The Heterogeneous Effects of Gasoline Taxes: Why Where We Live Matters

Heather Stephens (West Virginia University)
Elisheba Spiller (Environmental Defense Fund)
Yong Chen (Oregon State University)

33RD USAEE/IAEE North American Conference
October 27, 2015
Gasoline Consumption in the U.S.

• Gasoline consumption by U.S. households
  – 4 percent of household budgets
  – Accounts for 17 percent of total U.S. greenhouse gas emissions

• 40 percent of petroleum used in the U.S. comes from foreign sources

• Driving also contributes to local air emissions, congestion, and wear and tear on roads
Policy Solution?

• Implement a gasoline tax
  – To reduce consumption

• However:
  – Price elasticities of demand for gasoline vary widely
  – Distributional effects are uneven
For example: Rural vs. Urban

• Rural areas:
  – Poorer
  – More vehicles, less fuel efficient vehicles
  – Harder to substitute away from gasoline:
    • Fewer public transit options
    • Longer commute times/distances
Objective

• Estimate price elasticity across the U.S.
  – Allow for household heterogeneity
  – Control for location effects

• Examine the distributional effects of an increase in the gasoline tax
The need to recognize regional differences in policy-making is well-established:

- Porter (2003), Partridge et al. (2008): regional economic growth
- Ferguson et al. (2007): population change
- Wu, Perloff, and Golan (2006): income

Rural-urban differences:

- Poverty is most persistent in rural areas (Weber and Jensen, 2004)
- Even if places are becoming more “similar” there may be differences in driving patterns
Literature Review

• Elasticity literature: mostly looks at average values
• A few consider geographic/demographic heterogeneity:
  – Bento et al. (2008): number of children and type of car matter.
  – Schmalensee and Stoker (1999): household size matters, rural households drive the most.
  – Wadud, Graham, and Nolan (2010): households in rural areas have lower price elasticities; only considered intensive margin (choice of driving)
  – Gillingham (2014): find heterogeneous responses (geographic and demographic), in looking at California
  – Gillingham, Jenn, and Azevedo (2015), vehicle ownership types (will be presented today)
Model: Indirect Utility Function

Indirect utility at household level \((i)\)

\[ V_i = f \text{ (Household Characteristics, Household Char.} \times \text{Vehicle Char., Vehicle-State State Fixed Effects)} \]

Includes information about all vehicles in household’s garage.
Model: Indirect Utility Function

- Parameters vary across households:
- Interact coefficient with vehicle attribute \((z_j)\) and household attribute \((z_i)\):

\[
z_i^* z_j = z_{ij}
\]

\[
\alpha_{ij} = \alpha z_{ij}^\alpha
\]

\[
\beta_{ij} = -\exp(\beta z_{ij}^\beta)
\]

\[
\tau_{ij} = \tau z_{ij}^\tau
\]

\[
\varepsilon_{ij} \sim N\left(0, \sigma^2\right)
\]
Model

• Allow for household substitution between vehicles in garage
• Include vehicle-state specific fixed effects
  – Account for unobserved factors such as “style”
• Choice is model-year-nameplate (disaggregation of vehicle groups)
• Include a parameter that accounts for unobserved individual heterogeneity
  – Such that the optimally calculated driving = actual driving
Implied Optimal Driving Behavior

Derive Optimal driving for each vehicle $j$ in household $i$’s garage:

• Optimal driving for vehicle $j$ depends on characteristics/operating costs of all vehicles in household $i$
  – Substitute between vehicles!
Econometric Hurdle

• Allowing for interdependence between vehicles + disaggregated vehicles
  = Very large choice set!

• Implement revealed preference estimator
  – Based on Maximum Score, Manski (1975)
  – Parametric version developed in Spiller (2011)
    • Uses maximum likelihood (to get point estimates)
Revealed Preference Estimator

• Optimality assumption: each household makes optimal decisions (utility maximizing!) on which vehicles to own, how much to drive

• Any other decision would have resulted in lower utility
  – Set up inequality that says observed is better than random alternative.
Revealed Preference Estimator

• Only need to compare outcome with one different choice, *not* universe of choices
• Compare two households in the same state with different optimal bundles
  – Eliminates vehicle-state fixed effects
• Find parameters that maximize likelihood of observed choice being better than one alternate choice
Elasticity

- Use results from estimation to calculate elasticity for each household using:
  - Optimal $VMT_j$ (for each vehicle) given current gasoline prices and given a 1% increase in gasoline prices

\[
\varepsilon_i = \frac{\sum_{j_i}\left((VMT_{j_0} / mpg_j) - (VMT_{j_1} / mpg_j)\right)}{price_0 - 1.01 \times price_0} \times \frac{price_0}{\sum_{j_i}\left(VMT_{j_0} / mpg_j\right)}
\]
Data

• People and Households:
  – 2009 National Household Transportation Survey (NHTS) – includes geography, demographics, vehicle ownership and use
  – Regional Data - includes median rent (HHS), median income (Census) and distance to the nearest Metropolitan Area

• Vehicles:
  – Ward’s Automotive Yearbook – vehicle characteristics
  – National Automotive Dealers Association – used vehicle prices
Data, continued.

