Network Externality and Subsidy Structure in Two-Sided Markets:

Evidence From Electric Vehicle Incentives

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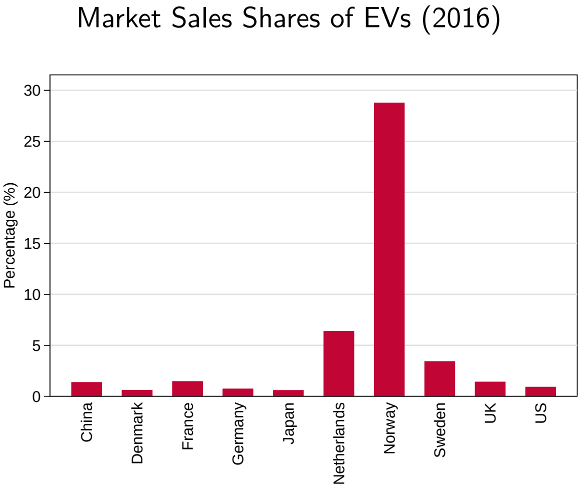
Motivation

- Environmental impact of emissions
- Transportation sector is a large contributor
  - 24% of global CO_2 emissions (IEA, 2015)
  - Road traffic accounted for 75%
- Governments introduced wide array of incentives
- Electric vehicles (EVs) play a key role
  - Estimated U.S. spending on EV policies ∼\$7.5bn (2012-2019)
  - Countries differ in terms of the adopted incentives

    → Target area, type, generosity

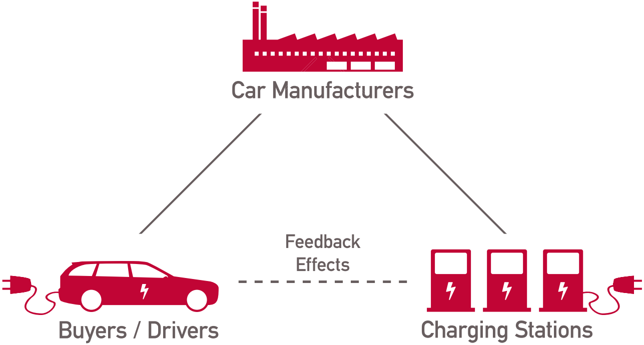
Motivation



Source: International Energy Agency (2017)

Motivation

Two-Sided Market for EVs



Research Question

What is the most effective subsidy structure in a two-sided market with network externalities?

Non-neutrality of revenue-equivalent subsidies

- Different economic impact
- Driven by positive externalities

Theory suggests it can go either way

- Open empirical question
- Focusing on the Norwegian EV market

Methodology

- Setting
  - Two-sided market of all-electric vehicles (AEVs)
  - Consumers $\rightarrow$ Vehicle purchase decision
  - Stations $\rightarrow$ Market entry decision
  - Government adopts various incentives
- Structural model jointly estimates
  - Random-coefficients discrete-choice model of vehicle demand
  - Station entry model
- Counterfactual policy settings $\rightarrow$ After recovering the fundamentals, determine which policy is more effective

Preview of Findings

- Significant, positive network effects in the AEV market
- Cross-price elasticities indicate complementarities between AEV models
- Policy Counterfactuals
  - During the observed time period (2010-2015) in Norway
    - Simulate AEV sales under station subsidy vs. price subsidy
    - Station subsidies are more than twice as effective as price subsidies
  - Starting from the status quo with increasing government spending
    - The relation inverts with increased spending
    - Purchasing price subsidy becomes more effective

Related Literature

- Two-sided markets
  - Katz & Shapiro (1985), Farrell & Saloner (1985)
  - Rochet & Tirole (2003, 2006), Armstrong (2006)
  - Hagiu & Lee (2011), Crawford & Yurukoglu (2012), Lee (2013)
- Environmental policies related to the car industry
  - Jacobsen (2013), Grigolon et al. (2015)
  - DeShazo et al. (2014), Pavan (2015), Li et al. (2016)
- Estimating demand system for automobiles
  - Bresnahan (1987), Berry, Levinsohn, & Pakes (1995)

This paper:
Builds a structural two-sided market model with membership externalities to **estimate the impact of different subsidy allocations**

Policy Background

- Electric vehicle supply equipment (EVSE) incentives
  - $\Rightarrow$ Differentiated by rate of charging (normal vs. fast)
  - $\Rightarrow$ Both at national level (since 2009) and in selected counties
- Purchasing price subsidies to consumers
  - $\Rightarrow$ Registration tax exemption (since 1990)
  - $\Rightarrow$ Reduced/No annual license fee (since 1996)
  - $\Rightarrow$ VAT exemption (since 2001)

