Spatial Patterns in Household Demand for Ethanol

Hayk Khachatryan, Ken Casavant and Eric Jessup
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Transportation Research Group, Washington State University

51st Annual Transportation Research Forum, 2010
ethanol, like anything else, can be good or bad

Biofuel policies and research
- proponents and opponents

Impact on consumer perception of biofuels
- corn vs. cellulosic feedstocks for ethanol
- the consideration of future consequences
- consumer demand-responsiveness to price changes
Background
- Minnesota’s ethanol policies
- Previous Literature

Theoretical framework
- Transportation fuel demand

Empirical framework
- Basic model
- Spatial expansion model
- Data
- Basic model results
- Spatial model results

Conclusions
Minnesota has been a leader in biofuel policy

**Financial incentives**
- tax credit for blending (1980 - 1997)
- ethanol production incentive
- E85 promotion - E85 taxed at a lower rate

**Consumption mandates**
- oxygenate mandate - gasoline must contain 10% ethanol (E10)
- effective August 30, 2013 - E20

**Regional biofuels promotion plan**
- reduce fossil fuels used in biofuels production (50%, 2025)
- increase regional production of cellulosic fuels (25%, 2015)
- total energy from renewables (25%, 2025)
Minnesota has been a leader in biofuel policy (cont.)

<table>
<thead>
<tr>
<th>State</th>
<th>Number of E85 Stations</th>
<th>State</th>
<th>Number of E85 Stations</th>
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<td><strong>Total</strong></td>
<td><strong>1928</strong></td>
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</table>
Ethanol demand estimation

- minimum information available on household-level ethanol demand
- high (in absolute value) own-price & cross-price elasticities

Spatial considerations

- regional dummy variable approach
- market segmentation approach
- lack of subcounty-level spatial models thus far
relative prices determine ethanol usage patterns

household’s utility in terms of transportation fuels $f(E, G, X)$,

- purchase ethanol if $p_e < \frac{p_g}{r}$, gasoline if $\frac{p_g}{r} < p_e$

where

- $E$ and $G$ denote ethanol and gasoline consumption
- $X$ is a composite good
- $p_e$ and $p_g$ denote prices for ethanol and gasoline
- $r$ is the “fuel switching” price ratio, the rate at which the consumer converts gasoline into ethanol-equivalent gallons
start with a base model

\[ y_{it} = \beta_0 + \sum_m \beta_m X_{it} + \theta Z_i + \gamma_t + \psi_t + \epsilon_{it} \]

where

- \( y_{it} \) = monthly ethanol sales
- \( X_{it} \) = matrix of explanatory variables (prices, income, vehicle stock and number of fueling stations)
- \( Z_i \) = distances from E85 pumps-to-racks and pumps-to-highways
- \( \gamma_t \) = regional dummy
- \( \psi_t \) = monthly dummies
- \( \epsilon_{it} \) = error term
there are spatial variations in people’s preferences...

- spatial dependence

\[ y_i = f(y_j), \quad i = 1, \ldots, n \quad j \neq i \]

- spatial heterogeneity

\[ y_i = X_i \beta_i + \varepsilon_i, \quad i = 1, \ldots, n \]
estimating price-elasticity of demand across the study area

\[ y_{it} = \beta_{0t} (v_i, v_i) + \sum_m \beta_{mt} (v_i, v_i) X_{it} + \sum_m \theta_k (v_i, v_i) Z_i + \varepsilon_{it} \]

where

- \( y_{it} \) = monthly ethanol sales
- \( X_{it} \) = matrix of explanatory variables (prices, income, vehicle stock and number of fueling stations)
- \( Z_i \) = distances from E85 pumps-to-racks and pumps-to-highways
- \( \varepsilon_{it} \) = error term
- \( (v_i, v_i) \) = projected coordinates of E85 fueling stations
- no categorical variables
geographically weighted regression estimator

\[ \hat{\beta}(v_i, v_i) = \left(X' W(v_i, v_i) X\right)^{-1} X' W(v_i, v_i) y \]

where \( W(v_i, v_i) \) is a distance-based weighting matrix

\[
W(u) = \begin{pmatrix}
  w(u)_1 & 0 & 0 & \cdots & 0 \\
  0 & w(u)_2 & 0 & \cdots & 0 \\
  0 & 0 & w(u)_3 & \cdots & 0 \\
  \vdots & \vdots & \vdots & \ddots & \vdots \\
  0 & 0 & 0 & \cdots & w(u)_n
\end{pmatrix}
\]
data sources

Minnesota Department of Commerce
- monthly E85 retail prices and sales volumes (1997 - 2009)
- 13,339 observations, 330 fueling stations

Energy Information Administration
- monthly retail gasoline prices
- monthly wholesale gasoline prices

Federal Reserve Economic Data
- per capita income

Minnesota Department of Public Safety
- vehicle stock

Geographic Information Systems
- distances (E85 pumps - racks, highways)

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Spatial Differences in Price-elasticities of Ethanol Demand
Spatial Differences in Price-elasticities of Ethanol Demand

Minnesota E85 station map

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Spatial Differences in Price-elasticities of Ethanol Demand

- **Basic model**
- **Spatial heterogeneity**
- **Spatial expansion model**
- **Data**
- **Results**

**gasoline and ethanol retail prices**

![Graph showing gasoline and E85 prices from 2000 to 2008](image)

- **Year**
- **$/gallon**

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## OLS and 2SLS estimates

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<td>LN(PE)</td>
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<td>LN (INC)</td>
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<td>LN (VEH)</td>
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<td>(0.03)</td>
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<td>LN (DISTR)</td>
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<td>Twin Cities</td>
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<td>(0.07)</td>
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<td>0.47</td>
<td>0.45</td>
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**Dependent variable = LN(ethanol monthly sales volume)**

2003-2008 (OLS)

2003-2006 (OLS)

2007-2008 (OLS)

2003-2008 (2SLS)

***p<0.05, **p<0.1, *p<0.2.  Standard errors are in parentheses.  Dependent variable is the monthly ethanol sales volume.
geographically varying price-elasticities (2004–2008)
**OLS vs. GWR estimates**

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<tr>
<td>ln(PG/PE)</td>
<td>-0.06</td>
<td>2.49</td>
<td>3.35</td>
<td>3.93</td>
<td>5.70</td>
<td>4.35</td>
<td>0.12</td>
<td>1.11</td>
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<tr>
<td>ln(INC)</td>
<td>-2.10</td>
<td>-0.48</td>
<td>0.95</td>
<td>2.02</td>
<td>2.50</td>
<td>0.41</td>
<td>0.08</td>
<td>1.36</td>
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<td>ln(VEH)</td>
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<td>-0.02</td>
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<td>0.59</td>
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<td>ln(NSTAT)</td>
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\[ \rho_i = \frac{\sum_i (\beta(u_i, v_i) - \beta_i)^2}{N}, \quad H_0: \beta(u_i, v_i) = \beta_{OLS}, \quad H_1: \beta(u_i, v_i) \neq \beta_{OLS} \]
what are the policy implications?

Current research
- geographic differences in the price-elasticity of demand for ethanol
- demand for ethanol is highly sensitive to both own- and gasoline-price changes

Limitations
- geographically bounded study area
- some portion of sales attributed to out of state households

Future research
- simulation of ethanol policy effects on environmental emissions
- spatio-temporal matrix
- incorporating flexible fuel vehicle stock data
Thank you!