Charging of EVs: Should we accept multiple standards?

Mads Greaker

Work-shop:

The Energy Transition in Land Transportation

Paris, 2017
The Norwegian Paris commitments

- 40% reduction as compared to 1990
- Joint implementation with the EU
- 43% reduction, together with the EU, in the ETS sectors
- 40% reduction in Non ETS sectors
- (based on 2005)
Electric vehicles centerpiece of Norwegian policy

- For Non-ETS transport is by far the biggest emitter
- Norway’s EPA (2016); EV share of sales 40-60% in 2025 from 60-100% in 2030.
- Road authorities plan for 2018-2029; all private road transport after 2025 should be zero emission vehicles
Charging of EVs

- Better access to charging increases willingness to pay for EVs (Zhang et al, 2016, Figenbaum and Kolbenstvedt, 2016)
- More than 40% of Norwegian households has only one car
- More than 25% of Norwegian households live in multi apartment buildings with lack of charging facilities
- Need for fast charging: > 50 kW effect
- Today there are four partly incompatible fast charging systems; Combo, Chademo, Renault Zoe og Tesla, and more may be on their way...
Research questions:

• What does fast charging compatibility imply for the diffusion of EVs?

• What are the private incentives to ensure compatibility?

• Should governments enforce compatibility?
Literature

- **General:**
  
  
  

- **On fast charging:**
  
  
  
  
Fast charging versus gasoline pump

- Gasoline pump; two standards, short refueling time, relatively low investment cost, big market for both standards
- Fast charger; four standards, long refueling time, relatively high investment costs, small market, competition from home charging
- Gasoline refueling capacity >> fast charging capacity
The economics of charging/fueling

I. Gasoline prices not as sensitive to capacity utilization

II. For fast charging to become profitable capacity utilization is key

III. Different standards -> less capacity utilization -> harder to build a competitive network
Outline

• Adapt general model of compatibility choice to EVs:
  • Katz og Shapiro (1986), *American Economic Review*

• Discuss the incentives for compatibility

• Calibrate the model to Norwegian data
  • Norwegian EPA (2016), *EV abatement costs*
The model

- Each consumer has an idiosyncratic ranking of EV brands
  \[ r = \max \{r_1, \ldots, r_n\} \]
- The max value is uniformly distributed \( r \sim [-\infty, A] \)
- The gross utility from an EV of type \( i \) is: \( r + v(y_i^e) \)
- The network benefit is equal for consumers \( v(y_i^e) \)
- The market size is given, and the market is covered
The network benefit

- There is a given relationship between the number of EVs of type i; $x_i$ and the number of fast chargers available for the type; $y_i$

- No compatibility: Each type can only use its own system: $y_i = x_i$

- Full compatibility: All chargers are available to all types: $y_i = \sum_{i=1}^{n} x_i$

- Partial compatibility: Some brands share network: $y_i = \sum_{i=1}^{m} x_i$, $m < n$
Demand

- Price and costs of a gasoline car are normalized to zero
- There is a subsidy $s$ for EVs, and production costs are $c > 0$
- A consumer chooses an EV if:
  \[ r + v(y_i^e) - p_i + s \geq 0 \]
- EV buyers then equal:
  \[ A - (p_i - v(y_i^e) - s) \]
- Demand for EVs can then be expressed

\[ p_i = A + v(y_i^e) + s - \sum x_i \]
Supply of EVs

- Producers do not know the idiosyncratic preferences of consumers
- Capacity game with perfect substitutes
- The $n$ producers maximize:

$$\max \left\{ (A + s + v(y^e_i) - \sum x_i - c)x_i \right\}$$

- Depending on the expectations, there may be multiple equilibriums
- Like Katz and Shapiro, we concentrate on the fulfilled expectations equilibrium
Markedsligevekt

- The n Foc’s:
  \[(A + s + ν(y^e_i) - \sum x_i - c) - x_i = 0\]
- Adding the Foc’s:
  \[n(A + s - c) + \sum_n ν(y^e_i) = (n + 1)z,\]
- Generally: More compatibility -> higher share of EVs
  \[(z = \sum x_i)\]
Alternative market structures

