not be welfare-improving *in the short run*; more stringent policies increasing public revenues can improve welfare

➢ But purpose of feebates is to provide long-term price signal, not work miracles in 1-2 years

Questions / Limitations of our approach

- Econometrically estimated non-dynamic models can simulate small changes from an equilibrium to another ⇨ may underestimate short-term consumer response
- Dynamic policy simulations necessary to make the analysis more realistic (e.g. more stringent taxation over the years), but needs assumptions about evolution on the supply side
- What is the role of changing consumer preferences / shifting demand function?
- What feebates for electric cars?
- What is the effect on i) used cars, ii) mileage?