The Tradeoff between Indirect Network Effects and Product Differentiation in a Decarbonized Transport Market
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Introduction: Decarbonization of road transport

• EU climate targets:
  – Medium-term: Reduce GHG emissions by 55% in 2030 vis-à-vis 1990
  – Long-term: Net-zero emissions by 2050

• Road transport sector
  – Important source of GHG emissions (one fifth of EU’s GHG emissions)
  – Switch from fossil to non-fossil technologies
    • European Commission target: 30 million zero-emission cars by 2030
    • Norway: Ban on sales of new fossil-based private cars from 2025

• Different non-fossil vehicle technologies exist
  – Biofuels – sustainable in the long run?
  – Electric vehicles
  – Hydrogen vehicles
Introduction: Electric and/or hydrogen vehicles?

Optimal with one or two non-fossil vehicle technologies?

What will the market choose?
What should the government do?
Introduction: Electric and/or hydrogen vehicles?

• Optimal with one or two non-fossil vehicle technologies?

• Different characteristics
  – Imperfect substitutes – product differentiation
  → Two alternatives better than one

• Indirect network effects
  – The utility a consumer gets from a good depends (indirectly) on the number of users who are in the same network (Katz & Shapiro, 1985)
    • Through the number of charging/filling stations
  → One “big” network better than two “small”
Introduction: Indirect network effects

• Coordination problem:
  – Demand for the vehicles depends on the availability of charging/filling stations
  – Investments in charging and filling stations depends on the number of vehicles

• Some relevant literature:
  – Katz and Shapiro (AER, 1985); Farrell and Saloner (AER, 1986)
  – Greeker and Midttømme (JPubE, 2016); Zhou and Li (JIE, 2018)
  – Meunier and Ponssard (EER, 2020)
Introduction: Research questions

• Trade-off between
  – Indirect network effects
  – Benefit of product differentiation

1. What factors determine whether there will be, or should be, one or two technologies in a decarbonized road transport market?
   – In the market without policies (BAU)
   – In the optimal solution

2. What policies should governments choose (first and second best)?

• Theoretical and numerical analysis
Introduction: Preview of findings

• Zero, one or two positive equilibria possible for each technology
  – Depends e.g. on the number of vehicles for the other technology

• With two equilibria, one is stable and the other is unstable
  → Lock-in situation is possible

• Choice of policy:
  – First-best: Subsidy of the monopoly markup on charging/filling
  – Additional stimulus may be needed to pass unstable equilibrium
  – Second-best policy cheaper for the government
Analytical model

• Static, partial equilibrium model for road transport sector
  – Private cars, buses, trucks etc

• Two types of economic agents
  – Representative consumer that buys and uses electric and/or hydrogen vehicles
    • Assume only one vehicle model of each technology (only non-fossil vehicles)
    • The two vehicle technologies are imperfect substitutes
    • Prices of vehicles are exogenous (e.g. imported)
  – Firms supplying the network of charging and filling stations
    • Monopolistic competition in the station market
    • Free entry → Zero profit

• Two competing, incompatible networks of charging and filling stations
  – Decisions of the two agents are interlinked through the indirect network effects
Existence and number of equilibria

• Derive two expressions that must hold in equilibrium
  – For both technologies

• Demand for vehicles \( (x_i) \) as a function of number of stations \( (M_i) \):

\[
x_i(M_i, x_{-i}) = g(M_i, x_{-i}) = A_i(x_{-i}) + B_i M_i^{\zeta_i}
\]

• Number of stations as an implicit function of number of vehicles:

\[
x_i(M_i) = h(M_i) = C_i M_i^{\gamma_i}
\]

• Both \( g(M_i, x_{-i}) \) and \( h(M_i) \) are increasing and concave in \( M \)
  – \( g(M_i, x_{-i}) \) is «more concave» than \( h(M_i) \) \( (\zeta_i < \gamma_i) \)
  – \( g(M_i, x_{-i}) \) is decreasing in \( x_{-i} \)
Three alternative cases for each technology

• Case I: One equilibrium
  – $A_i > 0$
  – Stable equilibrium

• Case II: Two equilibria
  – $A_i < 0$
  – Equilibrium with smallest (largest) values is unstable (stable)

• Case III: No equilibria
  – $A_i < 0$
  – $g(M_i, x_{-i}) < h(M_i)$ for all $M_i$
Likelihood of case I

- The likelihood of being in case I increases with:
  - The lower the price of the vehicle (and the higher the vehicle subsidy)
  - The higher the utility of the first vehicle
  - The fewer the number of vehicles of the other technology, and the lower the substitutability between the two technologies
Likelihood of equilibrium

- The likelihood of having an equilibrium also increases with (case I or II instead of case III):
  - The smaller the fixed costs for stations (and the higher the station subsidy)
  - The smaller the marginal costs for charging/filling (and the higher the subsidy to charging/filling)
  - The higher the utility of the charging/filling
First- and second-best policy

First-best policy:

• Subsidizing the markup on charging/filling: \( s = 1 - \rho \)

• However: This may not be sufficient to pass an unstable equilibrium

Second-best policy:

• What if subsidies to charging/filling are not feasible or too costly for the government?
  
