Are there environmental benefits from driving electric vehicles? The importance of local factors

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Electric Cars

- Increasing importance: 11 models in 2014
- $7500 Federal purchase subsidy
- Additional state subsidies (Colorado $6000)
Possible justifications for subsidies

- Environmental benefits relative to gas cars
- Reduce dependance on oil
- Dynamic efficiency (innovation spillovers, learning by doing, network externalities)
Our study

- Focus on environmental benefits
- Lifetime of use: electric car relative to gas
- Local factors
  - Local heterogeneity in benefits (county or state of use)
  - Global and local air pollution emissions
  - Uniform vs differentiated regulation
  - Local jurisdictions (pollution export)
Results

- Considerable heterogeneity in the environmental benefit of an electric car ($3000 in CA, -$4773 in North Dakota)
- Electric cars export pollution much than gas cars (at state level, 90% vs. 18%).
- Differentiated regulation can raise welfare (more for taxes on miles than purchase subsidies)
Methodology: extend and integrate 3 component models

- Discrete choice transportation model (De Borger and Mayeres 2007)
- Electricity generation and air pollution (Graff Zivin et al 2014)
- Air pollution integrated assessment (Muller and Mendelsohn 2009)
Spatial Discrete choice transportation model

- Consumer chooses gas or electric car and miles driven
- Externality from driving causes linear damages
  \[ \delta e_i \text{ and } \delta g_i \text{ (dollars per mile)} \]
- Policy choices
  - Purchase subsidy, taxes on miles driven for each fuel
  - Uniform, differentiated policy
  - Regulators care about full or native damages
Electricity generation and air pollution

- Model the US electricity grid
- NERC regions (9) are the spatial unit for electricity load shocks due to charging
- Load shock in one region may affect entire grid
- Electricity Regressions (ER) to estimate effects of change in load in NERC region on emissions of plants
- Time of day when charged matters
Air pollution integrated assessment

- AP2 model (Muller 2014)
- Emissions of CO2, PM2.5, SO2, NOx, and VOC from tailpipes/smokestacks
- Damages from CO2 and concentrations of SO2, O3, and PM 2.5
- Counties are spatial unit
Main Result 1

- Considerable spatial heterogeneity in the environmental benefit of an electric car
Figure 1: Marginal Damages for Gas and Electric Cars by County
Figure 2: Optimal Electric Vehicle Subsidy by County
Main Result 2

- Electric vehicles export local pollutants much more than gasoline vehicles
Figure 1  Panel A: Change in PM$_{2.5}$ Preliminary Fulton County: 1000 ICE Focus
Figure 1 Panel B: Change in PM$_{2.5}$ : 1000 EV Focus in SERC Region
When you buy an electric car, you generally make the air in your state cleaner (35/49 states)

When you buy an electric car, you generally make society worse off due to dirtier air overall (37/49 states)
State EV policies

- 8 states offer purchase subsidies
- Other policies such as carpool benefits, parking benefits, reduced electricity prices
- State policies more highly correlated with subsidy based on native damages than subsidy based on full damages
Main Result 3

- Welfare analysis
- Benefits of differentiated policy (i.e. state, county vs. federal)
- Compare purchase subsidies with VMT taxes (tax on gas miles, tax on electric miles)
## Welfare loss (millions $/year) of various policies

<table>
<thead>
<tr>
<th>Policy Level</th>
<th>Subsidy (Year)</th>
<th>Tax (g and e)</th>
<th>Tax (g only)</th>
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<tbody>
<tr>
<td>County Specific</td>
<td>1996</td>
<td>0</td>
<td>192</td>
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<tr>
<td>State Specific</td>
<td>2000</td>
<td>90</td>
<td>281</td>
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<tr>
<td>Uniform Federal</td>
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<td>163</td>
<td>336</td>
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<tr>
<td>County (native)</td>
<td>2022</td>
<td>1158</td>
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<td>State (native)</td>
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<tr>
<td>Federal (native)</td>
<td>2028</td>
<td>911</td>
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<tr>
<td>Actual Uniform Federal</td>
<td>2765</td>
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</tbody>
</table>
Interaction with other regulations

- CAFE standards
  - Electric car sale allows another consumer to replace high milage car with low milage car
  - May be significant additional cost to society ($1400).
- NOx, SO2 permit markets
Caveats

- Did not consider upstream air pollution (manufacturing, mining, refining)
  - Michalek et al 2011: Electric cars $1500 greater than gas cars
- Snapshot of electricity grid in year 2010-2012
- Marginal emissions from power plants
- Limitations of AP2 model
Conclusions

- Significant geographic variation in environmental benefits of electric cars.
- Local discretion in regulation? Problem of pollution export.
- Federal policy but differentiated by location.
- Environmental benefits do not justify $7500 subsidy.
- Pigovian taxes! But no, subsidy on purchase, CAFE. Unintended consequences.
Determining externalities

- Gas cars
  - GREET, EPA, Urban/Rural → emissions → AP2→ $\delta_{gi}$

- Electric Cars
  - EPA, temperature profile, charge profile → electricity load → ER → emissions → AP2→ $\delta_{ei}$
For power plant $i$ and time $t$, we regress:

$$y_{it} = \sum_{h=1}^{24} \sum_{j=1}^{J(i)} \beta_{ijh} \text{HOUR}_h \text{REGION}_j \text{LOAD}_{jt} + \sum_{h=1}^{24} \sum_{m=1}^{12} \alpha_{ihm} \text{HOUR}_h \text{MONTH}_m + \varepsilon_{it},$$

- $J(i)$: number of regions in $i$’s interconnection
- $\text{HOUR}_h$: hour of the day $h$
- $\text{REGION}_j$: electricity region
- $\text{MONTH}_m$: month
- $\text{LOAD}_{jt}$: electricity consumed in region $j$ at time $t$.

Emission factors $\beta_{ijh}$: marginal change in emissions at plant $i$ from an increase in electricity usage in region $j$ in hour $h$. 

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Proposition

The second-best subsidy on the purchase of the electric vehicle in region $i$ is given by $s_i^*$ where

$$s_i^* = (\delta_{gi} g - \delta_{ei} e).$$
Proposition

The second-best uniform subsidy on the purchase of an electric vehicle is given by

$$\tilde{s} = \left( \left( \sum \alpha_i \delta_{gi} \right) g - \left( \sum \alpha_i \delta_{ei} \right) e \right).$$

Furthermore, let $W(S^*)$ be the weighted average of welfare from using the differentiated subsidies $s^*_i$ in each region and let $W(\tilde{S})$ be the weighted average of welfare from using the uniform subsidy $\tilde{s}$ in each region. To a second-order approximation, we have

$$W(S^*) - W(\tilde{S}) \approx \frac{1}{2} \pi (1 - \pi) \left( \frac{1}{\mu} \sum \alpha_i (s^*_i - \tilde{s})^2 - \frac{1}{\mu^2} (1 - 2\pi) \sum \alpha_i (s^*_i - \tilde{s})^3 \right),$$

where $\pi$ is evaluated at the uniform subsidy.