Charging of EVs: Should we accept multiple standards?

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Work-shop:

The Energy Transition in Land Transportation

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Statistisk sentralbyrå
Statistics Norway

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% i 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:

  - Farrell, J og T. Simcoe, (2011), Four paths to Compatibility, Oxford Handbook of the Digital Economy edited by M. Peitz and J. Waldfogel.
  - Farrell, J., og G. Saloner, (1985). Standardizations, Compatibility, and Innovation. *Rand Journal of Economics* 16: 70-83.
  - Katz, M., og Shapiro, C. (1985). Network Externalities, Competition, and Compatibility. *American Economic Review* 75: 424-440.

- On fast charging:

  - Figenbaum, E. og M. Kolbenstvedt (2016). Learning from Norwegian Battery Electric and Plug-in Hybrid Vehicle users – Results from a survey of vehicle owners. Transportøkonomisk Institutt, Rapport 1492/2016.
  - Zhang, Y., Qian, Z., Sprei, F., og Li, B. (2016). The Impact of Car Specializations, Prices and Incentives for Battery Electric Vehicles in Norway: Choices of Heterogeneous Consumers. *Transportation Research Part C: Emerging Technologies* , 69: 386-401.
  - Kristoffersen M. (2016). Compatibility Choice: In the Electric Vehicle- and Charging Market. Thesis for the Masterdegree in Economics, UiO.
  - Li J. (2016), Compatibility and Investment in the U.S. Electric Vehicle Market, Job market paper, Harvard University.

Fast charging versus gasoline pump

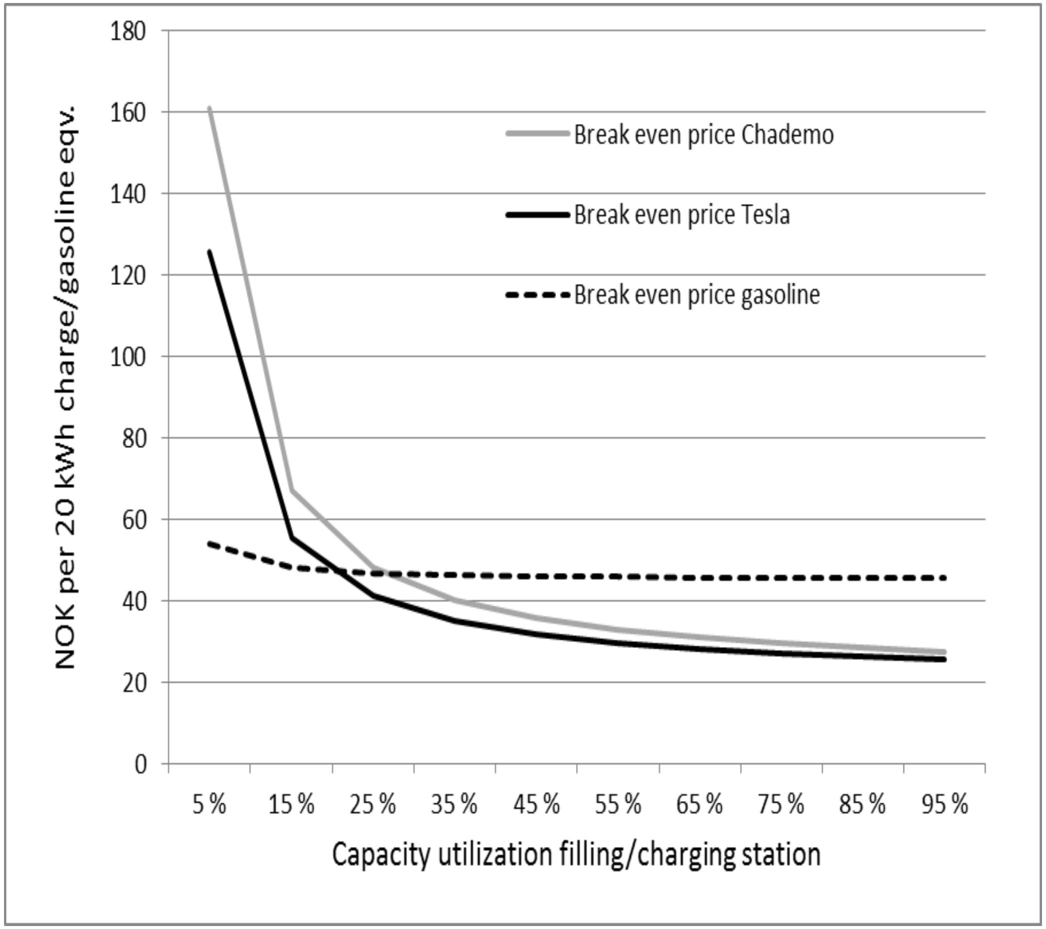
- Gasoline pump; two standards, short refueling time, relatively low investment cost, big market for both standards
- Fast charger; four standards, long refueling time, relatively high investment costs, small market, competition from home charging
- Gasoline refueling capacity >> fast charging capacity

