Distributional Effects of Air Pollution from Electric Vehicle Adoption

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\textsuperscript{4}University of North Carolina
Electric Cars

- Modern revival
- Tesla Model S, Nissan Leaf, BMW i3, Renault Zoe, etc.

<table>
<thead>
<tr>
<th>Country</th>
<th>Market Share</th>
<th>Purchase Subsidies</th>
</tr>
</thead>
<tbody>
<tr>
<td>US</td>
<td>0.8</td>
<td>$7500 Federal + some states</td>
</tr>
<tr>
<td>UK</td>
<td>1.3</td>
<td>£4500</td>
</tr>
<tr>
<td>Germany</td>
<td>1.0</td>
<td>€4000</td>
</tr>
<tr>
<td>France</td>
<td>1.1</td>
<td>€6300</td>
</tr>
<tr>
<td>Norway</td>
<td>30.4</td>
<td>≈ €12,000 (no purchase taxes)</td>
</tr>
</tbody>
</table>
Electric Cars and Air Pollution

- Environmental benefits of driving are equal to the reduced air pollution damages from the forgone gasoline car, less the resulting damages from an electric car
  - Tailpipe vs. smokestacks
- Literature finds EVs reduce CO$_2$ in US on average
  - Graff Zivin et al. (2014)
  - Michalek et al. (2011)
- Holland et al. (2016)
  - On average, damages from local pollutants (PM, ozone, etc.) roughly offset the benefits of CO$_2$ reductions
  - Significant heterogeneity in environmental benefits
    - Los Angeles ($4743$ per vehicle driving $150k$ miles)
    - New York ($-$32)
    - Fargo, North Dakota ($-$4605)
This Paper

- Analyzes entire fleet of electric cars in US
- Compares created and received environmental benefits
  - Created benefits are appropriate for efficiency
  - Received benefits are appropriate for distributional effects (equity)
- Considers efficiency of purchase subsidies
Caveats

- Local air pollution only (not CO$_2$)
- Driving only (not life-cycle)
- Model electricity grid circa 2011
- Distributional effects due to combination of consumer preferences and a suite of policies
  - Purchase subsidies, carpool access, discounted electricity, free parking, tax breaks for charging infrastructure, etc.
  - We do not attribute distributional effects to individual policies
Outline

Introduction

Summary of Holland et al. (2016)

Data and Methodology on Distributional Effects

Results of Distributional Effects

Efficiency of Purchase Subsidies

Conclusion
Summary of Holland et al. (2016)
An Overview of Calculating Damages from Driving

- Driving gasoline car in county $i$ causes damages in many counties
- Charging electric car in county $i$ increases electricity consumption (load) which causes damages in many counties

- For electric car
  - Damage matrix $E$
  - $e_{i,j}$ damages per mile in county $j$ due to driving electric car in county $i$

- For gasoline car
  - Damage matrix $G$
  - $g_{i,j}$ damages per mile in county $j$ due to driving gasoline car in county $i$
Details of Holland et al. (2016)

- Emissions per mile $\times$ damages per unit emissions
  - Emissions per mile
    - Gasoline car
      - Emissions per mile (sources: GREET & EPA)
      - Urban/rural adjustment
    - Electric car
      - kWh per mile (EPA)
      - Cold weather adjustment
      - *Electricity generation and air emissions model*
  - Damages per unit emissions
    - Global CO$_2$ at SCC (EPA)
    - Local pollutants SO$_2$, NO$_x$, PM$_{2.5}$, and VOC:
      - Where pollution goes and who it hurts
    - *Air pollution integrated assessment model* (AP2)
Electricity Generation and Air Emissions Model

- Model the US electricity grid
- Consumption (NERC) regions (9) are the spatial unit for electricity load shocks due to charging electric car
- Load shock in one region may affect plants in other regions
- Plant-level regressions to estimate effects of change in load in a given region on emissions
- Time of day when charged matters
- Data sources for emissions (EPA), load (FERC), & charging profile (EPRI)
Map of Electricity Load Regions

WECC w/o CA
MRO/MISO
ERCOT
SERC
RFC
NPCC

California
SPP (gray)
ERCOT
**Plant-Level Regressions**

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

- \( y_{it} \): emissions of plant \( i \) and time \( t \)
- \( J(i) \): number of regions in \( i \)'s interconnection
- \( \text{HOUR}_h \): hour of the day \( h \)
- \( \text{MONTH}_m \): month
- \( \text{LOAD}_{jt} \): electricity consumed in region \( j \) at time \( t \).

