Highway Investment and Induced Vehicle Emissions

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Background

- Roads are essential for economic mobility. A reliable and efficient transportation system can increase productivity, promote exports, integrate the regional economies, and ensure smooth movement of goods.
- 32% of America’s major roads are in poor or mediocre condition.
- Environmental issues related to public infrastructure projects are a significant concern for policy-makers. Transportation activities are the main source for CO2 and NOx.
- Transportation sector accounts for 28% U.S. Greenhouse Gas emissions. Within the sector, passenger vehicle and freight truck account for 56% and 22% of total transport emissions.

Figure: States’ Pavement Conditions in 2007

Pavement Conditions by State, 2007

Note: above figure shows the percentage of roads are in poor or mediocre condition by states.

Objectives

- Build a theoretical model to explain the impact of highway investment on passenger and freight emissions.
- Empirically test the theoretical predictions and quantify the effects.

Theoretical Model

Two-stage general equilibrium model:

- Stage 1: government chooses highway spending to maximize social welfare which consisting of consumer’s utility and producer’s profit.
- Stage 2: consumer and producer maximize own interests given highway quality.

Empirical Strategy

- Testable empirical relationship is a system of two equations:
  \[ Z_1 = \alpha_1 + \beta_1 x_1 + \gamma_1 x_2 + \delta_1 x_3 + \epsilon_1 \]
  \[ Z_2 = \alpha_2 + \beta_2 x_1 + \gamma_2 x_2 + \delta_2 x_3 + \epsilon_2 \]
- The system of two equations is estimated using Seemingly Unrelated Regression (SURE).
- Lane mile of rural and urban roads, rural and urban, as proxies for \( \epsilon_1 \) and \( \epsilon_2 \).
- GDP per land area, scale, as proxy for \( \epsilon_1 \); income per capita, income, as proxy for \( \epsilon_2 \).

Empirical Results

- Government highway expenditures have adverse effects on freight emissions.
- The effect of government highway expenditures on passenger emissions is ambiguous, depending on the value of time on freight and passenger driving.
- The determinants of freight emission (\( Z_1 \)) include:
  - Government spending on highway (\( \alpha_1 \)),
  - Value of time on freight (\( \beta_1 \)) and passenger driving (\( \gamma_1 \)),
  - Unit emission of freight truck (\( \delta_1 \)).
- The determinants of passenger emission per capita (\( Z_2 \)) include:
  - Government spending on highway per capita (\( \alpha_2 \)),
  - Value of time on freight (\( \beta_2 \)) and passenger driving (\( \gamma_2 \)),
  - Unit emission of passenger vehicle (\( \delta_2 \)).

Theoretical Results

- Highway investment raises both freight and passenger emissions, but the effect on freight is significantly higher than passenger.
- The scale effect increases freight emissions but reduces passenger emissions per capita while the income effect has the opposite effects.

Data

- Balanced panel dataset for the 48 contiguous states from 1995 to 2011
- CO2 emitted from heavy-duty and passenger vehicle (US Environmental Agency)
- State government expenditure on highway (US Census)

Table 1: Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight emission</td>
<td>million metric tons</td>
<td>7,347</td>
<td>.717</td>
<td>.676</td>
<td>50.635</td>
</tr>
<tr>
<td>Passenger emission per capita</td>
<td>metric tons</td>
<td>3.835</td>
<td>.668</td>
<td>2.162</td>
<td>6.916</td>
</tr>
<tr>
<td>Highway spending</td>
<td>billion dollars</td>
<td>1.683</td>
<td>1.615</td>
<td>.157</td>
<td>13.327</td>
</tr>
<tr>
<td>Highway spending per capita</td>
<td>thousand dollars</td>
<td>.338</td>
<td>.127</td>
<td>.139</td>
<td>1.012</td>
</tr>
<tr>
<td>Scale</td>
<td>million dollars per square mile</td>
<td>8.109</td>
<td>12.375</td>
<td>.120</td>
<td>68.543</td>
</tr>
<tr>
<td>Income</td>
<td>thousand dollars</td>
<td>32.171</td>
<td>7.559</td>
<td>17.375</td>
<td>57.547</td>
</tr>
<tr>
<td>Rural</td>
<td>thousand miles</td>
<td>128.699</td>
<td>80.299</td>
<td>2.499</td>
<td>459.250</td>
</tr>
<tr>
<td>Urban</td>
<td>thousand miles</td>
<td>44.115</td>
<td>48.788</td>
<td>2.810</td>
<td>231.499</td>
</tr>
</tbody>
</table>

Empirical Results

- A 1% increase in highway spending raises freight emissions and passenger emissions by 0.36% and 0.04%, respectively.
- A 1% increase in scale effect raises freight emissions by 0.10% but reduces passenger emissions per capita by 0.25%.
- A 1% increase in income effect reduces freight emissions by 3.11% but raises passenger emissions per capita by 2.35%.

Table 2: Results for Freight and Passenger Emissions

<table>
<thead>
<tr>
<th>Estimation Type</th>
<th>Separate OLS Estimation</th>
<th>SUR Estimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emission Type</td>
<td>Freighter</td>
<td>Passenger</td>
</tr>
<tr>
<td>Highways</td>
<td>(1.549)***</td>
<td>(1.305)**</td>
</tr>
<tr>
<td>Scale</td>
<td>(.149)***</td>
<td>(.140)***</td>
</tr>
<tr>
<td>Income</td>
<td>(0.071)**</td>
<td>(.030)**</td>
</tr>
<tr>
<td>Rural</td>
<td>(.001)**</td>
<td>(.000)**</td>
</tr>
<tr>
<td>Urban</td>
<td>(.001)**</td>
<td>(.000)**</td>
</tr>
</tbody>
</table>

Year and state dummies Yes Yes Yes Yes

Observations | 816 816 816 816

Note: * P value<0.1; ** P value<0.05; *** P value<0.001