EVALUATING NORWAY'S ELECTRIC VEHICLE INCENTIVES

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Motivation

MOTIVATION

The transition from ICEVs to EVs is a key component of emissions reduction strategies

- Road transport accounts for 15% of world CO2 emissions
  - compared to 2.5% from aviation (Our World in Data, 2020)
- Major economies are planning a complete phaseout of ICEVs
  - California and the EU envisaging bans starting in 2035

The electrification of the vehicle fleet in Norway has been faster than in most countries

- EVs comprised 65% of new car sales in 2021, and hybrids 22%
- In the same year, EV sales accounted for 3% of new vehicle sales in the US and 9% in the EU (USBTS, 2022; EEA, 2022)

MOTIVATION

The fleet electrification in Norway has been spurred by

(1) Global factors

- In 2010, only two car brands (Mitsubishi, Think) offered EVs in the Norwegian market
- In 2021, 33 out of 42 car brands did
- Sales-weighted engine power for EVs was more than four times higher in 2021 than in 2010

(2) Local factors

- National policies, incentives, infrastructure

The goal of this paper is to quantify the contribution of different national levers to the EV uptake

BACKGROUND: THE THREE POLICY LEVERS

(1) In Norway, EVs enjoy a favourable tax treatment in car purchase taxes

- They are exempt from **VAT** (otherwise 25% of pre-tax price) and from the CO2- and weight-based **registration tax** (otherwise 45% of pre-tax price on average in 2021)

(a) **Audi a7 petrol**

Pre-tax price 540,000 NOK (approx. 50,000 $)

Retail price 918,000 NOK (approx. 85,000 $)

(b) **Tesla model S**

Pre-tax price 453,000 NOK

Retail price 453,000 NOK (approx. 40,000 $)

BACKGROUND: THE THREE POLICY LEVERS

(2) EVs have substantially lower energy costs

- In 2021, the cost of driving an EV is on average 1/3 the cost of driving an ICEV, due to a combination of fossil fuel taxes and EV energy efficiency
- Example: The cost of driving a Tesla Model S for 10 km is 3 NOK, while that of driving an Audi a7 is 13 NOK.

(3) EVs are offered generous incentives including bus lane access, exemption from or discounts on road tolls, car ferry and parking charges

RELATED LITERATURE & CONTRIBUTION

- **Discrete choice demand models** on the implications of **subsidy design in the automobile sector** (Linn, 2023, Linn, 2022, Armitage and Pinter, 2021, Xing, Leard, and Li, 2021)
- **Impact of purchase and usage-related Incentives** (Halse et al., 2023, Muehlegger and Rapson, 2022, Isaksen and Johansen, 2021, Clinton and Steinberg, 2019,)
- **Energy costs of driving** (Leard, Linn, and Zhou, 2023, Bushnell, Muehlegger, and Rapson, 2022, Gillingham, Houde, and Van Benthem, 2021, Sallee, West, and Fan, 2016, Allcott and Wozny, 2014)
  - Analysis of the full spectrum of consumer-side incentives to identify the impact of each
  - Evaluation of taxing vs banning fuel cars as potential future policies
- **Norway-specific EV Incentives** (Johansen and Munk-Nielsen, 2022, Springel, 2021)
  - Scope extending beyond early adopters, with significant variations in EV market shares
  - Granularity in product offerings, focusing on substitution between individual products

Data

DATA

1. **Main data sources**: OFV **annual new car registrations and price lists** from 2000 to 2021
2. **Single car observations** (registrations): 2,668,035, with 52 brands & 515 models
3. **Final dataset**: Total of **10,349 products**. Products are combinations of year of purchase, brand, model, fuel type, 4WD/2WD, automatic/manual transmission, body style, engine power, price, fuel economy, and units sold
4. **Additional data**:
   - **Annual CPI** (Statistics Norway) is used for adjusted price and cost variables

DATA: THE THREE POLICY LEVERS

1. **Governmental rules** (Regjeringen.no) are used to compute **purchase taxes**

As of 2021, **EVs pay zero taxes, ICEVs pay 25% VAT and a CO2- and weight-based registration tax**

Registration tax CO2 component

- 0 for the first 87 g/km
- 801 NOK per g/km in the range 88–118 g/km
- 898 NOK per g/km in the range 119–155 g/km
- 2352 NOK per g/km in the range 156–225 g/km
- 3752 NOK per g/km from 226 g/km

Registration tax weight component

- 0 for the first 500 kg
- 27 kr/kg for the next 700 kg
- 67 kr/kg for the next 200 kg
- 209 kr/kg for the next 100 kg

Example: A 2021 Porsche Cayenne petrol with 309 g/km of CO2 emissions pays 539,737 NOK from the CO2 component, its weight of 2183 kg earns it a weight tax of 218,725 NOK (about 70,000 USD in total)