Examples of Savings from Subsidies (2015)

Luxury/Sports Cars

Tesla Model S

- MSRP: $78,343
- Engine power: 315kW
- Weight: 2,109kg
- Registration tax: $0
- VAT: $0
- Annual license fee: $49

Total tax: $49

BMW 7-Serie 750i

- MSRP: $77,653
- Engine power: 330kW
- Weight: 1,960kg
- Registration tax: $74,671
- VAT: $19,413
- Annual license fee: $346

Total tax: $94,430

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Examples of Savings from Subsidies (2015)

Compact Cars

Nissan Leaf

- MSRP: \$24,973
- Engine power: 80kW
- Weight: 1,474kg
- Registration tax: \$0
- VAT: \$0
- Annual license fee: \$49

Total tax: \$49

Volkswagen Golf

- MSRP: \$22,270
- Engine power: 81kW
- Weight: 1,249kg
- Registration tax: \$7,238
- VAT: \$5,567
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Total tax: \$13,151

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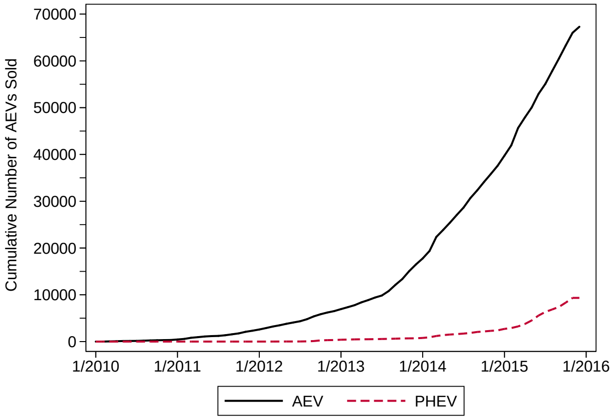
Vehicle Data

- Vehicle registry $\sim$ Norwegian Public Road Administration
  - $\Rightarrow$ Universe of registered vehicles in Norway
  - $\Rightarrow$ Owner ID and type
  - $\Rightarrow$ Vehicle specification: Maker/model/trim
  - $\Rightarrow$ All fuel types
  - $\Rightarrow$ Includes all technical characteristics
  - $\Rightarrow$ Geographic level: County/Municipality/Street Address
  - $\Rightarrow$ Time period: 2010-2015
- Price data $\sim$ OFV
  - $\Rightarrow$ Includes CIF, taxes, and importer/dealer profit

Vehicle Data

Cumulative All-Electric Vehicle Sales in Norway

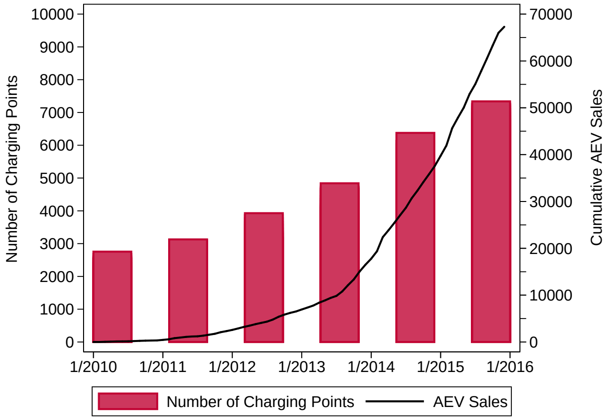


Station Data

- Public charging station network $\sim$ Nobil
  - $\Rightarrow$ Number of charging stations/outlets
  - $\Rightarrow$ Station characteristics
    - Location
    - Owner ID
    - Connector type

