Technology-Forcing Regulation: The Case of Automobile Emissions Technology

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Recently there have been many calls for a new relationship between business and the environment. People worldwide are concerned about environmental degradation and about the relationship between industrial development and the health of the environment. Environmental technology is considered a growing area in which the United States could develop a competitive advantage. As Vice President Al Gore asserts in his influential book, *Earth in the Balance*, leadership on the environment is "in our economic interest," and "we can prosper by leading the environmental revolution and producing for the world marketplace the new products and technologies that foster economic progress without environmental destruction."[1] There is also a call for a change in the way that government interacts with business to promote environmental protection. Some state that government should "make markets work"[2] through the use of economic incentives, and others believe that government should directly promote research and development.

However, government promotion of technological innovation is nothing new. "Technology-forcing" policies were used over 20 years ago--in the 1970 Clean Air Act--to force innovation within the automobile industry. This article presents a brief case study of this effort: the development of emissions technology for mobile sources that is, automobiles and light trucks, under the 1970 Act. This effort was only one part of the Act, which also regulated stationary sources such as electric utilities. An important lesson from this case study is that policies to promote technological innovation often must reflect complex interactions between the technical problem itself, industrial structure, and the political process.

In the 1990 Amendments to the Clean Air Act, several new types of policy instruments have been included in both the mobile and stationary source provisions [see sidebar, page 11]. This article does not discuss these provisions, although it will be interesting to see what the response of industry is to this latest attempt to force technology.

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The History of the 1970 Clean Air Act

Smog, defined as hazy and irritating photochemical air pollution, first appeared in Los Angeles in the early 1940s. Since that time it has been responsible for damage to buildings, crops, and human health. The severe problem which developed in Los Angeles led to research implicating the automobile as a significant polluter, and then to legislation in California in the early 1960s which required the use of emissions control devices after they had passed a certification process.

Over time, smog became a national problem. Successive federal air quality legislation culminated in the Clean Air Act of 1970. This ambitious legislation set "technology-forcing" emission standards for 1975 model-year cars and also regulated stationary sources. The technology-forcing emissions standards were set to protect human health and were set beyond the capabilities of then-known technologies. One of the reasons for this approach was the suspicion that auto companies were not doing all that they could to develop and implement control technologies. It was thought that the combination of tough standards and a short deadline (five years) would force the auto companies to devote more resources to solving this problem.

The 1975 standards were not met on time. The deadline was rolled-back several times and standards were finally met during the 1980s. During this time, technology advanced incrementally. Early responses to the legislation first included engine modifications and then simple catalytic converters. Later, three-way catalytic converters, capable of controlling all three major exhaust pollutants, and microprocessors were introduced.

Despite this progress, ambient air quality in many urban areas is still not adequate to protect human health.[3] Many reasons can be given for this including the possibility that a more radical change in automotive technology is needed--a move away from the gasoline-powered internal combustion engine. However, it should be noted that technology is not the only, and perhaps not even a sufficient, avenue towards attainment of this goal for all urban areas:

> When we analyze the failure of the 1970 Clean Air Act Amendments to reduce pollution from automobiles to the extent envisioned by Congress, several factors stand out. First, the growth in the total number of automobile vehicle miles travelled every year, combined with less stringent control requirements for other mobile sources, reduces the overall gains achieved by the standards that apply to the individual automobile. Moreover, the standards as such are not achieving the full benefit intended, mainly because of poor vehicle maintenance. Deterioration in fuel quality and the stipulation in the law that emission-control requirements apply only for five years or 50,000 miles--roughly half the lifetime of a car--also contribute to the problem.[4]

This article is concerned with only one piece of the pie: the development of emissions technology. The story of this technology is largely the story of the catalytic converter, presented below.

The Catalytic Converter

Catalytic converters are tailpipe devices that use catalysts mounted on a metal honeycomb or on pellets to change harmful gases to less harmful ones. The chemical processes and the basic design of converters were conceived early in the development of emissions control systems, and prototypes had been developed as early as 1957. However, these early prototypes did not meet common-sense requirements for implementation: they were too big, they did not reduce hydrocarbon and carbon monoxide emissions sufficiently, they were costly, their replacement costs were high, and they did not last long. Durability and cost were the chief problems. Catalytic converters were "poisoned" by the lead in gasoline so they soon stopped working. In addition, the catalysts often used precious (and expensive) metals such as platinum. The durability problem was greatly eased by the introduction of unleaded gasoline in the 1970s.

