Welfare, Redistributive and Revenue Effects of Policies Promoting Fuel Efficient and Electric Vehicles

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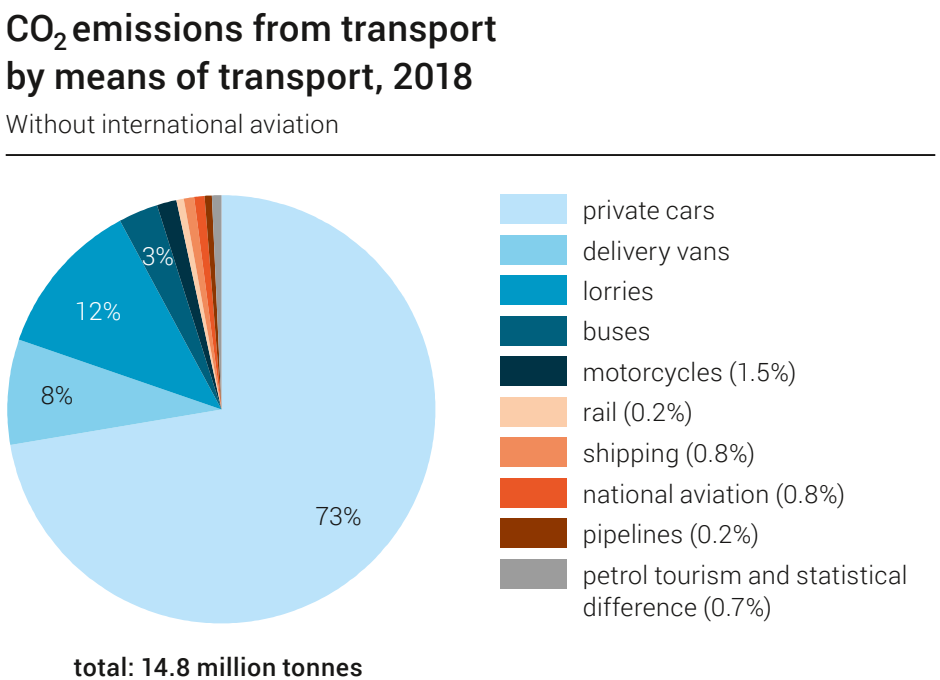
Motivation - CO_2 Emissions Transport Sector Switzerland

- Passenger car emissions increased by 44% since 2000 and represent 60% of road related emissions in Europe
- In Switzerland, the road transport sector accounts for around 39% of overall CO_2 emissions.
- Challenge: Achieve net zero emissions by 2050 while individual traffic projected to increase by 18% until 2040.



Research Questions

- What factors drive households' preferences towards electric and hybrid cars?
- How likely are different policies to increase the uptake of environmentally friendly cars? (i.e. Subsidy, fuel tax, mileage dependent charge)
- What are the effects of these policies across the income distribution?

Demand model (Grigolon, Reynaert, Verboven, 2018; Xing, Leard and Li, 2021)

Household $i's$ utility from purchasing new vehicle j :

$$u_{ij} = \beta^x x_j + \beta^z z_i x_j + \alpha_1 (log(p_j) + \gamma(G_{ij} + T_j)) + \alpha_2 \frac{log(p_j)}{y_i} + \epsilon_{ij} \quad (1)$$

Variable Costs:

$$G_{ij} = \rho m_i [e_j g_j (1 + \tau_j^g) + \tau_j^m] \quad (2)$$

$$T_j = \rho t_j \quad (3)$$

Capitalization factor:

$$\rho = \sum_{s=1}^{S} \frac{1}{(1+r)^s} \quad (4)$$

r=6%; S=10 years
Assumption:

- Households take prices and taxes as given
- Future expectation is based on today's value
- Inelastic mileage

Conditional Logit

Probability of household i to choose vehicle type j:

$$P_{ij} = \frac{e^{\beta^x x_j + \beta^z z_i x_j + \alpha_1 (log(p_j) + \gamma(G_{ij} + T_j)) + \alpha_2 \frac{log(p_j)}{y_i}}}{\sum_j e^{\beta^x x_j + \beta^z_j z_i x_j + \alpha_1 (log(p_j) + \gamma(G_{ij} + T_j)) + \alpha_2 \frac{log(p_j)}{y_i}}} \tag{5}$$

ϵ_{ij} i.i.d. Type 1 extreme value distributed

Choice Set

Each household's choice set consist of 489 theoretical options based on fuel type (Gasoline, Diesel, Hybrid, Electric) and make-model segmentation (i.e. VW Golf, Audi A6)

- include car type fe; brand country of origin fe
- address price endogeneity by using a cost shifter and control function approach (Train and Petrin, 2011) - annual penalties for fleet wide fuel efficiency standards car importers are subject to.
- Also include typical BLP instruments