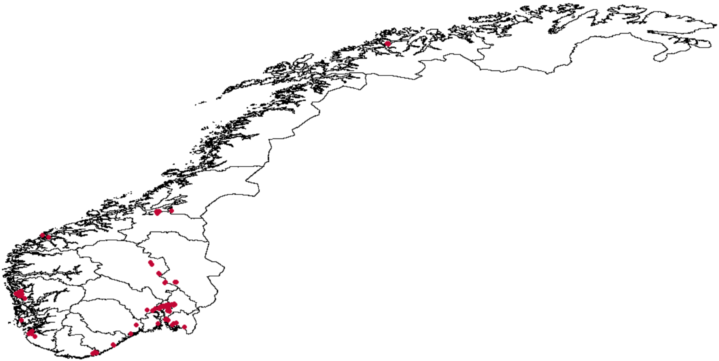
Station Data

All-Electric Vehicle Sales and Number of Stations in Norway



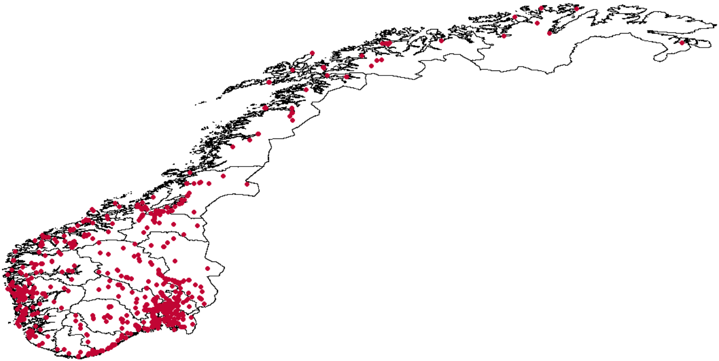
Station Data

Norwegian Station Network in 2009



Station Data

Norwegian Station Network in 2015



Other Data

- Fuel market data $\sim$ Norsk Petroleuminstitutt
- Macroeconomic variables $\sim$ SSB
    - GDP
    - Median household income
    - Unemployment
- Demographics (gender, age, income) $\sim$ OFV, SSB

Descriptive Statistics

Year	No. of Models	Sales	Stations	Price	HP/Wt	Consumption	EV	Length	Transmission
2010	170	140,763	2,755	296,367	0.0593	0.5194	0.0001	4.4063	0.2250
2011	182	150,976	3,129	294,038	0.0592	0.4912	0.0123	4.4049	0.3075
2012	199	154,451	3,929	303,686	0.0604	0.4789	0.0269	4.4140	0.3751
2013	206	158,383	4,841	299,364	0.0626	0.4569	0.0618	4.4181	0.4861
2014	208	156,592	6,377	305,873	0.0637	0.4106	0.1327	4.4129	0.5783
2015	203	144,614	7,361	305,075	0.0640	0.3587	0.2026	4.4129	0.6466

Note: The entry in each cell of the last six columns is the vehicle sales weighted mean.

Reduced-Form Analysis (1)

- To explore the relation between EV subsidies and EV purchases
- I estimate an ordinary least squares regression of vehicle sales of all fuel types on
  - EV incentives
  - Macroeconomic variables
  - Rich set of fixed effects across models, county, and time that captures unobserved characteristics implicit in each of the factors

Reduced-Form Analysis (2)

$$\log R_{jct} = \alpha + \sum_{E \in V} \beta_E V_{jct} + \sum_{G \in Y} \mu_G Y_{ct} + \vartheta_{jc} + \vartheta_t + \epsilon_{jct}$$

Notation:

- Unit of obs: model j in county c at time period t
- $R =$ number of newly registered vehicle models
- $V =$ set of available AEV incentives
- $Y =$ macroeconomics controls
- $\vartheta_{jc} =$ county-by-model FE
- $\vartheta_t =$ time FE

Results from the Reduced-Form Analysis

	log(No. of Registered Cars)		
	[1]	[2]	[3]
Registration Tax Exemption (10,000 NOK)	0.031***	0.031***	0.031***
	(0.004)	(0.004)	(0.004)
VAT Exemption (10,000 NOK)	0.003	0.003	0.003
	(0.015)	(0.015)	(0.015)
EVSE Normal (10,000 NOK)	-0.034*	-0.031*	-0.025
	(0.017)	(0.016)	(0.015)
EVSE Normal × EV	0.168***	0.086***	0.084***
	(0.026)	(0.028)	(0.028)
EVSE Fast (10,000 NOK)	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)
EVSE Fast × EV	0.003	0.004	0.004
	(0.005)	(0.006)	(0.006)
Observations	191,616	191,616	191,616
Adj. R-squared	0.40	0.40	0.40
Model × County and Time Fixed Effects	Y	Y	Y
Cluster on Model and County	Y	Y	Y
Local Incentives	N	Y	Y
Macroeconomic Controls	N	N	Y

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Model × County and Time Fixed Effects	Y	Y	Y
Cluster on Model and County	Y	Y	Y
Local Incentives	N	Y	Y
Macroeconomic Controls	N	N	Y

Robustness Checks for the Reduced-Form Analysis

- Potential concern: Identifying assumption is violated due to confounding factors.
- Robustness checks
  - Interaction of policy terms with a hybrid vehicle dummy