The development of an effective catalytic control device was difficult. First, the device had to operate effectively for years under conditions of high temperature and changing gas mixtures in the exhaust. Second, the catalysts were originally designed to "clean" only some components of emissions. The later introduction of microprocessors allowed the precise control of gases in the exhaust and therefore, the use of catalysts that were better able to "clean" more components of emissions.

Development of the catalytic converter was not consistently pursued from its genesis in 1957 through to its widespread adoption in the mid-1970s. During the 1960s the automobile industry had largely abandoned research on this technology because engine modifications and other technologies met the needs of the California standards.[4] Intensive research was begun after the passage of the 1970 Clean Air Act.[5]

Specific factors constrained the rapid development of the catalytic converter prior to and following the adoption of the 1970 legislation:

- *The high cost of installation and maintenance.* Under the 1970 act, legislators balanced costs against the benefits of better emissions control by requiring durability of only 50,000 miles. This meant that the consumer would not have to replace the catalytic converter.
- *The need for coordination with other industries (here, the petroleum industry).* The widespread adoption of the catalytic converter coincided with the requirement that new cars use unleaded fuel.
- *The nature of the technology itself.* A lot of vibration and great variation in temperature take place within an automobile. Catalytic converters were originally not rugged enough, and are still not effective over the entire temperature range of operation. Microprocessors have increased the effectiveness of catalytic converters by more closely controlling combustion.

Criticisms of the 1970 Clean Air Act's "Technology-Forcing" Approach

The above description of the development of the catalytic converter touches on some of the complexities that were involved in the development of this technology. One criticism of the 1970 Act is that it did not acknowledge these complexities. Even prior to subsequent deadlines, some analysts criticized the structure of the Clean Air Act. One book from this period, *Clearing the Air: Federal Policy on Automotive Emissions Control*, states "the regulatory mechanisms set up in the Clean Air Act are too primitive for the complex technical and manufacturing processes to which they have been applied."[6]

The 1970 Clean Air Act's "technology-forcing" pro-

Clean Air Chronology--

1925 -Public Health Service, a federal agency, studied carbon monoxide in automobile exhaust.

1940s -Smog first noticed in the Los Angeles area.

1943 -"Daylight Dimout" on September 8 in Los Angeles.

1947 -*Air Pollution Control Act* allowed California counties to establish air pollution control districts although permits could not be used on motor vehicles.

-Stanford Research Institute (SRI) began studying air pollution.

1948 -20 deaths and 6,000 cases of illness in Donora, Pennsylvania and up to 800 deaths in London, England are attributed to poor air quality.

1951 -Dr. A.J. Haagen-Smit at the California Institute of Technology identified the basic processes that create photochemical smog. Motor vehicle emissions identified as the major source of pollutants.

1952 -Payne and Sigworth concluded that blowby was not a significant source of air pollutants.

1953 -Automobile manufacturers formed the "Vehicle Combustion Products Committee," under the auspices of the Automobile Manufacturers Association to study pollution. Air Pollution Foundation (APF) was founded.

1954 -APF conference held in August on automotive engineering design and exhaust control devices.

-Emergency grants awarded to the University of California and to the Public Health Department for accelerated research.

1955 -Automobile manufacturers signed a cross-licensing agreement for free access to any emissions control patent owned by member firms.

-Auto companies began work on a device to curb tailpipe hydrocarbon emissions by 30 to 50 percent.

-APF affirmed Haagen-Smit's findings and determined relative role of the refineries.

-APCD established its Automotive Combustion Laboratory

1956 -APF concluded that motor vehicles were the principle contributor to smog.

-APCD called a meeting of chemical and auto accessory firms to stimulate interest in the development of an emissions control device.

1957 -First catalytic converter prototypes were developed by Ford and GM. Auto industry presented the results of a three-year study on induction devices.

