Environmental Regulation and Technological Innovation

David M. Hart (dhart@gmu.edu)
Schar School of Policy and Government
George Mason University

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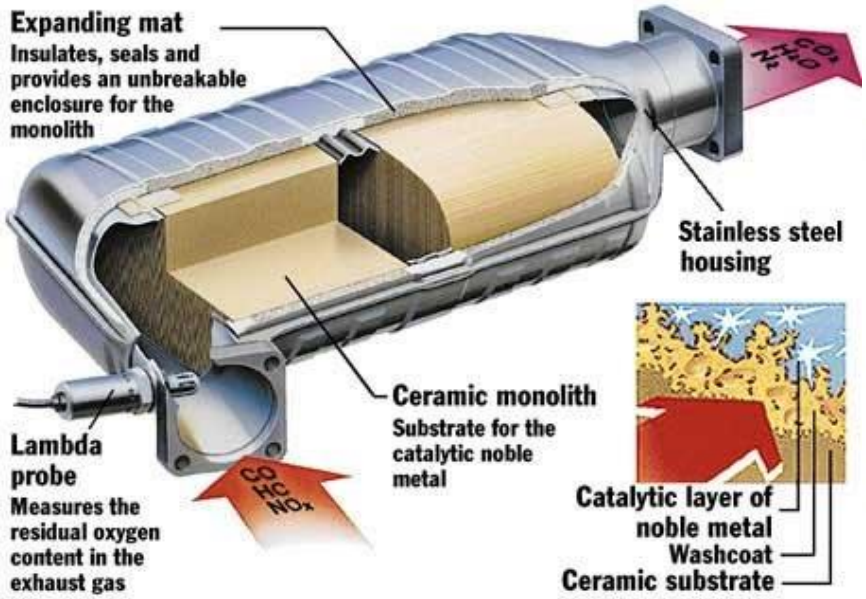
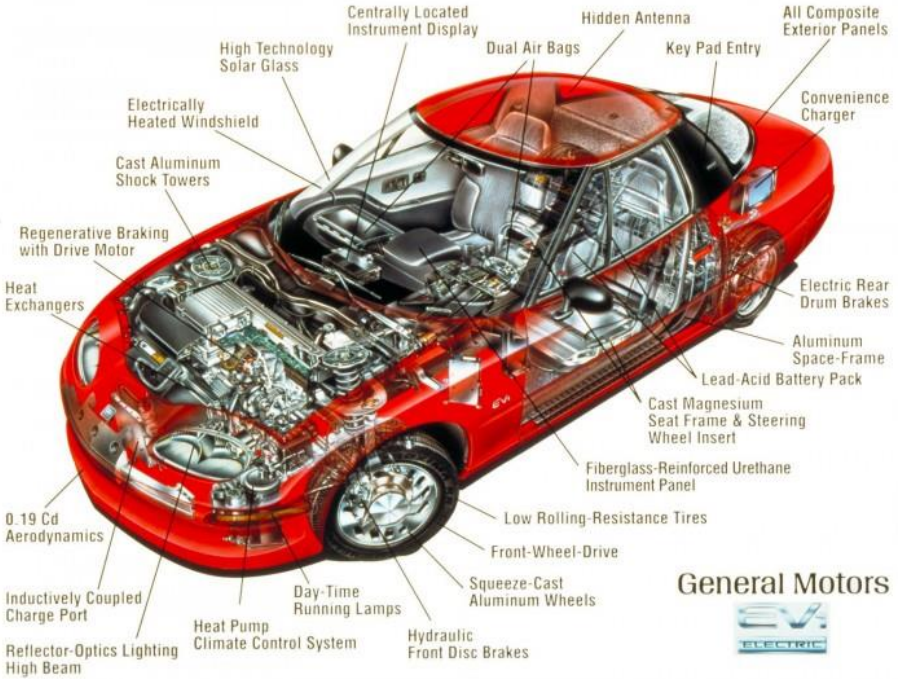
Catalytic Converters vs. Zero Emission Vehicles





