The Tradeoff between Indirect Network Effects and Product Differentiation in a Decarbonized Transport Market
(CESifo WP8298)

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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?

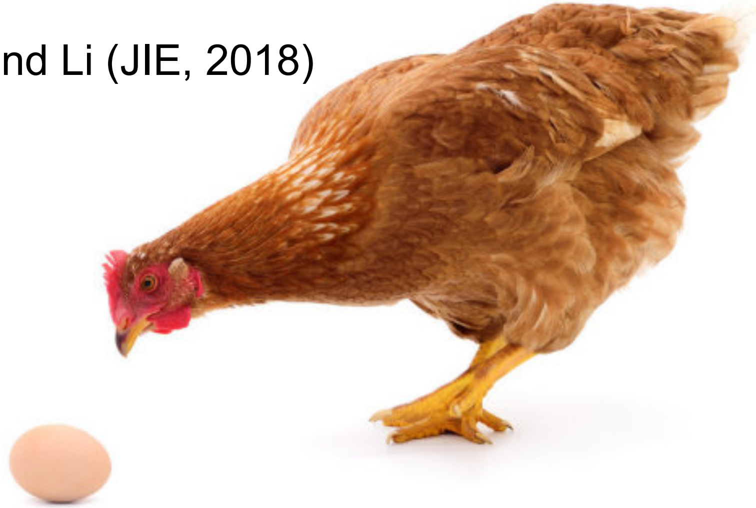
- Optimal with one or two non-fossil vehicle technologies?
- Different characteristics
  - Imperfect substitutes – product differentation

  → 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)
  - Greaker 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):

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

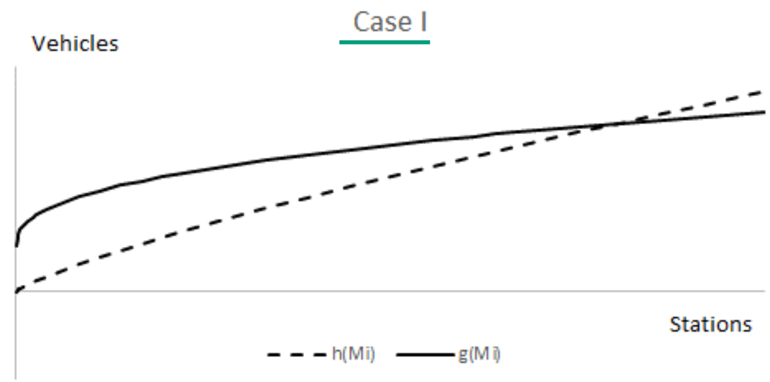
- Number of stations as an implicit function of number of vehicles:

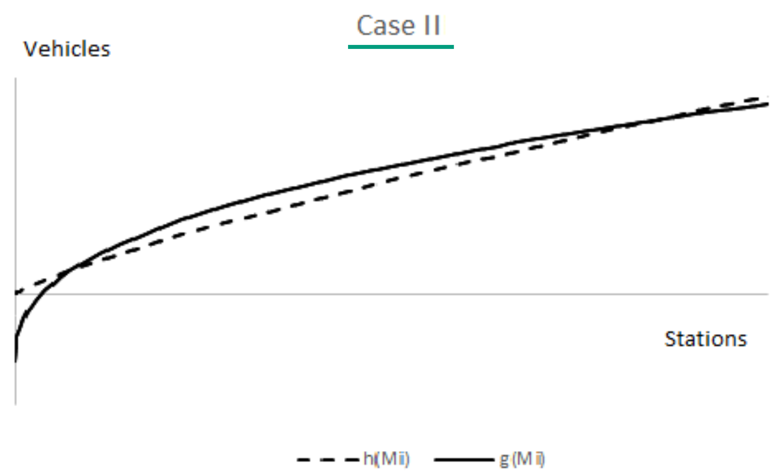
$$x_i(M_i) = h(M_i) = C_i M_i^{\gamma_i}$$