1959 -Engineers at GM found that blowby was a significant source of emissions.

-California legislature directed the Department of Health to adopt standards for community air quality, and in particular, for motor vehicles.

-Exhaust emissions standards were set by the Department of Public Health.

1960 -APF wrote that auto companies could have control devices to test within one year.

-GM developed crankcase device.

-*Motor Vehicle Pollution Control Act* established a Motor Vehicle Pollution Control Board (MVPCB) within the California Department of Health to certify control devices and require their use.

-Crankcase emissions standards set by the Department of Public Health.

-*Schenck Act* adopted in which Congress directed the Surgeon General to report on the effects of motor vehicle exhaust on human health.

1961 -Most American vehicle manufacturers voluntarily installed crankcase controls on vehicles marketed in California.

-MVPCB certified a GM crankcase device, which later proved to be defective.

-Secretary of Health, Education and Welfare (HEW) warned that if blowby devices were not placed on all cars, he would recommend that mandatory legislation be passed by Congress.

1962 -Up to 700 deaths were attributed to the "Killer Smog" which hit London in December.

-Several crankcase devices were certified. California legislature made improved crankcase devices mandatory on new American-made cars starting with the 1964 model year, and upon change of ownership within certain counties.

-*Air Pollution Control Act* is extended for two years. Studies called for in the Schenck Act are made a permanent task of the Surgeon General.

1963 -Most American vehicle manfuacturers voluntarily install crankcase devices nationwide.

Legislation and Regulation

-*Clean Air Act* , amending the Air Pollution Control Act of 1955, is adopted, directing the Department of HEW work with industry representatives on fuel and emissions technology, and to develop criteria on the effects of air pollution and its control.

1964 -In March, auto companies said there was no way that they could have a device ready until 1967. But, in August, after the certification of four devices by the MVPCB, the companies announced that they had engine modifications that were superior to the independant parts manufacturers.

1965 -Ralph Nader's *Unsafe at Any Speed* published.

-*Motor Vehicle Air Pollution Control Act* amended the Clean Air Act. Directed HEW to set emission standards for motor vehicles to become effective in 1968.

1966 -November inversion in New York City estimated to cause 80 deaths.

-All 1966 American-made cars sold in California required to have exhaust emissions controls and state legislation switches from a two- to one-device requirement.

-HEW set standards for motor vehicle emissions to become effective for the 1968 model year.

1967 -Inter-Industry Emission Control Program begun by Ford in conjunction with several oil companies and foreign manufacturers.

-MVPCB replaced by the Air Resources Board (ARB).

-*Air Quality Act* amended the Clean Air Act with provisions for assistance to states for vehicle inspection, registration of fuel additives and federally-designated air quality control regions, control criteria and suggested control techniques. Only California could establish new vehicle provisions more stringent than federal ones.

1968 -*Pure Air Act* included specific emission standards for HC, CO, and NOx for 1970 and 1972 models and provided that the ARB was to conduct assembly line testing. The ARB could make standards more stringent.

-1968 model cars subject to emissions standards set by HEW (based on California's 1967 standards).

-The National Center for Air Pollution Control, the Automobile Manufacturers Association, and the Petroleum Institute began a three-year, $10 million research program on air pollution (none of which were directed towards developing technologies to control or prevent emissions.

1969 -The anti-trust division of the U.S. Department of Justice brought suit against the manufacturers, charging them with collusion in delaying the development of emissions control technology. The suit was settled when the manufacturers agreed to end the cross-licensing agreement.

1970 -California legislation is passed which 1) creates a basinwide air pollution control coordinating councils, and 2)directs the ARB to study the costs and benefits of vehicle inspection.

-Clean Air Act Amendments set "technology-forcing" emission standards for automobiles for HC and CO by 1975 and for NOx by 1976. The National Academy of Sciences (NAS) was directed to study the technological feasibility of standards and deadlines and to submit semiannual reports for use in determining whether extensions would be granted.

1971 -California requires control of NOx on 1971 model automobiles and passes legislation requiring the ARB to set standards for NOx devices for 1966-71 models. U.S. EPA promulgated uniform national air quality standards and set emissions standards.