Robustness Checks for the Reduced-Form Analysis

	log(No. of Registered Cars)
EVSE Normal	-0.0208
	(0.0119)
EVSE Normal × Hybrid	-0.0165
	(0.0465)
EVSE Fast	-0.0007
	(0.0007)
EVSE Fast × Hybrid	-0.0004
	(0.0031)
Observations	191,616
Adj. R-squared	0.39
Model-County and Time Fixed Effects	Y
Cluster on Model and County	Y
Local and Tax Incentives	Y
Macroeconomic Controls	Y

Robustness Checks for the Reduced-Form Analysis

- Potential concern: Identifying assumption is violated due to confounding factors.
- Robustness checks
  - Interaction of policy terms with a hybrid vehicle dummy
  - Randomized assignment of station subsidies

Robustness Checks for the Reduced-Form Analysis

	log(No. of Registered Cars)
Placebo EVSE Normal	-0.0026
	(0.0019)
Placebo EVSE Normal × EV	0.0099
	(0.0171)
Placebo EVSE Fast	-0.0002
	(0.0003)
Placebo EVSE Fast × EV	-0.0005
	(0.0013)
Observations	191,616
Adj. R-squared	0.40
Model-County and Time Fixed Effects	Y
Cluster on Model and County	Y
Local and Tax Incentives	Y
Macroeconomic Controls	Y

Robustness Checks for the Reduced-Form Analysis

- Potential concern: Identifying assumption is violated due to confounding factors.
- Robustness checks
  - Interaction of policy terms with a hybrid vehicle dummy
  - Randomized assignment of station subsidies
  - Lead and lagged versions of station subsidies

Robustness Checks for the Reduced-Form Analysis

	log(No. of Registered Cars)
EVSE Normal × EV	0.1290**
	(0.0540)
Lead EVSE Normal × EV	0.00302
	(0.0322)
Lagged EVSE Normal × EV	-0.0155
	(0.1056)
Observations	62,758
Adj. R-squared	0.45
Model-County and Time Fixed Effects	Y
Cluster on Model and County	Y
Local and Tax Incentives	Y
Macroeconomic Controls	Y

The Setup

- Simultaneous-move complete information game
  - Consumers make vehicle purchase decision
  - Stations make entry decision
  - Consumers choose their demand for charging and stations provide charging
- Vehicle demand model $\sim$ Berry, Levinsohn, & Pakes (1995)
- Station entry model $\sim$ Gandal et al. (2000)
  $\sim$ Bresnahan & Reiss (1991)
- Consideration of dynamics

Vehicle Demand Model (1)

- Assume there are
  - $m = 1, ..., M$ markets (county $c \times$ year t)
  - $i = 1, ..., I_m$ consumers in each market
  - $j = 1, ..., J$ car models

- Indirect utility of consumer i from product j in market m specified as

$$u_{ijm} = \alpha \log(y_i - p_{jm}) + \beta_i^N \log N_{jm} + \beta_i^k x_{jm}^k + \xi_{jm} + \varepsilon_{ijm}$$

  - $y_i =$ consumer income
  - $p_{jm} =$ product price
  - $\log N_{jm} =$ network term

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  - x_{jm} = observed product characteristics
  - ξ_{jm} = unobserved product characteristics
  - ε_{ijm} = term has a Type I extreme value distribution
  - For ease of notation, I suppress market subscript m

Vehicle Demand Model (2)

- Allow for interaction between individual and product characteristics

$$u_{ij} = \alpha \log(y_i - p_j) + \beta^N \log N_j + \beta^k x_j^k + \xi_j + \sigma^N \log N_j v_i^N + \sum \sigma^k x_j^k v_i^k + \varepsilon_{ij}$$

- The consumer terms that interact with product characteristics
  - Income y_i estimated from population data
  - $v_i = (v_i^N, v_i^1, ..., v_i^K)$ has a standard multivariate normal distribution

- Utility from the outside good ($j = 0$) is normalized to zero

Vehicle Demand Model (3)

- $\zeta_i \sim P^*(\zeta)$ is the vector of unobserved individual attributes
- θ denotes the unknown parameters
- The predicted market share of good j is given by

$$s_j(p, N, x, \xi; \theta) = \int f_j(y_i, v_i, p, N, x; \theta) \ dP^*(\zeta)$$

$$f_j = \frac{e^{\alpha \log(y_i - p_j) + \beta^N \log N_j + \beta^k x_j^k + \xi_j + \sigma^N \log N_j v_i^N + \sum_k \sigma^k x_j^k v_i^k}}{1 + \sum_{l=1}^{J} e^{\alpha \log(y_i - p_l) + \beta^N \log N_l + \beta^k x_l^k + \xi_l + \sigma^N \log N_l v_i^N + \sum_k \sigma^k x_l^k v_i^k}}$$