The Dataset

We have access to several datasets for households in the Canton of Bern, merging data from

1. Tax office of Bern
   - Income, wealth, household size, marital status, age
2. Road Traffic Office Canton of Bern
   - Data on new car registrations between 2008-2019 (ownership in 2019)
3. Eurotax, Federal Roads Office (Switzerland) and LEMNET
   - Vehicle prices, Fuel efficiency, engine power, car size
   - Data on number and location of EV charging stations

Conditional logit - estimated coefficients

	(1)	(2)	(3)
Car price (log)	−0.227 ***	−0.034	−2.116 ***
	(0.03)	(0.04)	(0.11)
Price (log) / income	0.002+	0.003+	0.002+
	(0.00)	(0.00)	(0.00)
Variable costs (log pv)	−0.684 ***	−0.520 ***	−0.350 ***
	(0.08)	(0.10)	(0.10)
Engine power (KW)	−0.000	−0.001+	0.007 ***
	(0.00)	(0.00)	(0.00)
Car height	0.453 ***	0.466 ***	−1.550 ***
	(0.09)	(0.13)	(0.16)
Car weight	0.000	−0.001 ***	0.001 ***
	(0.00)	(0.00)	(0.00)
Hybrid engine	−0.751 ***	−0.690 ***	−0.205
	(0.16)	(0.16)	(0.16)
Electric engine	−1.983 ***	−1.731 ***	−1.178 ***
	(0.23)	(0.24)	(0.24)
Diesel engine	−0.760 ***	−0.732 ***	−0.567 ***
	(0.02)	(0.02)	(0.02)
Car size	−0.127 ***	−0.033	−0.006
	(0.02)	(0.02)	(0.02)
Size heterogeneity			
2 Persons	0.163 ***	0.187 ***	0.184 ***
	(0.02)	(0.02)	(0.02)
3 Persons	0.315 ***	0.362 ***	0.359 ***
	(0.03)	(0.03)	(0.03)
4 Persons	0.516 ***	0.582 ***	0.577 ***
	(0.02)	(0.03)	(0.03)
5+ Persons	0.714 ***	0.793 ***	0.785 ***
	(0.04)	(0.04)	(0.04)
KW heterogeneity			
40-60 years old	−0.003 ***	−0.003 ***	−0.003 ***
	(0.00)	(0.00)	(0.00)
60+ years old	−0.005 ***	−0.005 ***	−0.005 ***
	(0.00)	(0.00)	(0.00)
EV effects			
EV agglomeration	0.311*	0.311*	0.310*
	(0.14)	(0.14)	(0.14)
EV rural	−0.023	−0.025	−0.026
	(0.15)	(0.15)	(0.15)
Distance to EV	−0.030	−0.029	−0.029
	(0.02)	(0.02)	(0.02)
Nb. Charging (5km)	0.007*	0.007*	0.007*
	(0.00)	(0.00)	(0.00)
EV 2018	0.133	0.088	0.123
	(0.14)	(0.14)	(0.14)
EV 2019	1.357 ***	1.307 ***	1.359 ***
	(0.13)	(0.13)	(0.13)
Control function	*No*	*No*	*Yes*
Observations	9,816,000	9,816,000	9,816,000
Nr. of cases	23,074	23,074	23,074
Log Likelihood	−136,093.3	−134,604	−134,380.7
Car type fe	*No*	*Yes*	*Yes*
Car brand (country)	*No*	*Yes*	*Yes*

+p<0.1; * p<0.05; ** p<0.01; *** p<0.001

Coefficients based on estimated conditional and mixed logit model. Estimated standard errors in parentheses. Model (1) - (3) do not have random coefficients. Coefficients in Model (1) and (5) are based on control function approach with estimation of the pricing equation in a separate model based on cost shifters in a first step.

Increase in fossil fuel levy by 0.12 CHF/l - Change in Probabilities

	Overall	1st inc. quartile	2nd inc quartile	3rd inc quartile	4th inc quartile
Gasoline	-0.00077	-0.00077	-0.00076	-0.00077	-0.00078
Diesel	0.00028	0.00027	0.00028	0.00028	0.00028
Electro	0.00030	0.00031	0.00029	0.00029	0.00030
Hybrid	0.00020	0.00019	0.00020	0.00021	0.00021

Notes: 1st quartile: income $<$ 62.9 kCHF, 2nd quartile: 62.9$>=$income$<$ 93.67 kCHF, 3rd quartile: 93.67$>=$ income$<$131.7 kCHF and 4th quartile: income $>=$ 131.7 kCHF..