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
  - Farrell and Simcoe (2011), Oxford Handbook of the Digital Economy
- Calibrate the model to Norwegian data
  - Norwegian EPA (2016), EV abatement costs

The model

- Each consumer has an idiosyncratic ranking of EV brands

  $r = \max\{r_1, ..., r_n\}$

- 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:

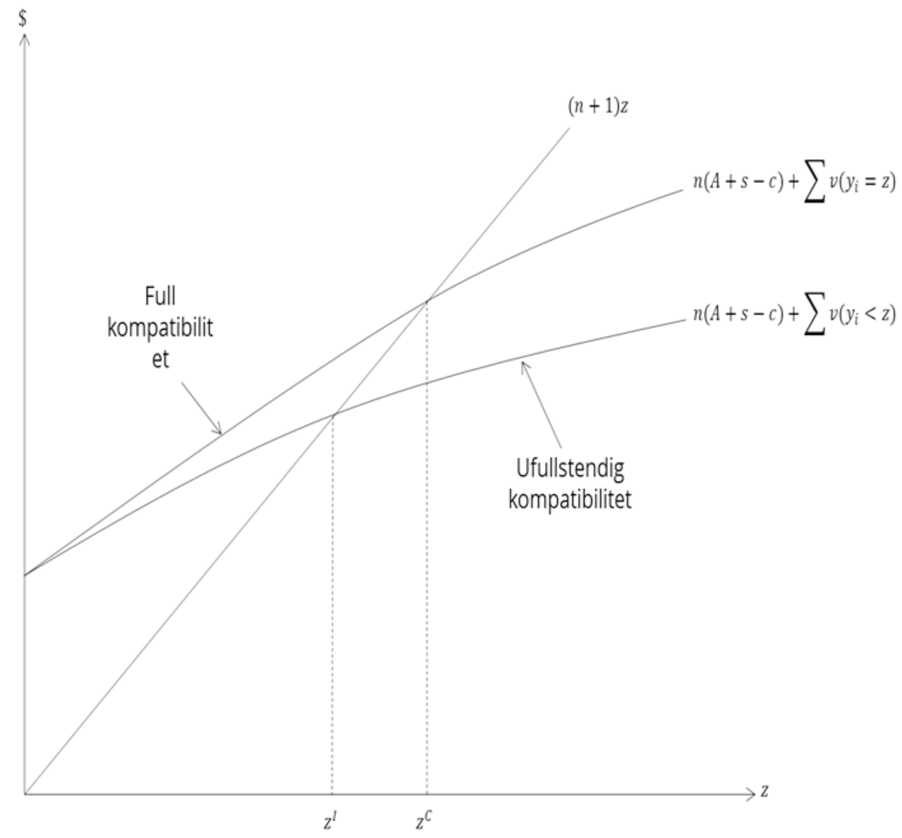
$$\max\left\{(A + s + v(y_i^e) - \sum x_i - c)x_i\right\}$$