Emission factors \( \beta_{ijh} \): marginal change in emissions from plant \( i \) from an increase in electricity usage in region \( j \) in hour \( h \).
Air Pollution Integrated Assessment Model

- AP2 model (Muller 2014)
- Maps emissions → ambient concentrations → damages
- Counties are spatial unit
- Chemical and physical processes
  \[ \text{PM}_{2.5} = F(\text{PM}_{2.5}, \text{SO}_2, \text{NO}_x, \text{VOC}) \]
  \[ \text{SO}_2 = G(\text{SO}_2) \]
  \[ \text{O}_3 = H(\text{NO}_x, \text{VOC}) \]
- Ambient concentrations of SO\(_2\), O\(_3\), and PM\(_{2.5}\) cause a myriad of health and environmental damages
  - Human health (mortality, morbidity; value of a statistical life estimates) due to PM\(_{2.5}\) and O\(_3\)
  - Crop and timber losses due to O\(_3\)
  - Building and material degradation due to SO\(_2\)
  - Reduced visibility and recreation due to PM\(_{2.5}\)
Gasoline Car Driven in Georgia (Fulton Co.): $g_{i,j}$
Electric Car Driven in Georgia (Fulton Co.): $e_{i,j}$

Ford Focus Electric
Results of Holland et al. (2016)
Environmental benefits of a Ford Focus electric vs. Ford Focus gasoline

- For county $i$, add up all damages over all counties from driving gasoline car, $\sum_j g_{i,j}$

- For county $i$ add up all damages over all counties from driving electric car, $\sum_j e_{i,j}$.

- Difference gives environmental benefits in county $i$
Damages for Gasoline Car by County

Ford Focus Gasoline, cents per mile
Damages for Electric Car by County

Ford Focus Electric, cents per mile
Environmental Benefits by County

Dollars per vehicle switched from gasoline to electric

Electric Vehicle Subsidy ($/car)

-5,445 - 3,000
-2,999 - 2,000
-1,999 - 1,000
-999 - 0
1 - 1,000
2,001 - 2,000
2,001 - 3,000
3,001 - 4,743

Dollars per vehicle switched from gasoline to electric
# Environmental Benefits Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Damages Focus Electric</td>
<td>2.59</td>
<td>0.67</td>
<td>4.72</td>
</tr>
<tr>
<td>Damages Focus Gas</td>
<td>1.86</td>
<td>1.03</td>
<td>4.32</td>
</tr>
<tr>
<td>Environmental Benefits (EB)</td>
<td>-0.73</td>
<td>-3.63</td>
<td>3.16</td>
</tr>
<tr>
<td>Global EB</td>
<td>0.44</td>
<td>-0.21</td>
<td>0.89</td>
</tr>
<tr>
<td>Local EB</td>
<td>-1.17</td>
<td>-3.43</td>
<td>2.28</td>
</tr>
</tbody>
</table>

*Notes*: Damages and benefits are in cents per mile. This is the distribution across all counties in contiguous US, regardless of whether there are electric cars (weight by total vehicle miles travelled).
Outline

Introduction

Summary of Holland et al. (2016)

Data and Methodology on Distributional Effects

Results of Distributional Effects

Efficiency of Purchase Subsidies

Conclusion
Data

› Electric car registrations by county and model, as of June 2014 (source: IHS Automotive)

› Market survey data on forgone, or second choice, gasoline vehicles (source: MaritzCX)

› Demographic data on income, race, and population by block group level (US Census)

› Local air pollution damages (extension of method of Holland et al. (2016))
What types of electric cars?

<table>
<thead>
<tr>
<th>Model</th>
<th>Registrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chevy Spark</td>
<td>1,899</td>
</tr>
<tr>
<td>Fiat 500</td>
<td>8,555</td>
</tr>
<tr>
<td>Ford Focus</td>
<td>4,436</td>
</tr>
<tr>
<td>Honda Fit</td>
<td>1,055</td>
</tr>
<tr>
<td>Mitsubishi i-Miev</td>
<td>1,721</td>
</tr>
<tr>
<td>Nissan Leaf</td>
<td>69,860</td>
</tr>
<tr>
<td>Smart EV</td>
<td>4,077</td>
</tr>
<tr>
<td>Tesla S</td>
<td>38,235</td>
</tr>
<tr>
<td>Toyota Rav4</td>
<td>2,456</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>132,294</strong></td>
</tr>
</tbody>
</table>

Source: IHS Automotive registration data
Where are the electric cars?