DATA: THE THREE POLICY LEVERS

2. **Annual average sales prices and taxes of petrol and diesel, electricity prices** (Statistics Norway) and **EVs' and hybrids' energy consumption** (fueleconomy.gov, evcompare.io, elbil.no, ev-database.org) are used to compute **energy costs**
   - ICEVs and non-PHEV: fuel economy (l/10km) times fuel prices in NOK
   - EVs: kWh/10km times electricity prices in the end-user market
   - PHEV: weighted average of kWh/10km times electricity prices and l/10km times fuel prices

3. **Year-specific EV effects collectively capture** the individual effects of
   - Zero or discounted toll road charges
   - Reduced ferry fares
   - Free or subsidized municipal parking
   - Access to bus lanes
   - Zero or reduced annual road tax
   - Expanding charging infrastructure and capacity

Model

We use a **BLP model** (from Berry, Levinsohn, and Pakes, 1995) with heterogeneous consumers to flexibly estimate demand responses for differentiated products

- Consumer *i* derives **indirect utility** from buying vehicle *j* at time *t* of

$$U_{ijt} = x_{jt}\beta_i - \alpha_i p_{jt} + \xi_{jt} + \epsilon_{ijt} \tag{1}$$

- Here, **the parameters α_i and β_i** capture the relative weight consumers put on price and product attributes

$$\beta_i = \beta + \boldsymbol{\Sigma}\nu_i^{\beta} \tag{2}$$

$$\alpha_i = exp(\alpha_0 + \alpha_1\nu_i^{\alpha}) \tag{3}$$

- δ_{jt} **and** μ_{ijt} represent the 'mean utility' and the consumer level variation across mean utility respectively

$$\delta_{jt} = x_{jt}\beta + \xi_{jt} \tag{4}$$

$$\mu_{ijt} = x_{jt}\boldsymbol{\Sigma}\nu_i^{\beta} - \alpha_i p_{jt} \tag{5}$$

- We derive **market shares** by integrating over the mixing distribution

$$s_{jt}(p_t, \delta_t, \theta) = \int \frac{exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{J} exp(\delta_{kt} + \mu_{ikt})} f(\nu_i) d\nu_i \quad (6)$$

Where $\delta_t = (\delta_{1t}, ..., \delta_{jt})$

- μ_{ijt} implies an interaction between consumer tastes and product attributes, and drives correlation in utility over products
- Different mixing distributions imply different patterns of substitution among products

J_{ft} is the set of products owned by firm f each year t. For each unit sold of product j, **the seller receives**

$$p^*_{jt} = \frac{p_{jt} - \tau_{jt}}{1 + v_{jt}} \tag{7}$$

Firm f chooses sales price p_{jt} **to maximize variable profit**

$$\sum_{j \in J_{ft}} (p^*_{jt} - c_{jt}) Q_{jt} \tag{8}$$

We compute c_t under observed prices and taxes, then find p_t under counterfactual scenarios, which change s_t

Results

RESULTS

1. **Price significantly affects demand**
   - Computing the semi-elasticities of demand with respect to price, for a 10,000 NOK price increase in 2021, we get an implied -0.12 proportional change or 12% drop in the sales of Tesla model 3. For the Nissan Leaf, the effect is a 17% reduction in sales
2. **Energy costs significantly affect demand**
   - Increasing energy costs per km by 0.8 NOK (the difference between the means for EVs and ICEVs in 2021), reduces the value of a car to the average consumer by ca. 36,000 NOK
3. **Petrol cars hold the least value for consumers**
   - EV, hybrid and diesel dummies show positive valuation advantages relative to petrol vehicles
4. **Consumers mainly substitute to products in or near their own group**

COUNTERFACTUALS

We look at counterfactual experiments where

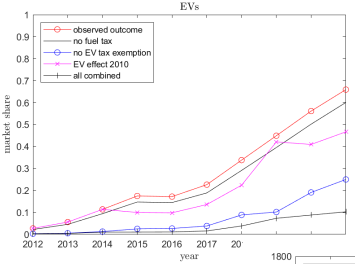
(A) There is **no fuel tax** for ICEVs

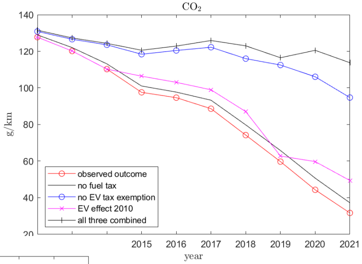
(B) There is **no EV exemption** from taxes

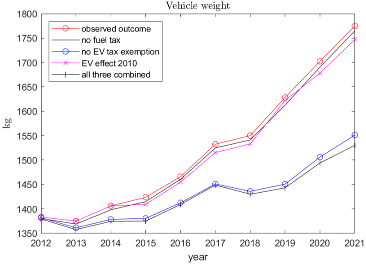
(C) the **EV preference effects** are set to the **estimated 2010 value**

(A+B+C) **Total effect of A, B and C**

COUNTERFACTUALS







COUNTERFACTUALS

In 2021

- *No fuel tax* reduces **EV market share by 6%**
- *No EV tax exemption* **reduces it to 25%** (similar to 20% market share of Sweden and the Netherlands)
    1. The sales-weighted **mean vehicle weight falls by about one fifth**, the **sales-weighted mean CO2 emissions of new vehicles increase by 170%**
    2. The counterfactual results in a total surplus loss per car sold of 5.9% of its price
- *EV effect 2010* **reduces it to 47%**