    – Consider subsidy to stations and/or vehicles in simulation model
Calibration of numerical model

• Calibrated to a future vehicle market in Norway
  – With only electric vehicles (EVs) and/or hydrogen vehicles (H2Vs)
  – Use various data from the Norwegian vehicle market
    • More information exist about EVs than H2Vs

• Much uncertainty due to
  – Technological progress for vehicles and stations
  – Future market structure
  – Consumers' utility from owning and using the vehicles
Only electric vehicles (EVs)

- We first consider a market with only EVs
  - EVs have gotten a head start over H2Vs (Norway: 50% of car sales)
- We are in case I (one equilibrium)
- Comparing BAU with First-best:
  - Total charging per vehicle drops 47%
  - No. of stations drops 52%
  - No. of vehicles drops 10%
  - Total welfare (road transport) drops 6%
- We also examine hypothetical market with only H2Vs
Interaction between technologies

- How does the number of vehicles of one technology depend on the number of the other type of vehicles?
  - Depends on substitutability between EVs and H2Vs – consider two alternatives
    - «Close» and «Distant»
  - Construct «reaction functions»
    - Where do they intersect?
- Close substitutes (First best):
  - Five equilibria
    - 1 and 5: Only one technology
    - 2 and 4: Unstable equilibria
      - 2: Unstable for H2Vs
      - 4: Unstable for EVs
    - 3: Stable equilibrium with 2 tech.
Interaction between technologies – first best

• How does equilibrium #3 (two technologies) compare with equilibria #1 and #5 (one technology)?

• Close substitutes (first best):
  • EVs drop 36%; H2Vs drop 51% → 29% more vehicles in total
    → EV market share 56%
  • No. of charging and filling stations drop 39% and 53%
  • Welfare increases by 2% (12%)
    vis-a-vis EV (H2V) alone
    → Only moderate welfare gains from two technologies
  • No feasible BaU-equilibrium with both technologies
One or two technologies in first best?

- How does equilibrium #3 (two technologies) compare with equilibria #1 and #5 (one technology)?
  - For different levels of substitutability ($\phi$)
- Large welfare gains when technologies are distant substitutes
- When technologies are sufficiently close substitutes, only one technology can sustain
  - With first-best policy
- For some levels of substitutability (ca. $\phi = 5$), both technologies can sustain even though only EVs is best

Level of $\phi$:
- Perfect subst.: $\phi = 6.8$
- Close subst.: $\phi = 4.5$
- Distant subst.: $\phi = 2.3$
Second best solutions

- Is first-best policy feasible/desirable?
  - More common to subsidize stations and/or vehicles

- Consider two alternative second-best policies:
  - Second-best I: Subsidies only to charging and filling stations
  - (Second-best II: Subsidies to charging and filling stations and to vehicles)

- Second-best I (close):
  - Subsidy rates: 42-47%
  - Much closer to first best than to BAU
    - Except for charging/filling
  - No. of EVs and charging stations almost identical to first best
Second best solutions

- Second-best I (close) – cont.:
  - H2Vs more negatively affected than EVs
    - Compared to first-best
  - Welfare is halfway between first best and BAU
  - Public expenditures reduced
    >50% compared to first best

- Second-best II (close):
  - Not much to gain compared to Second-best I
  - Almost as high public expenditures as in first best
Conclusions

• Important policy questions for the coming decade:
  – One or two zero-emission vehicle technologies? Let the market decide?
  – What is optimal policy?

• The answer depends in particular on:
  – The utility of owning vehicles relative to the utility of charging/filling
  – Prices/costs related to the vehicles, stations and charging/filling
  – The substitutability between the technologies
  – The number of vehicles of the other technology

• First best policy: Subsidy to charging/filling
  – Second best subsidies to stations better alternative?

• More stimulus may be needed temporarily to overcome critical mass
THANKS FOR THE ATTENTION!