Source: IHS
.. mostly in urban centers (98%)

<table>
<thead>
<tr>
<th>City (MSA)</th>
<th>Number of Vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, GA</td>
<td>14,496</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>13,854</td>
</tr>
<tr>
<td>San Jose, CA</td>
<td>11,170</td>
</tr>
<tr>
<td>Oakland, CA</td>
<td>8,131</td>
</tr>
<tr>
<td>San Francisco, CA</td>
<td>6,437</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>6,352</td>
</tr>
<tr>
<td>Santa Ana, CA</td>
<td>5,734</td>
</tr>
<tr>
<td>San Diego, CA</td>
<td>5,722</td>
</tr>
<tr>
<td>Portland, OR</td>
<td>3,105</td>
</tr>
<tr>
<td>Sacramento, CA</td>
<td>2,838</td>
</tr>
</tbody>
</table>

Source: IHS
Forgone Gasoline Cars

<table>
<thead>
<tr>
<th>Response</th>
<th>Frequency</th>
<th>Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Other Considered</td>
<td>31,081</td>
<td>61%</td>
</tr>
<tr>
<td>Chevrolet Volt</td>
<td>3372</td>
<td>7%</td>
</tr>
<tr>
<td>Toyota Prius</td>
<td>2166</td>
<td>4%</td>
</tr>
<tr>
<td>Ford Focus Electric</td>
<td>1889</td>
<td>4%</td>
</tr>
<tr>
<td>Toyota Prius Plug-in</td>
<td>1073</td>
<td>2%</td>
</tr>
<tr>
<td>Tesla Model S</td>
<td>903</td>
<td>2%</td>
</tr>
<tr>
<td>Honda Fit EV</td>
<td>590</td>
<td>1%</td>
</tr>
<tr>
<td>BMW i3</td>
<td>502</td>
<td>1%</td>
</tr>
<tr>
<td>Ford C-Max Energi</td>
<td>459</td>
<td>1%</td>
</tr>
<tr>
<td>Fiat 500 Electric</td>
<td>448</td>
<td>1%</td>
</tr>
<tr>
<td>Kia Soul</td>
<td>344</td>
<td>1%</td>
</tr>
<tr>
<td>Mitsubishi i-MiEV</td>
<td>332</td>
<td>1%</td>
</tr>
<tr>
<td>Ford Fusion</td>
<td>301</td>
<td>1%</td>
</tr>
</tbody>
</table>

Notes: * indicates plug-in vehicles. Source: MaritzCX Data
Defining Composite Gasoline Cars

- For each electric car model, select top 10 non-plug-in cars from most seriously considered list
- Composite car emissions equal to weighted average of emissions from these cars
- Use Holland et al. (2016) methodology to determine $G$ for composite car and $E$ for electric car model
- Compare electric car model to forgone composite gas car
Environmental Benefits Created and Received

- Accounts for entire fleet of electric cars and forgone composite gas cars
- Intuition: row sum (created) vs. column sum (received)
- Given specific model car (e.g. Nissan Leaf), there are $n_i$ vehicles for this model registered in county $i$.
- Environmental benefits created by county $i$
  \[ n_i \sum_j (g_{i,j} - e_{i,j}) \]
- Environmental benefits received by county $j$
  \[ \sum_i n_i (g_{i,j} - e_{i,j}) \]
- Repeat for all models (different $n$, $E$, $G$) and aggregate
## Results of Environmental Benefits

Benefits Created and Received by Region ($1000)

<table>
<thead>
<tr>
<th>Region</th>
<th>Benefits Created</th>
<th>Benefits Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midwest</td>
<td>-2,709</td>
<td>-2,329</td>
</tr>
<tr>
<td>Northeast</td>
<td>-2,437</td>
<td>-4,083</td>
</tr>
<tr>
<td>South</td>
<td>-5,174</td>
<td>-4,178</td>
</tr>
<tr>
<td>West</td>
<td>10,276</td>
<td>10,545</td>
</tr>
<tr>
<td>Total</td>
<td>-44</td>
<td>-44</td>
</tr>
</tbody>
</table>
## Results of Environmental Benefits

