Induced Innovation from CAFE Standards in the Automotive Industry: Evidence using Patent Data

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Overview

- 1973 oil embargo and 1979 Iranian revolution
- Energy Policy and Conservation Act (EPAC) enacted into law by Congress in 1975, added Title V, “Improving Automotive Efficiency”
- Corporate Average Fuel Economy program (CAFE)
- They expected to cut the oil consumption and foreign energy dependency.
- Porter Hypothesis (Michael Porter, 1991)
U.S. CAFE Standards

- Environmental Protection Agency (EPA) is responsible for calculating the average fuel economy.
- National Highway Traffic Safety Administration (NHTSA) is responsible for enforcing the CAFE program.
- Targeting – sales weighted average fuel economy in miles per gallon (mpg) of a fleet of passenger cars or light trucks with a gross vehicle weight rating of 8500 lbs or less. Combustion vehicle only.
- Fuel efficiency requirement—one universal standard for a fleet of cars (take the average mpg based on sales volume).
U.S. CAFE Standards

- Light-duty vehicle fuel economy standards, 1978-2025

Graph Source: Shrink That Footprint
U.S. CAFE Standards

- Penalty – $5.50 per 1/10 of mpg lower than the requirement
- Total penalty collected from automobile firms until 2010: $818,724,551 (data updated 2012)
- CAFE Credit is non tradable before 2007
- Energy Independence and Security Act (EISA), originally named the Clean Energy Act of 2007, regulates environment standards for the automotive industry. Under this Act, CAFE program renewed – with higher target and more scientific and flexibility way.
- 2007 changes to CAFE:
  - Transferable credit
  - Add CO2 and green house gas (GHG) in regulation system
  - Add electric powered vehicle (EV) incentive
  - Footprint model for new fuel efficiency calculation
CAFE Target Equation (since 2008)

\[
TARGET = \frac{1}{\text{MIN}[\text{MAX} \left( c \times \text{FOOTPRINT} + d, \frac{1}{a} \right), \frac{1}{b}]}
\]

Where
- TARGET = the fuel economy target (in mpg) applicable to vehicles of a given footprint (in square feet)
- a = the function’s upper limit (in mpg) for all vehicles
- b = the function’s lower limit (in mpg) for all vehicles
- c = the slope (in gpm per square foot) of the sloped portion of the function
- d = the intercept (in gpm) of the sloped portion of the function

Source of footprint graph: blogs.cars.com
Vehicle Fuel Efficiency Related Technology Development Overview

- Power unit
- Combustion engine
- Electric vehicle
- Hybrid vehicle
- Fuel cell vehicle
Vehicle Fuel Efficiency Related Technology Development Overview

- Power unit (Engine, EV, hybrid)
- Power distribution unit
- Lubrication
- All wheel drive system
- Continuously Variable transmission (CVT)
- Double clutch transmission (DCT)
- Differential

Übersetzungsdifferenz mittels Hohlradstufe:
- kompakte Bauweise
- minimales Gewicht
- optimaler Wirkungsgrad
- bestmögliche Verfügbarkeit

Kupplung im Leistungsfluss:
- minimale Schleppverluste
- höchste Stelldynamik
- optimale Regelgüte

Hydraulische Betätigung:
- optimale Regelgüte
- höchste Leistungsdichte
Vehicle Fuel Efficiency Related Technology Development Overview

Audi Matrix LED-Scheinwerfer
Audi Matrix LED headlight

10/13
Vehicle Fuel Efficiency Related Technology Development Overview

- Power unit (Engine, EV, hybrid)
- Power distribution unit (transmission, gear)
- Sub Electronic components
- Software control and support system
  - Engine control unit (ECU)
  - Electronic stability control (ESC)
  - Traction control system (TCS)
  - Electronic Valve Timing (EVT)
  - Idle stop/start
  - And many more…
Vehicle Fuel Efficiency Related Technology Development Overview

