How well can early adopters of electric vehicles be identified?

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To achieve Europe’s climate targets, a drastic reduction in transport CO2-emissions is needed

- The EU’s long term goal is to reduce GHG emissions by 80%
- Power production and road transport have to become almost CO2-free
- This is impossible with efficiency gains in combustion engines
- New technologies and concepts are clearly needed.
- Electric vehicles powered by renewable energies can contribute significantly

Source: www.roadmap2050.eu
Identification of the first buyers is essential for effective policies and marketing

- Policy makers are widely supporting electric vehicles
  - Policies that are applied differ widely, including CO$_2$-dependent taxes, subsidies, built-up of public charging infrastructure, pilot projects and many more
  - Identification of the first user groups is essential for effective policies
  - Also relevant for car makers and effective marketing (common myth: EVs in big cities)

- Aim: Identify the potential early adopter of electric vehicles on a sound statistical basis

More electric vehicles!
Data and Method: Determining the cost optimal vehicle type for a large sample

Data: German national travel survey
25,000 households report travel behaviour
- Nation-wide travel survey including different means of transportation
- Selected trips of 16,600 cars.
- All car trips over one day and annual mileage are reported
- Additional information on employment status (fulltime, part-time, pensioner, not working)
- Additional information on city-size by number of inhabitants (6 sizes)
- Distinguish 24 user groups

Method: Cost-optimal vehicle type
Optimise individual total cost of ownership
- Fuel consumption for inner-city and outer-city driving differ strongly
- Take average trip speed to compute share of inner-city km
- Calculate total cost of ownership (vehicle purchase + fuel costs) for each user (discount for 8 years at 5%)
- Cost parameters for year 2020
- Choose cost optimal propulsion technology: Gasoline, Diesel, BEV, or PHEV

Identification of economical EV early adopter from driving data.
Driving behaviour of users differs widely – the individual needs to be studied

Each cross marks one user; Coloured areas mark cost-optimal vehicle type
Users even within groups differ widely in their behaviour.

City size by number of inhabitants →

<table>
<thead>
<tr>
<th>Employment status</th>
<th>Full time working</th>
<th>Part time working</th>
<th>Pensioners</th>
<th>not working</th>
</tr>
</thead>
<tbody>
<tr>
<td>City size</td>
<td>&lt; 5k</td>
<td>5 – 20 k</td>
<td>20 – 50 k</td>
<td>50 – 100 k</td>
</tr>
<tr>
<td></td>
<td>share of city km</td>
<td>share of city km</td>
<td>share of city km</td>
<td>share of city km</td>
</tr>
</tbody>
</table>

X-axes range from 0 to 1 for the x-axis (km driven with average speed < 18 km/h) and from 0 to 60,000 km for the y-axis. The red dot marks the group average of both coordinates.
Electric vehicles mainly owned in small to medium city sizes and not in big cities

- Approximately 1,300 of 16,500 vehicles were cost-effective as EVs
- Find share of each group for total car ownership and for EV optimal drivers

- German EV users mainly full/part time employees in small to medium sized cities
Are any of the differences significant?

- Chi-square test of significance for difference of user shares for different sub samples

<table>
<thead>
<tr>
<th>Sub sample definition</th>
<th>City size</th>
<th>Sub sample size</th>
<th>Chi squared</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full time</td>
<td>5 – 20 k</td>
<td>196</td>
<td>2.24</td>
<td>13.4%</td>
</tr>
<tr>
<td>Full time</td>
<td>0 – 20 k</td>
<td>324</td>
<td>1.04</td>
<td>30.8%</td>
</tr>
<tr>
<td>Full time</td>
<td>0 – 50 k</td>
<td>471</td>
<td>1.64</td>
<td>20.1%</td>
</tr>
<tr>
<td>Part-time</td>
<td>5 – 20 k</td>
<td>110</td>
<td>16.4</td>
<td>&lt;10(^{-4})</td>
</tr>
<tr>
<td>Part-time</td>
<td>0 – 20 k</td>
<td>166</td>
<td>12.49</td>
<td>0.04%</td>
</tr>
<tr>
<td>Part-time</td>
<td>0 – 50 k</td>
<td>227</td>
<td>10.44</td>
<td>0.12%</td>
</tr>
</tbody>
</table>

p-value: probability that difference is due to random fluctuations
Sensitivity analysis: Significance also depends on subsample size, e.g. costs