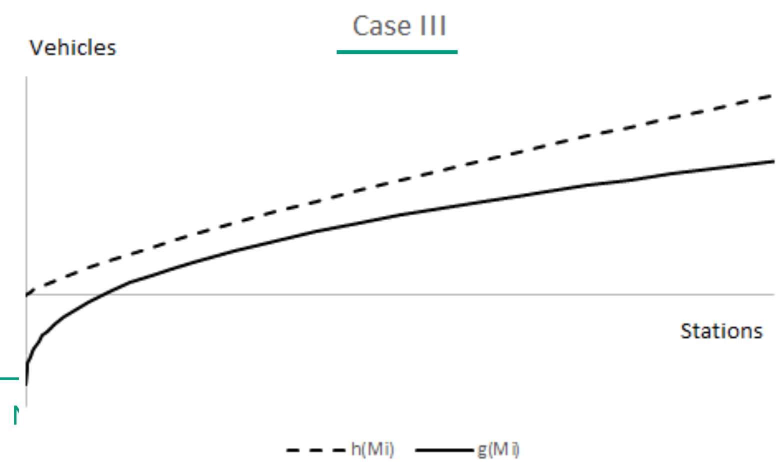
- Both $g(M_i, x_{-i})$ and $h(M_i)$ are increasing and concave in *M*
  - $g(M_i, x_{-i})$ is «more concave» than $h(M_i)$ ($\zeta_i < \gamma_i$)
  - $g(M_i, x_{-i})$ is decreasing in x_{-i}