- Power unit (Engine, EV, hybrid)
- Power distribution unit (transmission, gear)
- Sub Electronic components
- Software control and support system
- Architecture design
- Aerodynamic
- Build in chassis
- Vehicle weight distribution
- Crumple zone
Vehicle Fuel Efficiency Related Technology Development Overview
Patent Study

- Patent is an exclusive right to intellectual property
- It’s a better way to measure innovation improvement
  - Patent approval system guarantees the degree of innovation in the new patent
  - Data availability
  - Clear information
- I’m looking for fuel efficient related patents
- Group into six by classification and functionality
EXHAUST PURIFICATION SYSTEM FOR INTERNAL COMBUSTION ENGINE

Inventors: Hideki Matsunaga, Saitama (JP); Yuji Yasui, Saitama (JP); Eiji Hashimoto, Saitama (JP); Hisao Haga, Saitama (JP); Naohiro Sato, Saitama (JP); Masafumi Sakata, Saitama (JP)

Assignee: Honda Motor Co., Ltd., Tokyo (JP)

ABSTRACT
An exhaust purification system for an internal combustion engine is provided that can steadily maintain a NOx purification rate of a selective reduction catalyst to be high without allowing the fuel economy or marketability to deteriorate. The exhaust purification system includes a NO2—NOx ratio adjustment mechanism that causes a NO2—NOx ratio to...
WIPO patent

- Provide patent right in 148 contracting States
Porter Hypothesis

- Porter’s idea from 1991
- Win-win solution
- Benefits from regulation
  1. Diminishing inefficiency consumption in limited resource
  2. Raising awareness
  3. Promote investment in environmental improvement
  4. Create pressure that motivate innovation and progress
  5. Increase firms’ competitiveness
Literature Review


- Regulation and innovation (Gray et al. 1998; Jaffe et al, 1995; Berman and Bui, 2001; Popp, 2003, 2006; Lanjouw and Mody, 1996; Arimura et el., 2007; Van den Hoed et al, 2005;)

- CAFE and its effectiveness (Greene 1990; Liu and Green, 2014; Parry et al, 2005; Austin and Dinan, 2005; Goldberg, 1998;
Data

- Variable source (patent): World Intellectual Property Organization (WIPO); Number of patents from WIPO: 2314
- Variable source (patent): United States Patent and Trademark Office (USPTO); Number of patents from USPTO: 6076
- Market Share source: Wardsauto.com
- Number of firms: Firms from the US and international that sell car to the US market, Ford, TOYOTA, BMW... (20 firms)
- Year used in panel data range from 1965-2013
- Omitted firm: Aston Martin, Lotus, Ferrari, Maserati, Spyker, Sterling, Vector Aeromotive, Callaway Cars, and few small coach building company
## Summary Statistic

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<th>Variables</th>
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Fixed Effects Panel Model

• Dependent Variable: log (market share of auto firms)

• Independent Variables:
  • Number of patents
  • Number of patents in six groups
  • CAFE standard (in mpg)
  • Level change of CAFE standard (in mpg)
  • CAFE penalty dummy

• STATA estimation: xtset, xtreg, fe

• Fix effects using: brands of automobile manufacturers
## Patent Data Analysis Results – Fixed Effects

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<td>log MarketShare</td>
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Standard errors in parentheses  *** p<0.01, ** p<0.05, * p<0.1
Result

• Every mpg increase in CAFE standards will increase market share by 2.79 percentage points
• Every additional new patent in a year will increase market share 0.327 percentage points
• Increase patents in more seeable way by consumer will increase market share (power source); but increase in patents in less noticeable areas will reduce market share (software, architectures, and other)
Implications

- My study supports the Porter hypothesis. Increased innovation helps firms increase market share.
- Increases in future CAFE standards will promote increases in market share for those who innovate.
- Increases in the penalty level will force firms to increase innovation under the threat of losing market share.
Next Steps

• Combine market analysis results
• Eliminate other factors may change market share to robust the results of this paper.
• Collect data from R&D and compare result
• Better data from market share
• Use other measures for market performance measuring, robust my result. (like profit, marketing expenditures, market segments)
Thank you for your time!
Question?