Full time workers: Significance of difference between expected & observed share
Sensitivity analysis: Significance also depends on subsample size, e.g. costs

Part time workers: Significance of difference between expected & observed share
Comparison with other data: 6,500 driving profiles over one week from Germany

Share of EV users and all car owners from different user groups

City size by number of inhabitans

- full time (EV)
- part time (EV)
- not working (EV)
- pensioner (EV)
- full time (all)
- part time (all)
- not working (all)
- pensioner (all)
Conclusions and discussion

- **Potential early adopter** of electric vehicles in Germany from an economical perspective are full-time and part-time employees from small and medium sized cities.
- Economical early adopter in Germany do not live in big cities.
- These findings consider only the total cost of ownership but are robust and consistent with broader studies on early adopter of EVs in Germany (Plötz et al. 2013).
- **Policy implication**: Public charging infrastructure in Germany is not pressing since garages are widely available in smaller cities in Germany.

Thank you for listening!


### Assumed technical and economical parameters for Germany in 2020

- Four vehicle types
- Distinction between in-city and out-of-city driving (average speed below/above 18 km/h)
- Prices for 2020: increasing fuel prices, decreasing battery prices

<table>
<thead>
<tr>
<th>Group</th>
<th>Parameter</th>
<th>Unit</th>
<th>Gasoline</th>
<th>Diesel</th>
<th>PHEV</th>
<th>BEV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical</td>
<td>Inner city fossil fuel consumption</td>
<td>l/100 km</td>
<td>8.5</td>
<td>6.3</td>
<td>7.0</td>
<td>-</td>
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<tr>
<td></td>
<td>Inner city electric energy consumption</td>
<td>kWh/100 km</td>
<td>-</td>
<td>-</td>
<td>18.2</td>
<td>18.2</td>
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<tr>
<td></td>
<td>Out of city fossil fuel consumption</td>
<td>l/100 km</td>
<td>5.7</td>
<td>4.5</td>
<td>6.2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Out of city electric energy consumption</td>
<td>kWh/100 km</td>
<td>-</td>
<td>-</td>
<td>20.7</td>
<td>20.7</td>
</tr>
<tr>
<td></td>
<td>Battery capacity</td>
<td>kWh</td>
<td>10.0</td>
<td>24.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Economical</td>
<td>Investment for vehicle w/o battery</td>
<td>Euro</td>
<td>23,276</td>
<td>25,656</td>
<td>25,620</td>
<td>21,885</td>
</tr>
<tr>
<td></td>
<td>Electric driving share</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>60%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>Battery price incl. VAT</td>
<td>Euro/kWh</td>
<td>-</td>
<td>-</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td></td>
<td>Fossil fuel price</td>
<td>Euro/l</td>
<td>1.90</td>
<td>1.79</td>
<td>1.90</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Electricity price</td>
<td>Euro/kWh</td>
<td>-</td>
<td>-</td>
<td>0.24</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Pay back period</td>
<td>a</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Interest rate for investment</td>
<td>-</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
</tbody>
</table>
Most people could charge at home easily

Where do you park at night?

- ca. 60% of all car users park in a garage
- Few people searching for parking: only 11% do not park at home
- Installation of charging would be cheap and easy in a garage

source: own calculations based on "Mobilität in Deutschland" (2008)
Summary statistics of vehicle users

Percentage denotes share of all German vehicle users

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