ADDITIONAL COUNTERFACTUALS

In a final set of counterfactuals, we assess the relative merits of **differentiated purchase taxes and a ban** on ICEVs and hybrids

(D) EVs pay the imputed tax, ICEVs and hybrids pay **twice** this rate

(E) EVs pay the imputed tax, ICEVs and hybrids pay **four times** this rate

(F) EVs pay the imputed tax, ICEVs and hybrids **are banned**

We find that

- **EV market share** can be driven to **95 percent with sufficiently high taxes** on non-EVs
- The **reduction in CO2 emissions in the high-tax counterfactual (E) is 85%**, only slightly less than 100% reduction from banning ICEVs and hybrids altogether
- In 2021, **counterfactual E gives a higher total surplus than that from a ban on non-EVs**, equal to 4.9% of the average price per new vehicle sold

Conclusion

CONCLUSION

We examine the **effectiveness of Norwegian EV incentives in changing the composition of the vehicle fleet**, and find that

- **Tax exemptions are the most effective lever in driving EV adoption**. Without them, EV market share would drop to 25%
- Since an outright ban on ICEVs has emerged as a policy option, **differentiated purchase taxes may be an attractive alternative** for policymakers around the world

REFERENCES

Allcott, Hunt and Nathan Wozny (2014). **"Gasoline prices, fuel economy, and the energy paradox".** In: *Review of Economics and Statistics* 96.5, pp. 779–795.

Armitage, Sarah and Frank Pinter (2021). ***Regulatory mandates and electric vehicle product variety.*** Tech. rep. Technical report, Working Paper.

Berry, Steven, James Levinsohn, and Ariel Pakes (1995). **"Automobile Prices in Market Equilibrium".** In: *Econometrica* 63.4, pp. 841–890.

Bushnell, James B, Erich Muehlegger, and David S Rapson (2022). ***Energy prices and electric vehicle adoption.*** Tech. rep. National Bureau of Economic Research.

Clinton, Bentley C and Daniel C Steinberg (2019). **"Providing the Spark: Impact of financial incentives on battery electric vehicle adoption".** In: *Journal of Environmental Economics and Management* 98.C.

EEA (2022). ***New registrations of electric vehicles.*** URL: https://www.eea.europa.eu/ims/new-registrations-of-electric-vehicles (visited on 02/22/2023).

Gillingham, Kenneth T, Sébastien Houde, and Arthur A Van Benthem (2021). **"Consumer myopia in vehicle purchases: evidence from a natural experiment".** In: *American Economic Journal: Economic Policy* 13.3, pp. 207–238.

REFERENCES (cont.)

Halse, Askill et al. (2023). **“Local Incentives and Electric Vehicle Adoption1”.** In: *Available at SSRN 4390231*.

Isaksen, Elisabeth Thuestad and Bjørn Gjerde Johansen (2021). **“Congestion pricing, air pollution, and individual-level behavioral responses”.** In: *Available at SSRN 3832230*.

Johansen, Bjørn Gjerde and Anders Munk-Nielsen (2022). **“Portfolio Complementarities and Electric Vehicle Adoption”.** In.

Leard, Benjamin, Joshua Linn, and Yichen Christy Zhou (2023). **“How much do consumers value fuel economy and performance? Evidence from technology adoption”.** In: *Review of Economics and Statistics* 105.1, pp. 158–174.

Linn, Joshua (2022). **“Is there a trade-off between equity and effectiveness for electric vehicle subsidies”.** In: *Resources for the Future*.

— (2023). **“Emissions Standards and Electric Vehicle Targets for Passenger Vehicles”.** In.

Muehlegger, Erich and David S Rapson (2022). **“Subsidizing low-and middle-income adoption of electric vehicles: Quasi-experimental evidence from California”.** In: *Journal of Public Economics* 216, p. 104752.

REFERENCES (cont.)

Our World in Data (2020). ***CO_2 Emissions from Transport.*** URL: https://ourworldindata.org/co2-emissions-from-transport (visited on 02/22/2023).

Sallee, James M, Sarah E West, and Wei Fan (2016). **"Do consumers recognize the value of fuel economy? Evidence from used car prices and gasoline price fluctuations".** In: *Journal of Public Economics* 135, pp. 61–73.

Springel, Katalin (2021). **"Network externality and subsidy structure in two-sided markets: Evidence from electric vehicle incentives".** In: *American Economic Journal: Economic Policy* 13.4, pp. 393–432.

USBTS (2022). ***Gasoline, Hybrid, and Electric Vehicle Sales.*** URL: https://www.bts.gov/content/gasoline-hybrid-and-electric-vehicle-sales (visited on 02/22/2023).

Xing, Jianwei, Benjamin Leard, and Shanjun Li (2021). **"What does an electric vehicle replace?"** In: *Journal of Environmental Economics and Management* 107, p. 102432.