• Month-State level gasoline prices from March 2008-May 2009
  – Base gasoline prices: Energy Information Administration (EIA)
  – Tax information: Department of Transportation, EIA.
    • Percentage, flat, and sales
## Estimation Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Coefficient (standard error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration * rent ratio</td>
<td>-7.106*** (0.243)</td>
</tr>
<tr>
<td>Vehicle size * household size</td>
<td>13.046*** (2.932)</td>
</tr>
<tr>
<td>Wheelbase * distance to MSA</td>
<td>14.593*** (0.650)</td>
</tr>
<tr>
<td>Vehicle age * rent ratio</td>
<td>-0.045*** (0.003)</td>
</tr>
<tr>
<td>MPG * distance to MSA</td>
<td>-1.075*** (0.050)</td>
</tr>
<tr>
<td>Vehicle age * rent ratio</td>
<td>168.161*** (19.532)</td>
</tr>
<tr>
<td>Vehicle length * population density</td>
<td>-1223.737 (271329.1)</td>
</tr>
<tr>
<td>Implied average elasticity</td>
<td>-0.744 (0.712)</td>
</tr>
</tbody>
</table>

Statistical significance of coefficients: *** 99%
## Price Elasticity by Household Characteristics

<table>
<thead>
<tr>
<th>(Averages)</th>
<th>&lt;-0.22</th>
<th>-0.22:0.35</th>
<th>-0.35:0.52</th>
<th>-0.52:0.77</th>
<th>-0.77:1.22</th>
<th>&lt;=1.22</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance to MSA (in meters)</strong></td>
<td>13,099</td>
<td>22,984</td>
<td>32,132</td>
<td>40,949</td>
<td>53,025</td>
<td>81,600</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td>49,629</td>
<td>55,032</td>
<td>57,701</td>
<td>59,462</td>
<td>62,551</td>
<td>64,598</td>
</tr>
<tr>
<td><strong># Vehicles</strong></td>
<td>1.29</td>
<td>1.55</td>
<td>1.70</td>
<td>1.83</td>
<td>2.05</td>
<td>2.39</td>
</tr>
<tr>
<td><strong>Commute time</strong></td>
<td>6.87</td>
<td>7.73</td>
<td>8.54</td>
<td>9.09</td>
<td>9.67</td>
<td>10.68</td>
</tr>
<tr>
<td><strong>Gasoline price</strong></td>
<td>$2.26</td>
<td>$2.53</td>
<td>$2.73</td>
<td>$2.96</td>
<td>$3.12</td>
<td>$3.45</td>
</tr>
<tr>
<td><strong>MPG</strong></td>
<td>27.85</td>
<td>26.90</td>
<td>26.60</td>
<td>26.34</td>
<td>25.99</td>
<td>25.60</td>
</tr>
<tr>
<td><strong>VMT</strong></td>
<td>12,060</td>
<td>15,277</td>
<td>17,296</td>
<td>18,974</td>
<td>21,983</td>
<td>25,838</td>
</tr>
<tr>
<td><strong>% Rural</strong></td>
<td>0.11</td>
<td>0.19</td>
<td>0.24</td>
<td>0.30</td>
<td>0.35</td>
<td>0.42</td>
</tr>
<tr>
<td><strong># Obs.</strong></td>
<td>12,332</td>
<td>12,333</td>
<td>12,332</td>
<td>12,333</td>
<td>12,332</td>
<td>12,333</td>
</tr>
</tbody>
</table>
Elasticities by Characteristics

• What characteristics appear to lead to higher elasticities for households?
  – Higher income
  – More vehicles
  – Face higher gasoline prices
    ❖ More rural
    ❖ Farther from MSA
    ❖ Drive more

These people drive more overall, may be able to make more adjustments than those who simply drive less!
Heterogeneity of Elasticity

- Tremendous heterogeneity across locations!
Is Elasticity what matters?