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

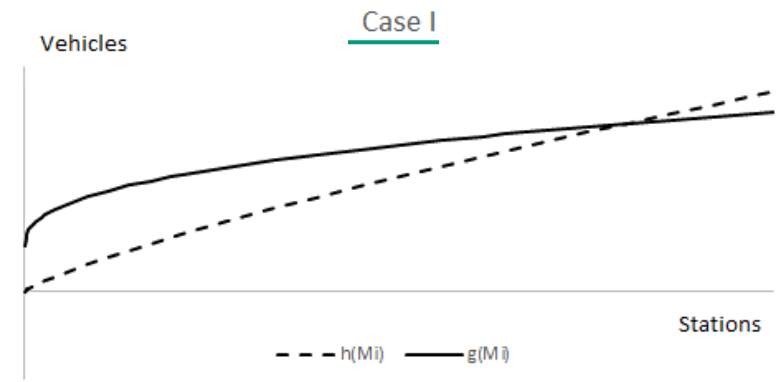


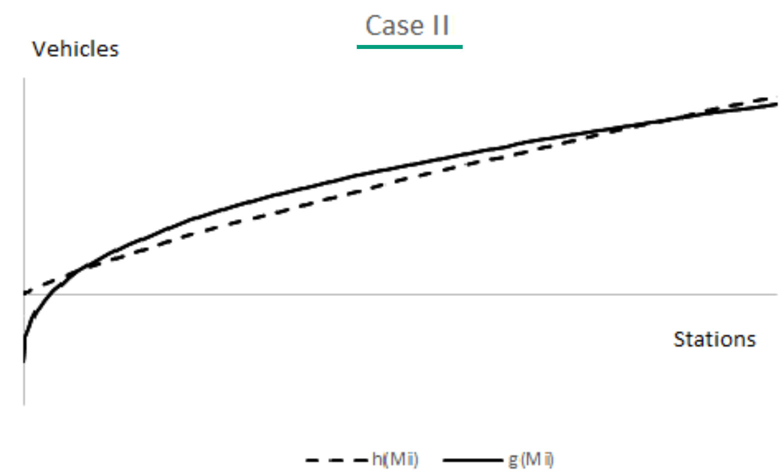


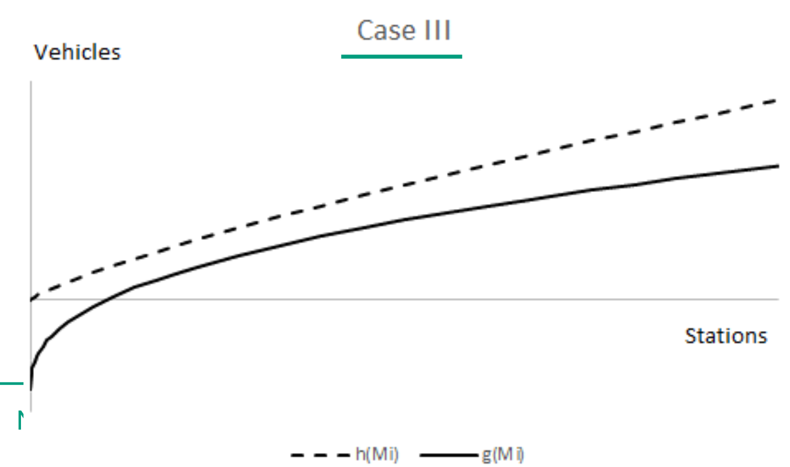


Likelihood of case I

- 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

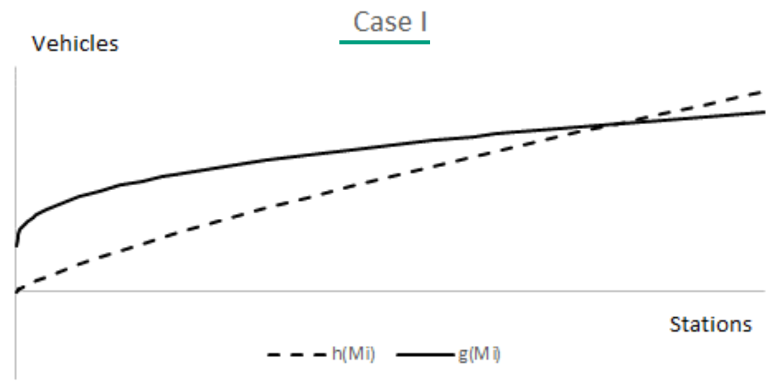


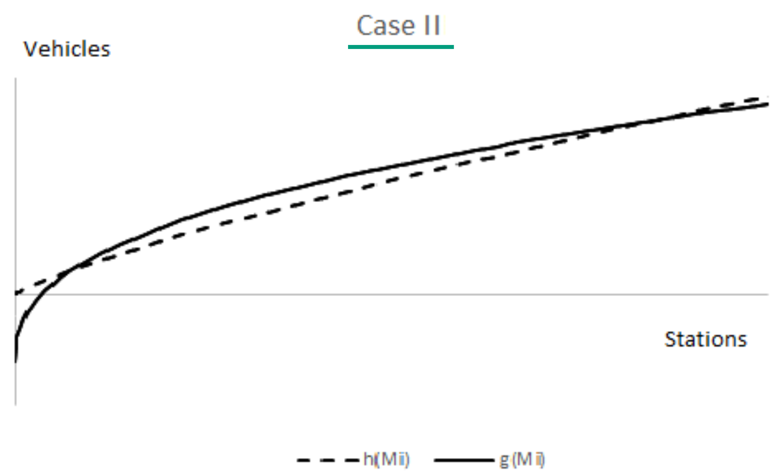


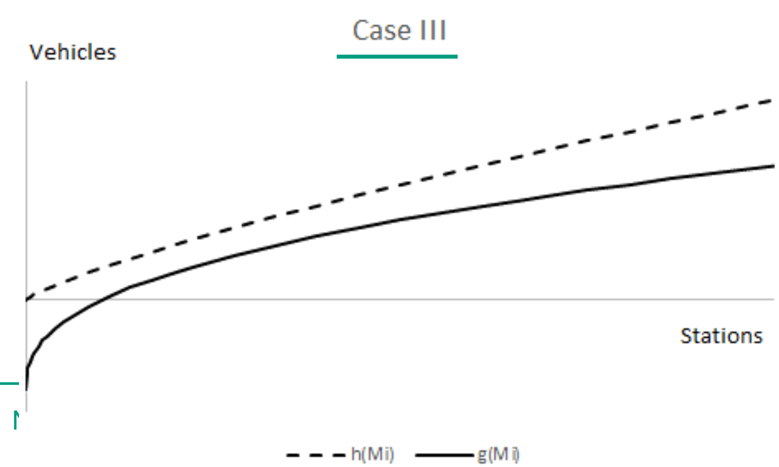


Likelihood of equilibrium

- 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:

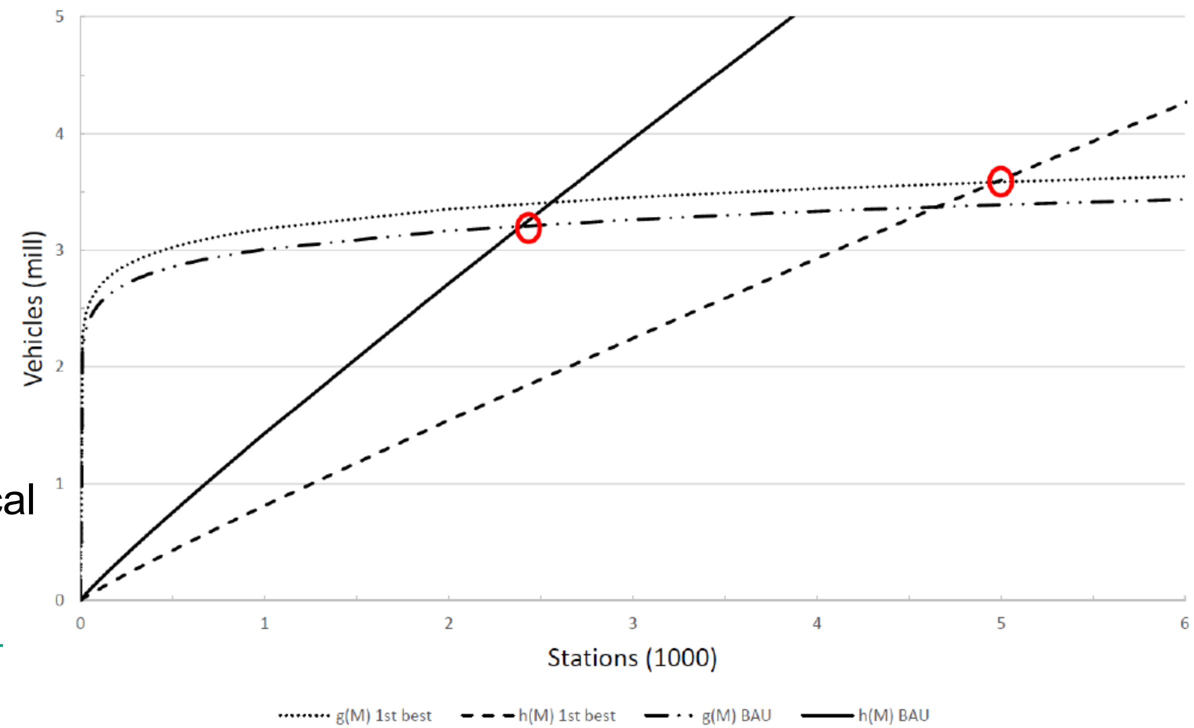
- What if subsidies to charging/filling are not feasible or too costly for the government?
  - Consider subsidy to stations and/or vehicles in simulation model

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

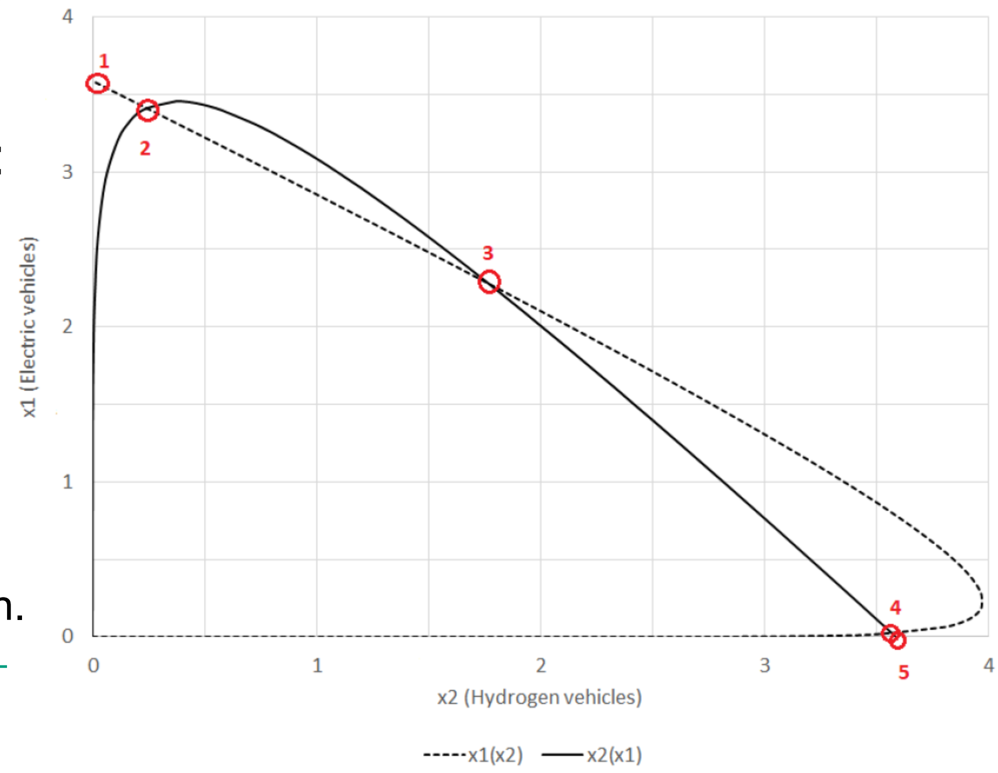
Only electric vehicles (EVs)

