Induced R&D in Automobiles: A Preliminary Study

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Outline

1 Regulations in the Automobile Industry and the Induced Innovation Hypothesis
   - A Brief History of Automobile Regulations
   - The Induced Innovation Hypothesis

2 Did Automobile R&D Respond to Regulations and Gasoline Price?
   - Automobile R&D
   - Evidence of Induced R&D?

3 Conclusion
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**A Brief History of Automobile Regulations**

**Figure:** US energy prices and major policy actions 1970-2011. Data come from the World Bank, the Bureau of Labor Statistics, and the US Energy Information Administration (EIA), and the Bureau of Labor Statistics. Policy information is taken from a similar figure published online by EIA under the title “Petroleum Chronology Graph”.

- **1973:** Emergency Petroleum Allocation Act (EPAA)
- **1975:** Energy Policy & Conservation Act (EPCA)
- **1978:** CAFE Standards implemented under EPCA
- **1990:** Clean Air Act Amendments (CAAA)
- **1994-1997:** Tier 1 emission standards under CAAA phased-in
- **2007:** Energy Independence and Security Act
- **2004-2009:** Tier 2 emission standards under CAAA phased-in
Induced Innovation in Short

Figure: Sir John R. Hicks
Induced Innovation in Short

- **Sir John Hicks**: “a change in the relative prices of the factors of production is itself a spur to invention . . . directed to economizing the use of a factor which has become relatively expensive” (Hicks 1932, p.124).

- The hypothesis formalized as a theory: a change in factor prices of production function leads to cost-saving innovation through changes in R&D incentive of firms (Ahmad 1966, Kaimen and Schwartz 1968, and Binswanger 1978).

- The hypothesis applied to energy price and regulations: higher price of energy (or pollution) induces innovation in the energy-saving (or pollution-reducing) technologies (e.g., Newell et al. 1999).
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Induced Innovation in Automobiles

- Induced innovation in automobiles is an important topic because of the industry’s economic and environmental significance.
- But papers have generated different answers (e.g., Greene 1990, Berry et al. 1996, Popp 2002 vs. Crabb and Johnson 2010).
- A difficulty: innovation output combines the impact of both private and public R&D → I study innovation input measured by private R&D

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<th>Year</th>
<th>Research and Development Funds</th>
<th>Domestic Sales</th>
<th>R&amp;D Scientists and Engineers</th>
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Other years are omitted for space

Table: Private and federal R&D in transportation manufacturing. The statistics come from the National Science Foundation’s “Summary data for R&D-performing companies, by detailed industry and by size of company: 1969–98.” The column title “Ind” denotes the transportation industry total (SIC code 37).
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Figure: R&D Expenditure by Top Automobile Sellers, 1970-2011 (in Millions of 2011 US Dollars). R&D expenditure data come from CRSP-Compustat Merged Data and CPI data come from the Bureau of Labor Statistics.
A Reduced-Form Model

- Use previous studies on R&D to partial out the usual determinants of R&D → e.g., revenue, debt-to-assets, market-to-book

\[
\ln (R&D_{i,t}) = \beta_0 + \beta_1 \ln (\text{control 1}) + \ldots + \beta_N \ln (\text{control N}) + \beta_{N+1} q_t + \alpha p_t + k_i + u_{i,t}
\]

- \( q_t \) denotes the vector of time effects other than policy or price effects
- \( p_t \) denotes the vector of policy dummies and energy prices
- \( k_i \) denotes the firm fixed effects and \( u_{i,t} \) denotes the residual effects

- Run LSDV estimation to see how the unexplained part of R&D is correlated with a policy introduction or energy price variation
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Policy Dummies and Energy Prices


- Energy price: weighted average of projected future gasoline prices

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Some Evidence of Induced R&D

- R&D by firms were higher when projected gasoline price high or emission standards were introduced/began.
- R&D by US firms were higher than R&D by non-US firms when CAFE standards were introduced/began.
- A dollar increase (25% increase) in gasoline tax can be associated with 14.5% increase in R&D activities.
- R&D activities by automakers increased by approximately 10-15% during the early years of emission standards’ introduction.
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- The reduced-form approach shows some evidence of induced R&D
- Difficulty in interpreting the effects with causation
- Need to build a structural model of R&D to identify the causal effects