Source: https://schoolworkhelper.net/catalytic-converter-parts-function/

Source: https://www.hemmings.com/blog/2013/06/27/cars-of-futures-past-gm-ev1/

Work in Progress, Feedback Welcome

- NSF SciSIP research report
  - Synthesize and clarify what is known
  - Provide recommendations for policy and practice
  - Suggest areas for additional research

Scope

- Type of regulation:
  - Environmental
    - With an emerging focus on automobile emissions
  - Possibly generalizable to health and safety
  - Probably not to economic regulation or taxation
- Geographical/jurisdictional
  - United States
  - Probably generalizable to states and localities
  - Perhaps not to international locations

Why Should We Care?

- Not because we like new technology
  - Purpose: reduce externalities
  - Innovation: means not end
- But because innovation may reduce cost and increase efficacy of compliance
- And because innovation may open up new market opportunities

Poorly-Framed Question, Inconclusive Results

- The “Porter Hypothesis”: regulation may stimulate innovation to such an extent that regulated firms are better off than they were before being regulated
- Cohen and Tubb (2017) meta-analysis:
  - “We find considerable heterogeneity in both the sign and significance level of the over 2,000 estimated “effect sizes” found in these studies.”

A Better…
But More Difficult Question

- "Under what conditions does environmental regulation induce technologically innovative responses by regulated firms that achieve regulatory goals more efficiently or effectively than alternative responses?"

Firm Responses to Regulation (Not Mutually Exclusive)

1. Resist
2. Comply by reducing (or ceasing) regulated activities in regulated jurisdiction
3. Comply by applying existing technology
4. Comply by innovating in order to reduce the cost or increase the efficacy of compliance

Four Kinds of Conditions that Shape Firm Responses

1. Technological opportunity
2. Industrial competition
3. Political environment
4. Regulatory design

1. Technological Opportunity

- Condition 1-1: “Expensive”
  - Expected cost of compliance is high
- Condition 1-2: “Target-rich”
  - Innovation pathways that might become cost-effective are perceived to be available by some regulated firms

Example: Not "Target Rich" California's 1990 ZEV Mandate

Table 1. Vehicle Categories Established in the ZEV Program Through October 2006

Vehicle Category	Date Introduced in ZEV	Vehicle Sales 2001–2005	Example Models
Zero-emission vehicle	1990	4,400[a]	Toyota RAV4 electric vehicle
Partial-zero-emission vehicle (PZEV): Vehicle that meets the most stringent tailpipe standards, meets the zero-evaporative-emission standard, and has a 150,000-mile emission warranty	1998	430,000	Some models of Ford Focus, Toyota Camry
Advanced technology partial-zero-emission vehicle (AT-PZEV): Vehicle that meets the PZEV requirements and incorporates such advanced technology as energy storage or electric motors	2001	70,000	Toyota Prius, Honda Civic Hybrid, Honda Civic GX (CNG)
Fuel cell vehicle (FCV)	2003	None to date, although some demonstration vehicles are in use	

Source: Vehicle sales figures were obtained through personal communication with K. Eley, Air Pollution Specialist, ZEV Implementation Section, California Air Resources Board, 2006.
[a]These are BEVs that were either sold or placed into use between 1996 and 2003.

Source: Bedsworth and Taylor 2007

2. Industrial Competition

- Condition 2-1: “No exit”
  - Jurisdictions where firms might plausibly locate regulated activity do not vary significantly in stringency
- Condition 2-2: “Slack”
  - Firms have resources available to invest in innovation
- Condition 2-3: “No cushion to sleep on”
  - Competition exists in the regulated industry, or there is a real threat of entry

Example: "No Cushion": The Catalytic Converter

Table 1. Chronological development of the automotive catalytic converter (*Source*: Haagen-Smit, 1970; Twigg, 1999; Mondt, 2000; Acres and Harrison, 2004; Interviews with Gary Acres, 2007)