1972 -NAS released its first report.

1973 -EPA granted one-year delays for all standards.

1974 -The *Energy Supply and Environmental Coordination Act* delays standards a second year and gives EPA the power to delay all standards for a third year.

1975 -McJones discovers that disconnecting the spark advance greatly reduces NOx emissions.

-California alters requirement so that exhaust emissions controls are only required upon initial registration or transfer of ownership.

-EPA grants another year's delay of HC and CO standards because of a possible problem with the production of sulfates by catalysts.

1977 -Clean Air Act Amendments delay the 1970 emissions requirements until the early 1980s, set targets for trucks, set separate standards for vehicles at high altitudes, and required that these vehicles meet nationwide standards by 1984.

1990 -Clean Air Act Amendments set new emission standards for various pollutants and air toxics, evapo-

visions were written to prod auto companies into action, developing technologies that Congress was confident that they (or their suppliers) could produce. The deadlines written into the law were very ambitious, but the law also provided for an evaluation of the feasibility of achieving them on time. Despite this provision, short deadlines were included because there was a widespread perception that auto companies were simply resisting the development of new technologies. Congress was careful to not specify which technology was to be adopted by including only performance standards in the legislation. Unfortunately, Congress' "hands-off" approach to the choice of technology, combined with its strong push for rapid development, may have ultimately hindered widespread innovation and the development of radical improvements. In hindsight, it is possible to identify key technical, structural, and political considerations that contributed to the slow progress under the 1970 Clean Air Act. The following is a discussion of each of the three dimensions.

Under the 1990 Amendments, fuel oxygenation is required in the Durham, North Carolina area due to poor air quality.

Technical Considerations

The combination of short deadlines and the use of performance standards may have discouraged radical innovation. As a prescient engineer stated early in the saga of emissions control:

> Great care must be taken in developing intelligent legislation with respect to the car exhaust problem. The ultimate solution cannot be brought into being in the first stage of effort. Overrestrictive legislation could cause termination of the more imaginative and complex research approaches and thus delay greatly the optimum solution to this problem.[8]

William Abernathy, a scholar of the automotive industry, has raised other, related issues. He suggests that technology-forcing regulation may contain a paradox: "Regulation may encourage rapid incremental progress and, at the same time, 1) by diverting resources away from research into them ..., and 2) erecting barriers", hinder the development of more epochal innovations.[9]

The National Academy of Sciences Automobile Panel, in which Abernathy participated, argues that regulations interact with one another to reinforce the existing technology and that this interaction raises the cost of developing new technologies:

> As new requirements create new demands, R&D tasks associated with each change become more complex, costly, and subject to risks. Each change, too, becomes more costly while at the same time more changes are required .... In attempting to protect the innovative process by undertaking piecemeal regulations ... government agencies ... may have created a sequence of independent regulatory actions that, taken as a whole, form a tightening web of constraints that envelop the existing technology.[10]

Structural Considerations

The 1970 Clean Air Act did not consider the nature of the automobile industry or the automotive market. The

Act pushed auto manufacturers to innovate but ignored the role of the industry's suppliers. This group, historically a source of numerous inventions, is typically less able to weather the uncertainty and costs of changing requirements. The technology-forcing provisions were designed to push a deep-pocketed yet reluctant industry rather than to work with capital cycles, the market's price sensitivity, and other parameters.

The exclusive focus on the auto industry, combined with a reluctance to specify a preferred technology, also hindered the development of emissions technology. Ultimately, the development of the catalytic converter required inter-industry cooperation. Specifically, the use of unleaded fuel was required, and the development of microprocessors aided their effectiveness. However, because the 1970 Act was not written to promote a certain technology, it was also not written to martial the resources of different industries to its development.