- 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



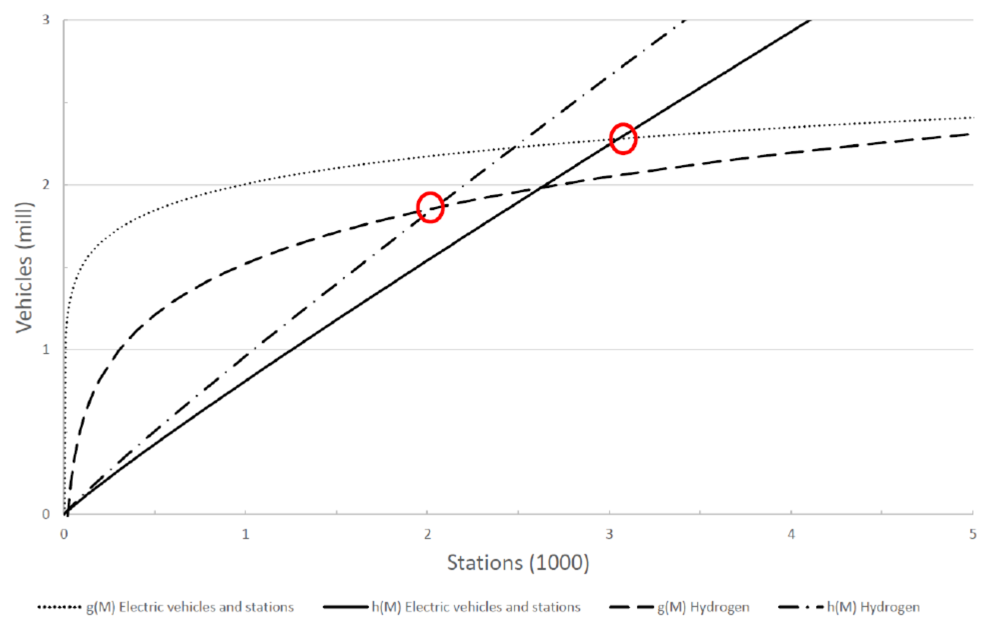
Interaction between technologies

- 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

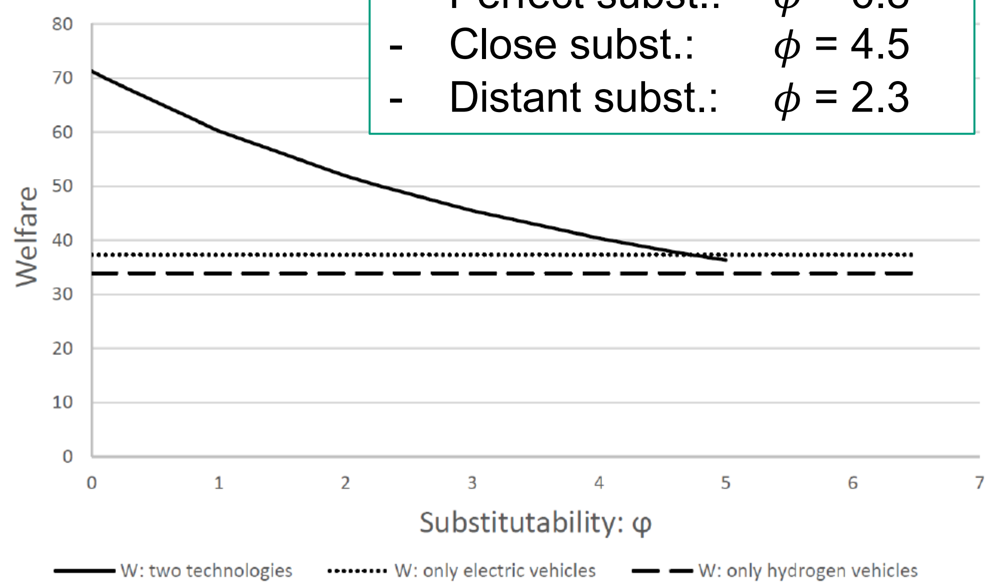


One or two technologies in first best?