Benefits Created and Received by Metropolitan Statistical Area ($1000)

<table>
<thead>
<tr>
<th>MSA</th>
<th>Benefits Created</th>
<th>Benefits Received</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, GA</td>
<td>-2,032</td>
<td>1,237</td>
</tr>
<tr>
<td>Los Angeles, CA</td>
<td>4,615</td>
<td>3,382</td>
</tr>
<tr>
<td>San Jose, CA</td>
<td>1,647</td>
<td>941</td>
</tr>
<tr>
<td>Oakland, CA</td>
<td>1,241</td>
<td>1,573</td>
</tr>
<tr>
<td>San Francisco, CA</td>
<td>797</td>
<td>1,012</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>97</td>
<td>336</td>
</tr>
<tr>
<td>Santa Ana, CA</td>
<td>910</td>
<td>1,387</td>
</tr>
<tr>
<td>San Diego, CA</td>
<td>664</td>
<td>677</td>
</tr>
<tr>
<td>Portland, OR</td>
<td>-34</td>
<td>82</td>
</tr>
<tr>
<td>Sacramento, CA</td>
<td>112</td>
<td>138</td>
</tr>
</tbody>
</table>
Results of Environmental Benefits
Benefits Created and Received by County

Created

Received
## Summary Statistics

County-Level Benefits Received per Capita and Census Block Group-Level Demographic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas vehicle damages p.c.</td>
<td>0.081</td>
<td>0.19</td>
<td>0.001</td>
<td>1.335</td>
</tr>
<tr>
<td>Elec vehicle damages p.c.</td>
<td>0.081</td>
<td>0.075</td>
<td>-0.002</td>
<td>0.546</td>
</tr>
<tr>
<td>EV net benefits p.c.</td>
<td>0</td>
<td>0.139</td>
<td>-0.297</td>
<td>0.813</td>
</tr>
<tr>
<td>Income (10k)</td>
<td>6</td>
<td>3.143</td>
<td>0.25</td>
<td>25</td>
</tr>
<tr>
<td>Share Black</td>
<td>0.126</td>
<td>0.217</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Share Hispanic</td>
<td>0.161</td>
<td>0.229</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Share Asian</td>
<td>0.046</td>
<td>0.093</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Share White</td>
<td>0.643</td>
<td>0.311</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Urban Indicator</td>
<td>0.836</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Share Poverty</td>
<td>0.136</td>
<td>0.129</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

**Notes:** There are 215,328 block groups; total population of 305 million.
Lorenz Curves
Separate Curves for Income and for Each Type of Damages Received

Gini 0.28
Gini 0.43
Gini 0.77
Relationship between Damages and Income

Kernel-Weighted Local Polynomial Regressions

Environmental Damages per Capita

Fitted Gas Damages
Fitted EV Damages

95% Confidence Interval

Median Household Income ($1000s)
Who Receives Environmental Benefits from EVs?
Benefits per Capita, Income, and Race

<table>
<thead>
<tr>
<th>Income Decile</th>
<th>Demographic Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Black</td>
</tr>
<tr>
<td>1</td>
<td>-0.032</td>
</tr>
<tr>
<td>2</td>
<td>-0.021</td>
</tr>
<tr>
<td>3</td>
<td>-0.020</td>
</tr>
<tr>
<td>4</td>
<td>-0.009</td>
</tr>
<tr>
<td>5</td>
<td>-0.007</td>
</tr>
<tr>
<td>6</td>
<td>-0.001</td>
</tr>
<tr>
<td>7</td>
<td>0.007</td>
</tr>
<tr>
<td>8</td>
<td>0.011</td>
</tr>
<tr>
<td>9</td>
<td>0.011</td>
</tr>
<tr>
<td>10</td>
<td>0.016</td>
</tr>
<tr>
<td>Total</td>
<td>-0.013</td>
</tr>
</tbody>
</table>
## Correlations