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

Markedslikevekt

- The n Foc's:
- $(A + s + v(y_i^e) - \sum x_i - c) - x_i = 0$
- Adding the Foc's:
- $n(A + s - c) + \sum_n v(y_i^e) =$

  $(n+1)z.$
- 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;
- $v(y_i^e) = \gamma\sqrt{\mu \sum x_i}$
- γ 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

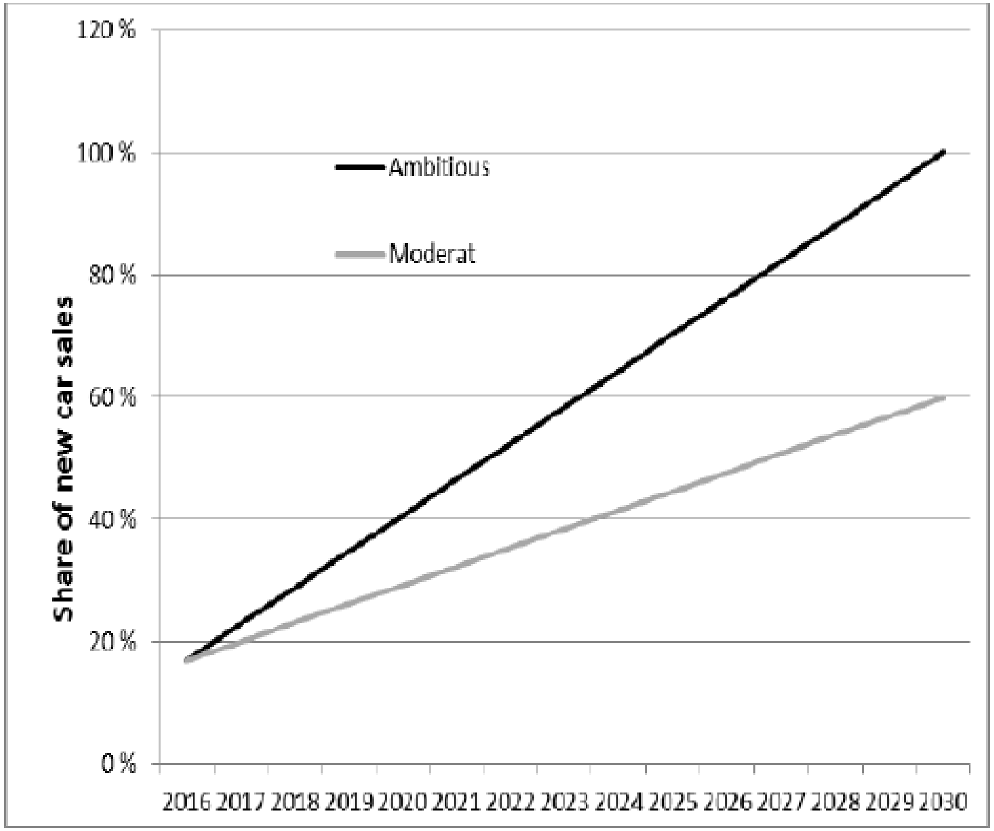
	2012-2016 11% share	**2021-2025 40% share**
Extra cost EV (c)	143.000	88.150
Subsidie EV (s)	232.540	177.690
A	-76.995	125.318

The effect of compatibility depends on the net work effect

	Case 1 Low network utility		Case 2 High network utility	
	3 different networks	Common network	3 different networks	Common network
Market share 2012–2016	11%	13%	11%	17%
Market share 2021–2025	40%	44%	40%	48%
Net price 2012–2016 (NOK)	-62204	-56783	-62204	-48682
Net price 2021–2025 (NOK)	10460	19851	10460	31399

Norwegian EPA scenarios

- With γ -> 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.