• Policy makers are most concerned about the burden of higher gasoline prices

• Someone who drives a lot – even who appears to be fairly elastic – may still pay a lot if the price at the pump is higher
Tax Burden

• Parry and Small (2002) estimated the optimal, second-best (welfare enhancing) gas tax to be $1.01

• Thus, we consider the tax burden of such a tax
  – An increase of 60 cents from the average of current gasoline taxes
Tax Burden

• Increasing in:
  – Distance to MSA
  – Income
  – Commute time
  – VMT
  – Percent rural

• Households with higher price elasticities also have higher tax burdens!
Heterogeneity in Tax Burden (Weighted By Income): By “Ruralness” and Income
Evaluating the “optimal” gas tax

• We consider the progressivity of the tax
  – Using the Suits Index
  – Compares cumulative tax burden at each income decile to the cumulative income percentage at each income decile
  – Ranges from -1 (fully regressive) to +1 (fully progressive)

• The Suits Index for the 60-cent tax:
  – Is -0.09, or somewhat regressive
  – Consistent with previous literature on gasoline taxes (Sterner, 2011)
Revenue Recycling

• We calculate the adjusted tax burden for each household given a Suits index of 0, or a proportional tax

• We then assume that each household gets a tax credit/refund
  = The difference between the actual tax burden and the adjusted tax burden for that income decile
## Tax Burden: Before and After Revenue Recycling

### Table: Cumulative Income, Tax Percentage, and Refund Amount

<table>
<thead>
<tr>
<th>Income Decile</th>
<th>Cumulative Income Percentage Before Refund</th>
<th>Cumulative Tax Percentage Before Refund</th>
<th>Cumulative Tax Percentage After Refund</th>
<th>$P_d$ (Before)</th>
<th>$P_d$ (After)</th>
<th>Refund Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.27</td>
<td>4.51</td>
<td>2.68</td>
<td>1.99</td>
<td>1.18</td>
<td>81.02</td>
</tr>
<tr>
<td>2</td>
<td>6.43</td>
<td>10.55</td>
<td>6.99</td>
<td>1.64</td>
<td>1.09</td>
<td>86.26</td>
</tr>
<tr>
<td>3</td>
<td>12.07</td>
<td>17.93</td>
<td>12.81</td>
<td>1.49</td>
<td>1.06</td>
<td>86.42</td>
</tr>
<tr>
<td>4</td>
<td>19.28</td>
<td>26.17</td>
<td>20.10</td>
<td>1.36</td>
<td>1.04</td>
<td>80.09</td>
</tr>
<tr>
<td>5</td>
<td>27.93</td>
<td>34.70</td>
<td>28.10</td>
<td>1.24</td>
<td>1.01</td>
<td>59.69</td>
</tr>
<tr>
<td>6</td>
<td>38.23</td>
<td>45.16</td>
<td>38.56</td>
<td>1.18</td>
<td>1.01</td>
<td>58.11</td>
</tr>
<tr>
<td>7</td>
<td>50.55</td>
<td>57.02</td>
<td>50.94</td>
<td>1.13</td>
<td>1.01</td>
<td>49.14</td>
</tr>
<tr>
<td>8</td>
<td>65.65</td>
<td>70.61</td>
<td>65.96</td>
<td>1.08</td>
<td>1.00</td>
<td>34.91</td>
</tr>
<tr>
<td>9</td>
<td>82.75</td>
<td>85.21</td>
<td>82.60</td>
<td>1.03</td>
<td>1.00</td>
<td>15.33</td>
</tr>
<tr>
<td>10</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### Formula

$$ P_d = \frac{CumTax\%_d}{CumIncome\%_d} $$
Result of Proposed Revenue Recycling?

• Approximately Proportional Tax
  – Suits Index = -0.006

• Government still keeps 85 cents per dollar
  – Or, 51 cents of the new 60 cent tax!
Income Weighted Tax Burden: Before and After Tax Refund

Weighted Tax Burden

Income Decile

Before Refund

After Refund
Conclusion

• Large amounts of heterogeneity in price elasticities of gasoline

• Perhaps even more significant for policymakers is the heterogeneity in the tax burden imposed
  – Highest for those households who appear to be able to adjust their consumption
  – In other words, those who have high gasoline price elasticities
Conclusion

• Large amounts of heterogeneity discredit “one size fits all” analysis of gasoline price impacts

• Demonstrates the need to take into account regional and demographic differences in policy making
Conclusion

• Gasoline taxes can still be an effective policy tool for reducing gasoline consumption

• Our proposed policy for recycling of the tax revenue based on income
  – Would address the tax burden regressivity
  – Still generates positive government revenues

• We are exploring a more complicated tax recycling scheme to better account for regional heterogeneity
  – Although the implementation may be more complicated