### Correlates of Environmental Benefits Received per Capita

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income (10k)</td>
<td>0.007***</td>
<td>(0.002)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share Poverty</td>
<td>-0.035</td>
<td></td>
<td>(0.024)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Urban Indicator</td>
<td></td>
<td>0.071***</td>
<td>(0.016)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population Density</td>
<td></td>
<td>0.002*</td>
<td></td>
<td>(0.001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share Black</td>
<td></td>
<td>-0.034</td>
<td></td>
<td>(0.021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share Hispanic</td>
<td></td>
<td></td>
<td>0.179***</td>
<td>(0.051)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Share Asian</td>
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<td></td>
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<td>0.616***</td>
<td>(0.118)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.140***</td>
<td>(0.038)</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.10

**Notes:** Dependent variable is environmental benefits per capita. These WLS regressions weight by total population and cluster standard errors by county.
## Descriptive Regressions

Descriptive Regressions of Environmental Benefits Received per Capita

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income (10k)</td>
<td>0.007***</td>
<td>0.005***</td>
<td>0.010***</td>
<td>0.009***</td>
<td>0.003**</td>
<td>0.002</td>
<td>0.011***</td>
<td>0.011***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Urban Indicator</td>
<td></td>
<td></td>
<td>0.034***</td>
<td></td>
<td></td>
<td>0.041***</td>
<td></td>
<td>0.019***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.007)</td>
<td></td>
<td></td>
<td>(0.011)</td>
<td></td>
<td>(0.005)</td>
</tr>
<tr>
<td>Share Black</td>
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<td>-0.025</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share Hispanic</td>
<td></td>
<td></td>
<td>0.206***</td>
<td></td>
<td></td>
<td>0.194***</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>(0.055)</td>
<td></td>
<td></td>
<td>(0.053)</td>
<td></td>
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</tr>
<tr>
<td>Share Asian</td>
<td></td>
<td></td>
<td></td>
<td>0.595***</td>
<td></td>
<td>0.572***</td>
<td></td>
<td></td>
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<td></td>
<td>(0.116)</td>
<td></td>
<td>(0.115)</td>
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<td></td>
</tr>
<tr>
<td>Share White</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.171***</td>
<td></td>
<td>-0.164***</td>
<td></td>
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<tr>
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<td></td>
<td></td>
<td>(0.042)</td>
<td></td>
<td>(0.042)</td>
<td></td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.10

Notes: These WLS regressions weight by total population and cluster standard errors by county.
Summary of Distributional Results

- Environmental benefits per capita as a function of income and race
- Environmental benefits positively correlated with
  - Income
  - Urban
  - Hispanic and Asian population shares
- Environmental benefits negatively correlated with
  - White population shares
## Sensitivity Analysis

Environmental Benefits Received Per Capita, All Households by Income Decile

<table>
<thead>
<tr>
<th>Income Decile</th>
<th>Baseline</th>
<th>MSA</th>
<th>PM$_{2.5}$</th>
<th>Road</th>
<th>Forgone Vehicle</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Subst</td>
</tr>
<tr>
<td>1</td>
<td>-0.023</td>
<td>-0.023</td>
<td>-0.024</td>
<td>-0.006</td>
<td>-0.024</td>
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<tr>
<td>2</td>
<td>-0.016</td>
<td>-0.017</td>
<td>-0.018</td>
<td>-0.006</td>
<td>-0.018</td>
</tr>
<tr>
<td>3</td>
<td>-0.018</td>
<td>-0.018</td>
<td>-0.020</td>
<td>-0.016</td>
<td>-0.020</td>
</tr>
<tr>
<td>4</td>
<td>-0.014</td>
<td>-0.015</td>
<td>-0.016</td>
<td>-0.008</td>
<td>-0.016</td>
</tr>
<tr>
<td>5</td>
<td>-0.011</td>
<td>-0.012</td>
<td>-0.013</td>
<td>-0.007</td>
<td>-0.013</td>
</tr>
<tr>
<td>6</td>
<td>-0.007</td>
<td>-0.008</td>
<td>-0.010</td>
<td>-0.004</td>
<td>-0.010</td>
</tr>
<tr>
<td>7</td>
<td>0.001</td>
<td>0.000</td>
<td>-0.002</td>
<td>0.000</td>
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<tr>
<td>8</td>
<td>0.012</td>
<td>0.010</td>
<td>0.008</td>
<td>0.011</td>
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<tr>
<td>9</td>
<td>0.025</td>
<td>0.023</td>
<td>0.020</td>
<td>0.016</td>
<td>0.021</td>
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<tr>
<td>10</td>
<td>0.050</td>
<td>0.047</td>
<td>0.045</td>
<td>0.018</td>
<td>0.045</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>-0.000</td>
<td>-0.001</td>
<td>-0.003</td>
<td>-0.000</td>
<td>-0.003</td>
</tr>
</tbody>
</table>