Identification (1)

The vehicle demand model introduces two identification problems

1. Endogeneity of the price term
   - BLP-style instruments
     - Observed exogenous model characteristics
     - Sum of the values of the same characteristics of other models offered by other firms
   - Instrument validity
     - Other product attributes have no direct impact on consumer utility for a product, but through competition (impacts prices)
     - Validity is violated if observed characteristics (x) are chosen after unobserved attributes (ξ) are known

Identification (2)

2. Endogeneity due to network effects

   - EV sales and the number of stations are determined simultaneously
   - Suggested instruments are EVSE incentives
   - Validity of instruments ensured as
     - Most policies were adopted before the start of the EV market
     - Usually introduced in the context of multi-year transportation plans
     - County fixed effects control for local preferences
   - Robustness check with alternative set of instruments (location types)

Station Entry Model (1)

- Modeling assumptions
  - $s = 1, ..., N_{ct}$ stations in each market
  - Per-consumer profit is $D_{sct}(p_{sct}, p_{-sct}, N_{ct})(p_{sct} - mc_{sct})$
    - $D_{sct} \sim$ per-consumer demand
    - $mc_{sct} \sim$ marginal cost
    - $p_{sct} \sim$ price charged by station
  - Symmetric demand functions
  - Profit functions are quasi-concave in price
  - Equilibrium price declines in number of stations
  - Each station earns equal portion of the market

Station Entry Model (2)

- Per-period profit is $\pi_{ct+1} = Q_{ct}^{EV} D(p(N_{ct}))\varphi(N_{ct})/N_{ct}$
    - Q_{ct}^{EV} = cumulative EV base
    - $\varphi(N_{ct})$ = markup ($= p - mc$)
    - Let $f(N_{ct}) \equiv D(p(N_{ct}))\varphi(N_{ct})/N_{ct}$
- Sum of discounted earnings, if a station enters in period t

$$-F_{ct} + d\pi_{ct+1} + d^2\pi_{ct+2} + ...$$

- or in period $t+1$

$$-dF_{ct+1} + d^2\pi_{ct+2} + ...$$

Station Entry Model (3)

- In a free-entry equilibrium stations are indifferent between entering now or next period

$$d\pi_{ct+1} = F_{ct} - dF_{ct+1}$$

- After re-organizing

$$\log f(N_{ct}) = -\log d - \log Q_{ct}^{EV} + \log\left(F_{ct} - dF_{ct+1}\right)$$

Station Entry Model (4)

- To complete the model I assume

$$\log \underbrace{f(N_{ct})}_{=b(N_{ct})^{-\omega}} = -\log d - \log Q_{ct}^{EV} + \underbrace{\log(F_{ct} - dF_{ct+1})}_{=a_0+a_1 EVSE_{ct}+a_2\rho_c+a_3 h(t)+e_{ct}}$$

- Station entry model specification is given by

$$\log N_{ct} = \lambda_0 + \lambda_1 \log Q_{ct}^{EV} + \lambda_2 EVSE_{ct} + \lambda_3 \rho_c + \lambda_4 h(t) + \epsilon_{ct}$$

Identification

- Endogeneity due to network effects
- Proposed instrument: Gas station density
  - Main driver of competition and prices in the fuel market
  - Correlates with EV sales
- Validity of instruments ensured if
  - There are no unobserved time-invariant factors that correlate with both the IV and the charging network.
- Lagged instruments are also included

Estimation Methodology

- System is estimated using Generalized Method of Moments
- Assume $\mathbb{E}([\epsilon\ \xi] \mid Z_S, Z_D) = 0$
  - $(Z_S,\ Z_D) \sim$ set of exogenous variables for the station entry and vehicle demand models
- Estimation problem
  - Choose parameters $[\theta\ \lambda]$ to minimize GMM objective function $[m'\Phi^{-1}m]$, where Φ^{-1} is the weighting matrix and

$$m = \begin{bmatrix} Z_S' & \hat{\epsilon} \\ Z_D' & \hat{\xi} \end{bmatrix}$$

Effectiveness of EV Policies (1)

- The effect of a purchasing price subsidy on the total sales of AEVs:

$$\sum_{j \in EV} \frac{\partial Q^{EV}}{\partial p_j} = \sum_{j \in EV} \frac{\sum_{k \in EV} \eta_{kj} I}{1 - \sum_{k \in EV} \gamma_k \lambda_1 / Q^{EV}}$$

