Correcting heterogeneous externalities: Evidence from local fuel price controls

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Motivation

- Demand for and damages from the consumption of externality producing goods vary across agents and regions
  - Heterogeneous externalities
- Theory predicts targeted regulations will outperform uniform regulations when correcting heterogeneous externalities (Peltzman and Tideman, 1972)
  - Result is rarely practiced
- In the transportation sector, demand for and damages from vehicle travel vary vastly between urban and rural areas
  - Despite this, uniform federal and state fuel taxes are the primary policy instruments
  - Targeted fuel taxes, based on local demand elasticities and damages may be welfare improving
Uniform versus Targeted Regulation

Diagram showing the relationship between prices and pollution under uniform and targeted regulations.
This research
To what extent are targeted fuel taxes welfare improving relative to uniform fuel taxes?

1. Estimate travel demand elasticities for a large portion of the U.S. at a fine geographic level (310 county specific estimates)

2. Estimate county specific congestion damages

3. Evaluate welfare effects of county specific fuel taxes based on the estimated local demand elasticities and congestion damages and pollution damages from Muller and Mendelsohn (2012)

Results

- Significant heterogeneity in demand elasticities and congestion damages across regions. Elasticities and congestion damages increase with urbanization level

- Large county specific fuel taxes levied on a handful of large metro areas significantly improves welfare relative to a revenue neutral fuel tax levied on all counties
Methodology I

1. County specific travel demand elasticities
   ▶ 770 million hourly vehicle counts from universe of traffic sensors in U.S. from 2013-2016
   ▶ Local fuel price data scraped from GasBuddy.com
   ▶ Instrumental variables strategy utilizing a novel instrument, gasoline content regulations (summer and winter fuel blends), which provides exogenous shocks to county fuel prices

\[
\ln(P_{it}) = \beta + \gamma \cdot R_{it} + \psi \cdot X_{it} + \theta_i + \rho_t + \nu_{ijt} \tag{1}
\]

\[
\ln(T_{it}) = \omega + \eta \cdot \ln(\hat{P}_{it}) + \psi \cdot X_{it} + \theta_i + \rho_t + \epsilon_{it} \tag{2}
\]
Methodology II

2 County specific congestion damages
   ▶ Combine traffic sensor data with Google Maps predictions of trip travel times in traffic
   ▶ Determine effect of increasing vehicle counts on average county speeds
   \[
   \text{Speed}_{int} = \beta + \gamma \cdot \ln(T_{nt}) + \lambda_i + \omega_{int} \tag{3}
   \]

3 Welfare effects
   ▶ Simulation which minimizes total damages in all county by setting optimal county specific fuel taxes subject to the constraint that revenue generated is equal to that of a $0.10 uniform fuel tax increase
Notes: County populations, in thousands, were obtained from the NCHS and indicated by the marker size. County level travel demand elasticities were estimated using an IV model which instrumented for gasoline prices with gasoline content regulations. This model was estimated for each county individually controlling for HDD, CDD precipitation, snow fall, and snow depth and included traffic sensor, day-of-week, and month-of-year fixed effects.
County Travel Demand Elasticities by Urbanization Level

Notes: County level travel demand elasticities were estimated using an IV model which instrumented for gasoline prices with gasoline content regulations. Z-statistics in the bottom panel are calculated using standard errors are clustered at the traffic sensor level. This model was estimated for each county individually controlling for HDD, CDD precipitation, snow fall, and snow depth and included traffic sensor, day-of-week, and month-of-year fixed effects. Urban-Rural classifications were obtained from the National Center for Health Statistics.
County effects of vehicle counts of trip speeds

Notes: County-specific speed effects were estimated using a regression of average trip speeds on the natural logarithm of average vehicle counts and an origin-destination pair fixed effect. The semi-elasticities can be interpreted as the corresponding change in a trip’s average mph when vehicle counts increase by 1%. The bottom panel shows t-statistics calculated using robust standard errors.
## Welfare Simulation

<table>
<thead>
<tr>
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<th>Maximum tax increase constraint</th>
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<td>142</td>
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Notes: Maximum tax increase constraint refers to the maximum tax increase allowed within the simulation. Interior refers to a tax rate solution between the maximum and zero. Each suite of tax increases is revenue neutral to a uniform $0.10 fuel tax increase on all counties.
Welfare Gains at Varying Maximum Tax Increases

Notes: Dollars are reported in billions. The first point forces the maximum allowable tax increase to be equal to $0.10, and, as such, is equivalent to the uniform fuel tax across all counties, resulting in no gains in welfare. The simulation is then run with maximum tax increases between $0.25 and $3.00, with the relevant gain in welfare relative to the uniform tax increase plotted on the y-axis.
Conclusion

- Empirically estimated the welfare effects of local externality regulations in the transportation sector
  - Estimated county specific travel demand elasticities
  - Estimated county specific congestion damages
  - Simulated the welfare effects of uniform fuel taxes and a suite of revenue neutral county specific fuel taxes set on local information

- Results show that local fuel tax increases could significantly improve societal welfare
  - Substantial heterogeneity in travel demand elasticities and congestion damages
  - Levying hefty fuel tax increases in only a handful of large metro areas is optimal
Thank you

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Gasoline Content Regulation Background

- **Reid Vapor Pressure (RVP) Regulations**
  - RVP measures intensity with which volatile organic compounds (VOCs) are emitted from gasoline in pounds per square inch (psi)
  - VOCs react with nitrogen oxides to create ground-level ozone in warm sunny environments
  - Three levels of stringency 9.0, 7.8, and 7.0 psi
  - Meet regulation by removing butane from fuel

- **Reformulated Gasoline (RFG) Regulations**
  - More stringent than RVP (max benzene restrictions, min oxygen requirement)
Notes: No data refers to counties that do not have matching price data. The map depicts the most stringent regulation a county was treated by between 2013-2016.
Data

Traffic Volume
- Federal Highway Administration
- Hourly vehicle counts from the universe of traffic sensors in the U.S.
  - Over 770 million hourly observations

Fuel Prices
- Scraped from GasBuddy.com
- City or county level weekly prices
- Data from over 300 locations

Gasoline Content Regulations
- Energy Information Administration
  - Cross referenced with individual state archives
- City or county level regulations
Data

Fuel taxes
  ▶ International Fuel Tax Association
  ▶ Energy Information Administration

Weather
  ▶ NOAA
## Descriptive Statistics

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<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
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<td>120,577</td>
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**Notes:** HDD denotes heating degree days and CDD denotes cooling degree days. Both HDD and CDD have a base of 65 degrees Fahrenheit. Temperature is recorded in Fahrenheit. VMT is recorded in millions of miles per state.
Sensor Data

Notes: The vehicle count data reports the daily average hourly count. Only days that reported data for the full 24 hour period are shown. Gasoline prices are county week averages.
Sensor Data

Station in Spokane County, WA

Notes: The vehicle count data reports the daily average hourly count. Only days that reported data for the full 24 hour period are shown. Gasoline prices are county week averages.
Sensor Data

Station in Los Angeles County, CA

Notes: The vehicle count data reports the daily average hourly count. Only days that reported data for the full 24 hour period are shown. Gasoline prices are county week averages.