**Notes:**
- “MSA” assumes vehicles in urban areas are driven throughout MSA. “PM” includes damages from re-suspended particles. “Road” apportions own-county emissions to census block groups that are near major roads. “Subst” uses alternative forgone gasoline vehicles that are close engineering substitutes for each electric vehicle (e.g. Ford Focus for Focus EV). “Prius” uses the Toyota Prius as the forgone substitute for all electric vehicles. “Benz” uses the Mercedes S550 as the forgone substitute for all electric vehicles.
Outline

Introduction

Summary of Holland et al. (2016)

Data and Methodology on Distributional Effects

Results of Distributional Effects

Efficiency of Purchase Subsidies

Conclusion
Purchase Subsidies

- Federal $7500 tax credit per vehicle purchased

- 11 States offer additional purchase subsidies
  - Colorado $6000
  - Georgia $5000
  - Illinois $4000
  - Louisiana & Maryland $3000
  - California, Massachusetts & Texas $2500
  - New Jersey $2461
  - Washington $2321
  - Utah $605

- Additional benefits excluded here
Subsidy (state and federal) per capita by county
Purchase Subsidies and Created Env. Benefits

Regression: \[ EB = \alpha \text{Indicator} + \beta \text{Subsidy} + \varepsilon \]
Conclusion

- Distribution of received damages
  - Gas damages have high Gini and positive income correlation
  - Electric damages have low Gini and low income correlation

- Environmental benefits received correlated with
  - Income (+), Urban (+)
  - Hispanic (+), Asian (+), White (-)

- Conditional on a state offering subsidies, increase in subsidy is associated with a decrease in created environmental benefits
### Descriptive Regressions

**Additional Descriptive Regressions of Benefits Received per Capita**

<table>
<thead>
<tr>
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<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
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<tbody>
<tr>
<td>Income (10k)</td>
<td>0.006***</td>
<td>0.004***</td>
<td>0.009***</td>
<td>0.006***</td>
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<tr>
<td></td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.001)</td>
<td>(0.002)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Share Poverty</td>
<td>-0.017</td>
<td>-0.013*</td>
<td>-0.064***</td>
<td>-0.022***</td>
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<tr>
<td></td>
<td>(0.013)</td>
<td>(0.007)</td>
<td>(0.020)</td>
<td>(0.008)</td>
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<td></td>
</tr>
<tr>
<td>Urban Indicator</td>
<td>0.014***</td>
<td>0.013***</td>
<td>0.016***</td>
<td>0.014***</td>
<td>0.014***</td>
<td>0.017***</td>
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<tr>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
<td>(0.005)</td>
<td>(0.003)</td>
<td>(0.004)</td>
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<tr>
<td>Population Density</td>
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<tr>
<td></td>
<td>(0.001)</td>
<td>(0.000)</td>
<td>(0.001)</td>
<td>(0.000)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share Black</td>
<td>0.028</td>
<td>0.042***</td>
<td></td>
<td>0.023</td>
<td>0.050***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.009)</td>
<td></td>
<td>(0.017)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>Share Hispanic</td>
<td>0.191***</td>
<td>0.017</td>
<td>0.186***</td>
<td>0.034**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.015)</td>
<td>(0.050)</td>
<td>(0.015)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share Asian</td>
<td>0.559***</td>
<td>0.241***</td>
<td>0.551***</td>
<td>0.271***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.103)</td>
<td>(0.055)</td>
<td>(0.111)</td>
<td>(0.057)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Share White</td>
<td></td>
<td></td>
<td>-0.163***</td>
<td>-0.048***</td>
<td></td>
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<td>(0.038)</td>
<td>(0.008)</td>
<td></td>
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<tr>
<td>State FE</td>
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<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*** p<0.01, ** p<0.05, * p<0.10

**Notes:** These WLS regressions weight by total population and cluster standard errors by county.