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- **Own- and cross-price elasticities (η_{kj})** are given by

$$\eta_{kj} = \begin{cases} \int \frac{-\alpha s_{ij}(1-s_{ij})}{y_i - p_j} dP_v^*(v) & \text{if } j = k \\ \int \frac{\alpha s_{ij} s_{ik}}{y_i - p_j} dP_v^*(v) & \text{otherwise} \end{cases}$$

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- The effect of a purchasing price subsidy on the total sales of AEVs:

$$\sum_{j\in EV}\frac{\partial Q^{EV}}{\partial p_j}=\sum_{j\in EV}\frac{\sum_{k\in EV}\eta_{kj}I}{1-\sum_{k\in EV}\boldsymbol{\gamma_k}\lambda_1/Q^{EV}}$$

- Own- and cross-price elasticities ($\boldsymbol{\eta_{kj}}$)
- **Feedback effects on the consumer side (γ_j)** are given by

$$\gamma_j=\int\frac{\beta_i^N s_{ij}(1-s_{ij})}{y_i-p_j}dP_v^*(v)$$

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- Own- and cross-price elasticities ($\boldsymbol{\eta_{kj}}$)
- Feedback effects on the consumer side ($\boldsymbol{\gamma_j}$)
- **Feedback effects on the station side ($\boldsymbol{\lambda_1}$)**

Effectiveness of EV Policies (2)

- The effect of a station subsidy on the total sales of AEVs:

$$\frac{\partial Q^{EV}}{\partial EVSE} = \frac{\sum_{k \in EV} \gamma_k \lambda_2 I}{1 - \sum_{k \in EV} \gamma_k \lambda_1 / Q^{EV}}$$

Effectiveness of EV Policies (2)

- The effect of a station subsidy on the total sales of AEVs:

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- **Feedback effects on the consumer side ($\boldsymbol{\gamma_j}$)** are given by

$$\gamma_j = \int \frac{\beta_i^N s_{ij}(1 - s_{ij})}{y_i - p_j} dP_v^*(v)$$

Effectiveness of EV Policies (2)

- The effect of a station subsidy on the total sales of AEVs:

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- Feedback effects on the consumer side (γ_j)
- **Feedback effects on the station side (λ_1)**

Effectiveness of EV Policies (2)

- The effect of a station subsidy on the total sales of AEVs:

$$\frac{\partial Q^{EV}}{\partial EVSE} = \frac{\sum_{k \in EV} \gamma_k \boldsymbol{\lambda_2} I}{1 - \sum_{k \in EV} \gamma_k \lambda_1 / Q^{EV}}$$

- Feedback effects on the consumer side ($\boldsymbol{\gamma_j}$)
- Feedback effects on the station side ($\boldsymbol{\lambda_1}$)
- **Elasticity of station entry with respect to EVSE subsidies ($\boldsymbol{\lambda_2}$)**

Structural Estimation Results

Vehicle Demand	Variable	Parameter Estimate	Standard Error
	log(Income - Price)	4.3905	0.8329
Means	Station Network	0.4184	0.1430
	EV	0.7574[a]	0.0481
	Transmission	0.0480[a]	0.0149
	Acceleration	11.5859[a]	0.4150
	Size	0.1069[a]	0.0166
	Consumption	-0.2588[a]	0.0656
Std. Deviations	Station Network	0.2809	1.0849
	EV	0.6613	4.4303
	Transmission	0.2331	0.0772
	Acceleration	0.9643	4.0888
	Size	1.1458	0.0844
	Consumption	3.6586	1.0488

Structural Estimation Results

Station Entry	Parameter Estimate	Standard Error
log(EV base)	0.1628	0.0537
EVSE normal (10,000 NOK)	0.1832	0.0544
EVSE fast (10,000 NOK)	-0.0017	0.0018
Trend	0.0751	0.0518

Structural Estimation Results

- Feedback effects are positive and significant.
- Vehicle demand:
  - The mean coefficients of vehicle attributes have the expected signs
  - The price term is of the expected sign and significant
- Station entry:
  - Installment of stations is positively responsive to the AEV base
  - A 1% increase in the stock of AEVs increases stations by 0.163%

Sample of Own- and Cross-Price Semi-Elasticities

AEV Make and Model	i3	C-Zero	i-Miev	Leaf	Ion	E-Up!
No Feedback Effects						
BMW i3	-5.495	0.014	0.014	0.020	0.014	0.014
Citroen C-Zero	0.003	-5.782	0.002	0.003	0.002	0.002
Mitsubishi i-Miev	0.003	0.004	-5.829	0.005	0.004	0.003
Nissan Leaf	0.095	0.051	0.047	-5.746	0.049	0.070
Peugeot Ion	0.003	0.003	0.002	0.003	-5.812	0.003
Volkswagen E-Up!	0.019	0.015	0.014	0.018	0.015	-5.709

Each cell entry, where i denotes rows and j denotes columns, shows the percentage change in market share of model i with a $10,000$ NOK change in price of model j.