- Strategic investing in network
  \[ A + s + v(y_i^e) + v' \frac{dy_i^e}{dx_i} x_i - \sum_i x_i - c - x_i = 0 \]

- Main results still hold if \( v' + v'' y_i^e > 0 \)

- Asymmetric firms
  \[ \pi_i = (A + s + \alpha_i y_i^e - x_i - x_j - c) x_i \]

- Dominant firm prefers non-compatibility if
  \[ 2\alpha_1 - (\alpha_1)^2 \geq \alpha_2 \]
Results

- Higher degree of compatibility:
  - More EVs, less gasoline cars, less GHG emissions
- But how large is the effect?
Numerical illustration

- Assume 3 networks and calibrate the model to EV sales in the period 2012-2016.
- In total 729609 new cars of which 82009 EVs (11%).
- In 2016 there was 1452 fast charging connectors e.g. 0.018 per EV.
- Willingness to pay for network:
  \[ v(\gamma_i^e) = \gamma \sqrt{\mu \sum x_i} \]
- \( \gamma \) is set such that WTP for an EV increases with 2.5 (5) Nok per additional charger.
- A is then fixed such that a market share of 11% results.
- For 2021-2025: \( c \) and \( s \) is reduced (Norwegian EPA, 2016).
- A is changed (technological improvements+) such that a market share of 40% with 3 networks results.

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<tr>
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<th>2012-2016 11% share</th>
<th>2021-2025 40% share</th>
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<tbody>
<tr>
<td>Extra cost EV (c)</td>
<td>143.000</td>
<td>88.150</td>
</tr>
<tr>
<td>Subsidie EV (s)</td>
<td>232.540</td>
<td>177.690</td>
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<tr>
<td>A</td>
<td>-76.995</td>
<td>125.318</td>
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Norwegian EPA, 2016
The effect of compatibility depends on the net work effect

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<th>Case 1 Low network utility</th>
<th>Case 2 High network utility</th>
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<tr>
<td></td>
<td>3 different networks</td>
<td>Common network</td>
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<tr>
<td>Market share 2012–2016</td>
<td>11%</td>
<td>13%</td>
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<tr>
<td>Market share 2021–2025</td>
<td>40%</td>
<td>44%</td>
</tr>
<tr>
<td>Net price 2012–2016 (NOK)</td>
<td>-62204</td>
<td>-56783</td>
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<tr>
<td>Net price 2021–2025 (NOK)</td>
<td>10460</td>
<td>19851</td>
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Norwegian EPA scenarios

- With $\gamma \rightarrow 100$ Nok per additional charger
- Full/no compatibility the whole distance between ambitious/moderate
- But now ambitious much «cheaper»!
How to estimate the network effect?

- Daziano: WTP for bigger battery $100/mile
- Bigger battery imperfect substitute for fast charging
- CES function with elasticity of substitution 1.5 -> € 10 per extra charging station
- Better -> use panel data on EV sales and charger network from Norway
Private incentives for compatibility?

- Full compatibility is best for social welfare (in our static model)
- Compatibility profitable for symmetric firms, but not necessarily for asymmetric (new result in paper)
- Farrell og Simcoe (2011) three ways to compatibility:
  - i) Coasian standard setting institutions
  - ii) Through adapters
  - iii) Government legislation
- Both i) and iii) can reduce incentives for innovation
- Innovation is happening: VW/Audi talk about 300 kW, or “cable free charging”
Discussion and conclusion

- Fast charging compatibility should worry the EU
- Proprietary systems should only be allowed to the extent that they spur innovation
- Public subsidies to stations must require compatibility and be able to supply 120 kW
- Do local grids have enough capacity for a large scale introduction of fast chargers
- In Norway: Skotland m/fler (NVE, 2016); Yes
- Hydrogen cars require a network of hydrogen filling stations with high investments costs
- In a bad state both technologies obtain to little diffusion due to low density of both fast chargers and hydrogen filling stations.