Increase in fossil fuel levy by 0.12 CHF/l - Welfare analysis

	Cons. surplus (MCHF)	CS (% change)	CO_2 levy (kCHF)	Levy incidence (%)	Car taxes (CHF)	CO_2 (t)	CO_2 (% change)
1st inc quartile	-1.530	-0.0999	195.65	0.204	-228.33	-2.084	-0.054
2nd inc quartile	-1.585	-0.105	191.34	0.106	-217.40	-1.978	-0.052
3rd inc quartile	-1.710	-0.109	197.7	0.077	-223.07	-2.079	-0.055
4th inc quartile	-2.044	-0.108	188.89	0.036	-231.23	-2.027	-0.054
Total	-6.870	-0.106	773.56	0.073	-900.02	-8.171	-0.053

Notes: 1st quartile: income $<$ 62.9 kCHF, 2nd quartile: 62.9$>=$income$<$ 93.67 kCHF, 3rd quartile: 93.67$>=$ income$<$131.7 kCHF and 4th quartile: income $>=$ 131.7 kCHF. Consumer surplus based on logsum formula.

Introduction of mileage tax (0.023 CHF/km) - Change in Probabilities

	Overall	1st inc. quartile	2nd inc quartile	3rd inc quartile	4th inc quartile
Gasoline	0.0018	0.0018	0.0018	0.0018	0.0018
Diesel	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002
Electro	-0.0012	-0.0012	-0.0011	-0.0011	-0.0012
Hybrid	-0.0004	-0.0004	-0.0004	-0.0005	-0.0005

Notes: 1st quartile: income $<$ 62.9 kCHF, 2nd quartile: 62.9$>=$income$<$ 93.67 kCHF, 3rd quartile: 93.67$>=$ income$<$131.7 kCHF and 4th quartile: income $>=$ 131.7 kCHF..

Introduction of mileage tax (0.023 CHF/km) - Welfare analysis

	Cons. surplus (MCHF)	CS (% change)	Mileage tax (kCHF)	Incidence (%)	Car taxes (CHF)	CO_2 (t)	CO_2 (% change)
1st inc quartile	-5.212	-0.340	666.69	0.696	3,172	13.924	0.360
2nd inc quartile	-5.375	-0.355	650.21	0.360	3,046	13.004	0.344
3rd inc quartile	-5.764	-0.367	666.65	0.260	3,039	13.478	0.344
4th inc quartile	-6.901	-0.367	636.39	0.122	3,023	12.807	0.342
Total	-23.252	-0.358	2,619.92	0.248	12,279	53.213	0.348

Notes: 1st quartile: income $<$ 62.9 kCHF, 2nd quartile: 62.9$>=$income$<$ 93.67 kCHF, 3rd quartile: 93.67$>=$ income$<$131.7 kCHF and 4th quartile: income $>=$ 131.7 kCHF.. Consumer surplus based on logsum formula.

EV subsidy (4k CHF) - Change in Probabilities

	Overall	1st inc. quartile	2nd inc quartile	3rd inc quartile	4th inc quartile
Gasoline	-0.0029	-0.0031	-0.0028	-0.0027	-0.0028
Diesel	-0.0010	-0.0010	-0.0010	-0.0010	-0.0010
Electro	0.0041	0.0043	0.0040	0.0039	0.0041
Hybrid	-0.0002	-0.0002	-0.0002	-0.0002	-0.0002

Notes: 1st quartile: income $<$ 62.9 kCHF, 2nd quartile: 62.9$>=$income$<$ 93.67 kCHF, 3rd quartile: 93.67$>=$ income$<$131.7 kCHF and 4th quartile: income $>=$ 131.7 kCHF.

EV subsidy (4k CHF) - Welfare analysis

	Cons. surplus (kCHF)	CS (% change)	Total subsidy (kCHF)	Car taxes (kCHF)	CO_2 emission (t)	CO_2 (% change)
1st inc quartile	387.93	0.025	201.53	-3.021	-17.057	-0.44
2nd inc quartile	369.37	0.024	186.90	-2.813	-15.376	-0.406
3rd inc quartile	384.51	0.025	185.64	-2.785	-15.485	-0.396
4th inc quartile	487.83	0.026	193.85	-2.905	-15.370	-0.411
Total	1,629.63	0.025	767.91	-11.524	-63.289	-0.414

Notes: 1st quartile: income $<$ 72.5 kCHF, 2nd quartile: 72.5$>=$income$<$ 101.6 kCHF, 3rd quartile: 101.6$>=$ income$<$138.6 kCHF and 4th quartile: income $>=$ 138.6 kCHF. Consumer surplus based on logsum formula.

Conclusion

- Overall probability to acquire a gasoline, hybrid or EV amounts to 67%, 5% and 1.7% respectively
- Increase in fuel tax
  - Decreases consumer surplus; small reduction in CO_2 emissions of the new car fleet; regressive effects
- Introduction of EV subsidy
  - Increases consumer surplus; significantly decreases CO_2 emissions of the new car fleet; requires moderate outlays
- Introduction of mileage tax
  - Increases probability to buy gasoline driven cars; increases CO_2 emissions of the new car fleet; highly regressive