Sample of Own- and Cross-Price Semi-Elasticities

AEV Make and Model	i3	C-Zero	i-Miev	Leaf	Ion	E-Up!
With Feedback Effects						
BMW i3	-5.507	0.006	0.006	0.015	0.006	0.007
Citroen C-Zero	-0.002	-5.803	-0.012	-0.007	-0.012	-0.005
Mitsubishi i-Miev	-0.009	-0.048	-5.899	-0.030	-0.051	-0.014
Nissan Leaf	0.026	-0.038	-0.041	-5.812	-0.041	-0.022
Peugeot Ion	-0.002	-0.013	-0.014	-0.007	-5.836	-0.005
Volkswagen E-Up!	0.007	0.001	0.000	0.008	0.000	-5.731

Each cell entry, where i denotes rows and j denotes columns, shows the percentage change in market share of model i with a $10,000$ NOK change in price of model j.

Sample of Own- and Cross-Price Semi-Elasticities

- Compared to traditional vehicle markets $\rightarrow$ Network externalities
- Feedback loops affect elasticities of AEV models
- Negative cross-price semi-elasticities indicate that network effects dominate

  $\rightarrow$ AEV models can act as complements

- Network effects slightly increase magnitude of own-price semi-elasticities

Policy Counterfactuals

- Consider alternative counterfactual incentive structures:
  1. AEV price discounts (e.g. tax exemption)
  2. Station cost discounts (e.g. direct one-time subsidies)

- Jointly determine equilibrium $\hat{N}_{tr}$ and $\hat{s}_{tr}$ using the GMM estimates of the model parameters $(\hat{\theta}, \hat{\lambda})$ and counterfactual incentive structures.

- Set the magnitude of the discounts so that there is revenue equivalence between incentive schemes.

- Compare how changes in the two subsidies affect total AEV sales, given a fixed amount of resources.

Policy Counterfactuals (Average Impact)

	Status quo	Counterfactuals	
	Current Subsidies	Only Price Subsidy	Only Station Subsidy
	[1]	[2]	[3]
ΔTotal EV Purchases	18,005	16,921	869
ΔTotal Stations	707	352	343
ΔTotal Government Spending (Million NOK)	4,552	4,374	104
ΔEV Purchases / ΔGovernment Spending	3.96	3.87	8.35
Normal EVSE incentives	Y	N	Y
Car Purchase Incentives	Y	Y	N