1950s	1960s	1970	1971	1972	1975	1976	1977	1980s
Work by Dr Haagen-Smit at the California Institute of Technology proved that automotive exhaust emissions were a major source of photochemical smog in Los Angeles	In 1965, the US Motor Vehicle Air Pollution Act set the first federal emission standards to control pollution from automobiles. Targets were met without catalysts JM set up Catalyst Research Group	The US EPA was established and US Congress passed a major revision of the Clean Air Act (1970 amendments) Agreement to phase out lead in gasoline in the US from 1972 onwards JM carried out research with Ricardo and Corning	JM filed a patent covering the use of a rhodium – promoted platinum catalyst to control NO_x and other compounds JM approached car companies such as Ford, Chrysler, and GM	Corning developed ceramic support for catalyst monoliths JM proved to EPA that US emissions regulations could be met using rhodium-platinum catalyst JM was competing with Engelhard, and Degussa, etc.	The first cars fitted with oxidation catalysts reach the showroom in the US Unleaded gasoline was widely available	Japanese vehicle emissions standards to control HC, CO and NO_x came into effect	US Clean Air Act amendments agreed to tighten emissions standards further from 1981 onwards	To meet the strict NO_x limits under the amended Clean Air Act, more sophisticated 'three-way' catalytic converters were introduced in 1981 Vehicle emissions regulations were introduced in Australia and Germany

Source: Tao, et al 2010

3. Political Environment

- Condition 3-1: “No appeal”
  - Regulated firms do not expect to be successful contesting regulation in non-regulatory venues
- Condition 3-2: “Strong state”
  - Enforcement is perceived to be legitimate and credible
- Condition 3-3: “Package deal”
  - Regulation is one element of a broader policy package to build industrial innovation capacity

Example: "Package Deal" EPA Flue Gas Desulphurization R&D

- Close coordination with User and A&E communities; TVA and Bechtel partners
- R&D was conducted in parallel with the passing of tough SO2 NSPS (based on BACT) regulations, driven by the 1970 CAA
- Primary R&D was via three large (3x10 Mw(e)) parallel pilot plants evaluating competing scrubbers; *smaller in-house pilot plant provided rapid low cost technology fixes to guide large pilots. Both lime and limestone reagents tested*
- Economics were seriously considered, goal was to minimize capital and operating costs with reliable operation

Source: Frank Princiotta

4. Regulatory Design

- Condition 4-1: “No straitjacket”
  - Regulatory standards are based on performance
- Condition 4-2: “Frank and open”
  - Regulated industry and regulator engage in a robust information exchange
- Condition 4-3: “No dummies”
  - Regulatory staff and decision-makers have a sophisticated understanding of industry
- Condition 4-4: “Ratchet”
  - Regulated industry and regulators share expectations of regulatory stringency over time

Example: "Frank and Open" CAFÉ Standards under Obama

"The "letters of commitment" signed by the stakeholders, although not legally binding, resemble legal documents. They envision a detailed step-by-step process of implementation, which requires reciprocal demonstrations of good faith by regulators and industry: the auto companies would stay the lawsuits upon issuance...All of this was done…voluntarily….the parties entered an agreement that is best described as a "trust, but verify" regime." (Freeman 2011, p. 369)

Recommendations for the Research Community

- Do more research (especially on the US)
- Ask different questions
- Take the long view
- Assume strategic behavior
- Incorporate context (political, competitive, technological)
- Focus on regulatory design features, rather than binary command and control vs. market-based instruments

What I Might Say to Policy-Makers

- Don’t neglect innovation as a mechanism for reducing compliance costs
- But it’s not a sure thing, and it takes time to discover if it will work
- Achieve stringency over the long term by building credibility over the intermediate term
- Trust, but verify, what “industry” says
  - “Industry” probably isn’t monolithic
  - Verification requires sophisticated regulators
- Embed regulation in broader innovation policy package (R&D funding, procurement, trade, etc.)