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

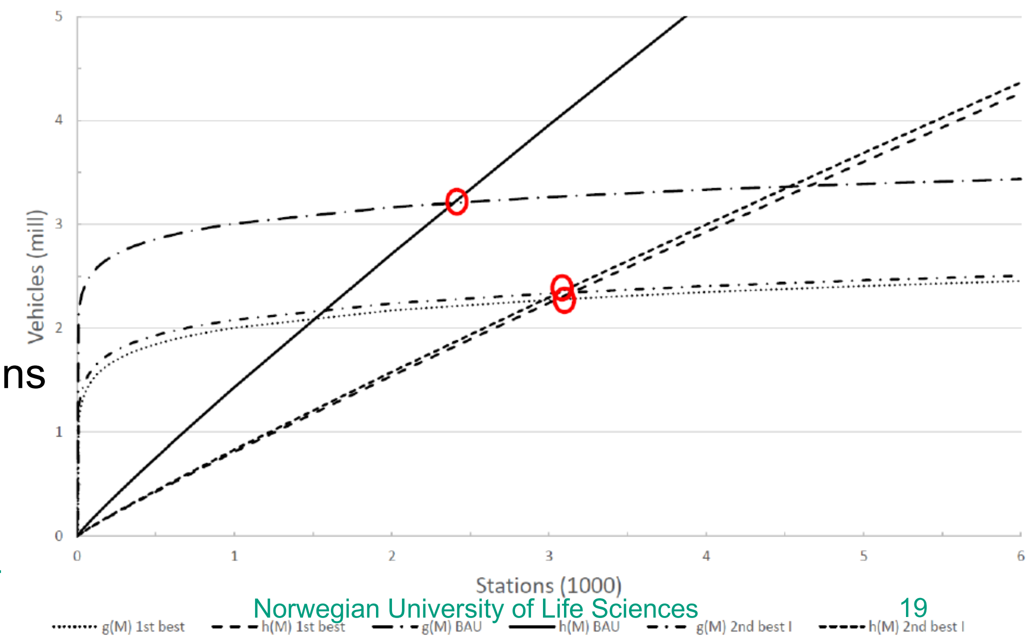
<u>Level of ϕ:</u>

- Perfect subst.: ϕ = 6.8
- Close subst.: ϕ = 4.5
- Distant subst.: ϕ = 2.3



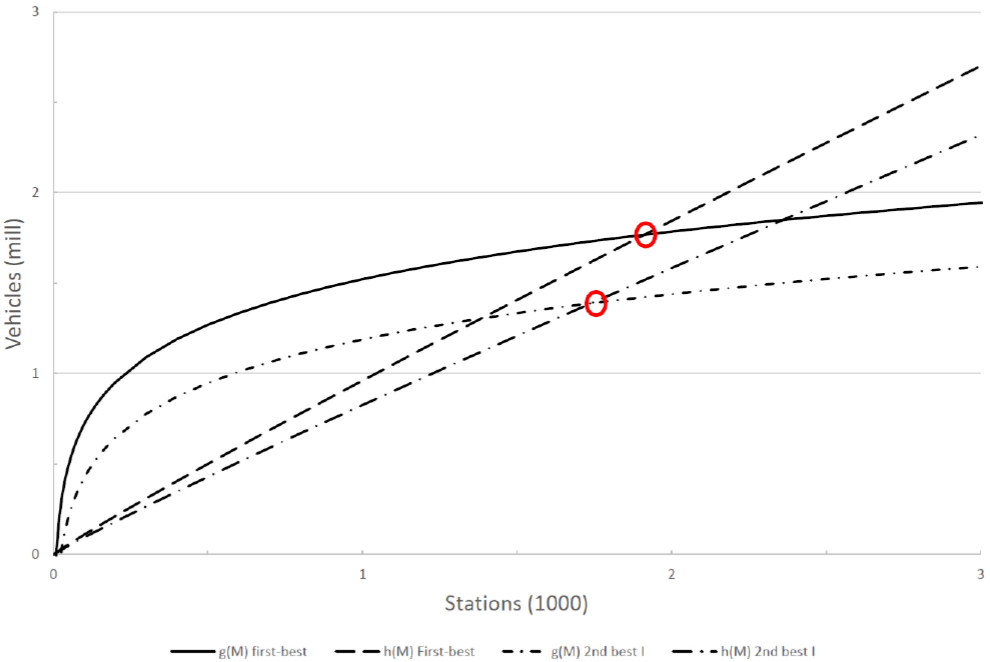
Second best solutions

- 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!