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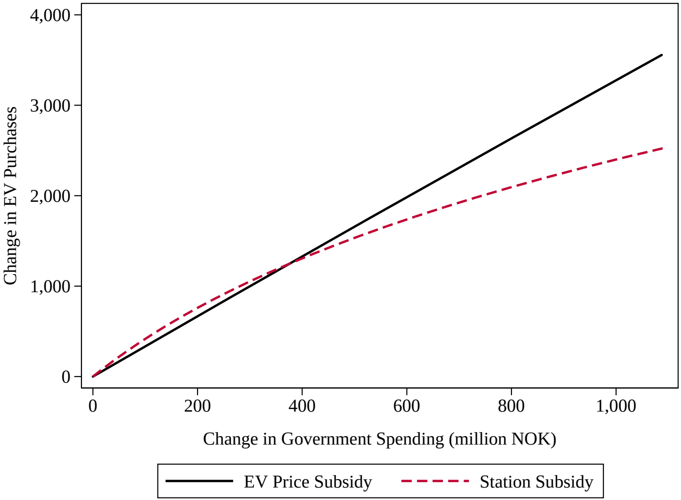
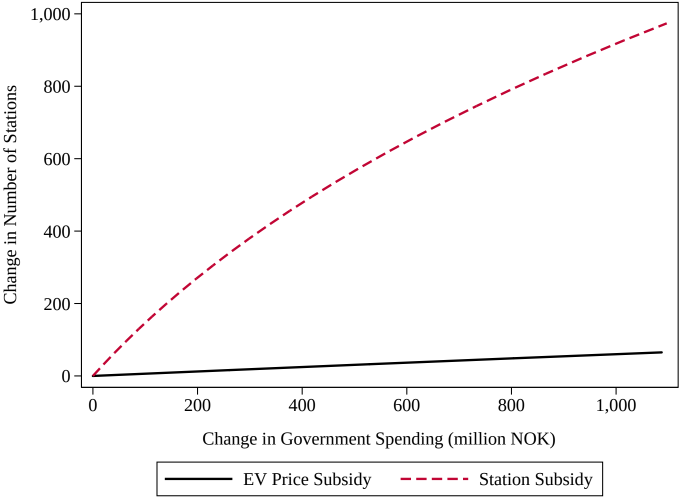
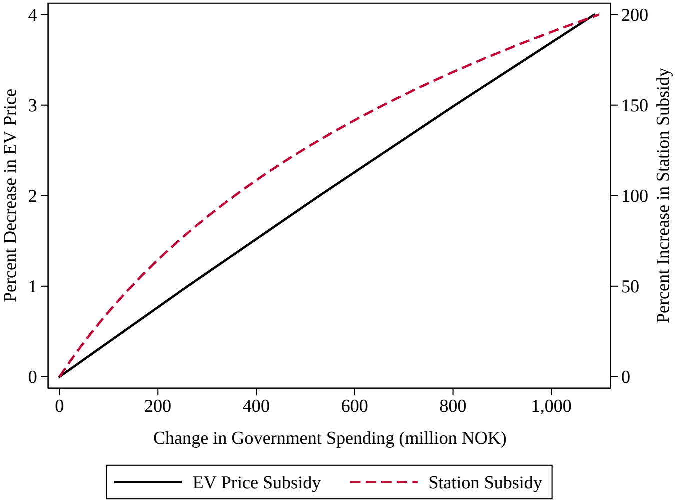
Policy Counterfactuals (Marginal Impact)



Policy Counterfactuals (Marginal Impact)

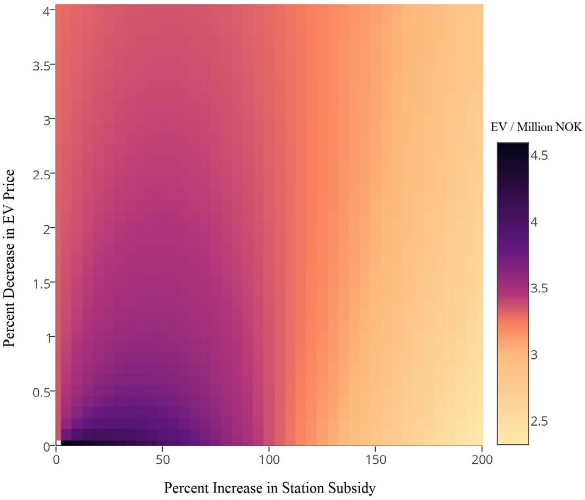


Policy Counterfactuals (Marginal Impact)



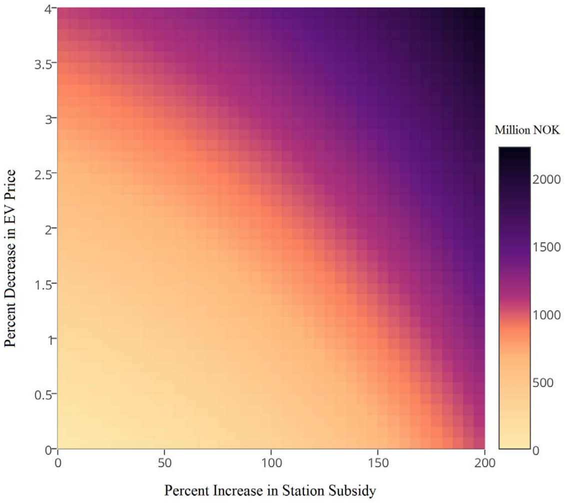
Policy Counterfactuals (Marginal Impact)

Efficiency of Price and Station Subsidies



Policy Counterfactuals (Marginal Impact)

Implied Change in Government Spending



Conclusion

- What do we learn?
  - Network effects play a key role in the AEV market
    - $\Rightarrow$ Feedback effects result in complementarities between AEVs
    - $\Rightarrow$ The feedback loops further amplify the effect of subsidies
  - Heterogeneity in consumer valuation is similarly important
    - $\Rightarrow$ Provides more realistic substitution patterns
    - $\Rightarrow$ Affects the impact price subsidies have on demand for AEVs
  - Counterfactual policy analysis shows that
    - $\Rightarrow$ Effectiveness of subsidies is an open empirical question

Thank you!

Comments and questions appreciated

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