Political Considerations

Emissions-control legislation presents a unique political challenge because of the enormous power of both the consumers, everyone who may buy a car in the future --most of the voting public--and the producers, the automobile industry. Although other factors besides technological improvement (for instance, a reduction in driving) could also contribute to clean air, the power of the voting public has limited this option. The mood of Congress is nicely summarized by Gary Bryner in his recent analysis of the 1990 Clean Air Act Amendments, *Blue Skies, Green Politics*:

> The battle between the auto industry and clean air advocates over the extent to which cleanup can be achieved through technological controls on tailpipe emissions has dominated the debate over clean air legislation .... Aware that technological changes are less difficult to bring about than changes in the driving habits of Americans, Congress has hesitated to impose aggressive transportation control measures.[11]

The power of the voting public is also reflected in the decision to require that any technology last for five years or 50,000 miles, and to not require as high a level of emissions reduction after this time. This provision was designed to keep the public from having to purchase replacement control equipment, and thus to keep the cost of the control equipment hidden in the sticker price of the car. It is possible that, if such durability had not been required, emissions control could have been implemented earlier.

The auto industry itself presents an unusual situation. As Douglas Ginsburg, a scholar of regulation, stated: "automobile regulation faces a special challenge...it applies to an industry that is at once highly concentrated and almost unimaginably large and important to the American economy."[12] Ginsburg explains that the small number of firms in the industry make it possible for firms to collude, and that it is in the government's interests not to cause further concentration of the industry.[13] The size of the industry lends it the political power that made sanctions in the 1970 Clean Air Act unfeasible:

> The government cannot credibly threaten to impose severe sanctions when the industry fails to meet a standard. To prohibit a single domestic firm from marketing nonconforming vehicles would (1) concentrate the market further in the remaining hands; and, if it is one of the big three firms, (2) have unacceptable consequences for the national economy. Therefore, the industry ... has a degree of immunity from prosecution. Since both the industry and the government know that the Draconian sanctions now provided by law cannot be used, the industry may be readier to resist regulation.[15]

The 1990 Clean Air Act Mandates

In contrast to the 1970 Act, the 1990 Act has detailed provisions covering many factors that contribute to emissions. These provisions cover inspection and maintenance, fuels, fueling, economic incentives for consumers such as congestion pricing, evaporation from the gas tank, measures to discourage single occupancy vehicles, and many other items.

The 1990 Act also specifies some of the technologies that are to be phased-in. A notable departure from the 1970 act is the use of pilot programs (California and also fleet vehicles in urban areas) for radically different automotive technologies, such as electric cars.

A short list of the provisions of the Act include:

1992 - Oxygenated fuels are required in areas which exceed the carbon monoxide standard.

1994 - Onboard diagnostic control devices to detect emission-related system malfunctions required on cars and light trucks.

1996 - Start of the California pilot program with the production of 150,000 clean-fueled vehicles annually, to be increased to 300,000 vehicles by 1999.

By 1998 - New emissions standards phased-in.

By 1998 - Canisters to absorb evaporative emissions phased-in.

1998 - The sale of very clean gasoline or alternative-fueled vehicles required in ozone or carbon monoxide nonattainment areas, if these vehicles have been developed for the California market.

Conclusion

Several key considerations for the success of innovation-promoting legislation were illustrated by this case study. These lessons can be widely applied--they are not simply restricted to environmental-protection technologies or to the automobile industry. They form a useful framework for the consideration of different policies of variousways to promote government and business interaction in the development of technology. These lessons may be relevant for situations which lend themselves to "command-and-control" legislation, as was applied in this case, or to incentive-based solutions:

·Policy makers may need to choose a particular technology or devise a program which blends the initial choice of a preferred technology with incentives for the development of more effective long-range solutions.[15]

·Policy makers need to be aware of an industry's structure and the behavior of its markets. Some industries are likely to be much more entrepreneurial because the industry is relatively new or new markets are developing for its products. Large, mature industries (such as the auto industry) however, may be much more resistant to innovation because of their level of investment in the status quo. Further, the most likely source of innovation may not be the manufacturer but the suppliers, who have less capacity to overcome cost barriers and uncertainty. Policies that provide profit opportunities will encourage interest in innovation.

·Some technologies require direct government involvement in the development of standards and the coordination of activities among different industries. In this case, a supply network for unleaded fuel was needed. If electric cars are promoted in the future, an entirely new supply network will need to be developed.

·Policy makers need to keep an eye on the political feasibility of provisions and enforcement measures. Provisions which ultimately lead to "show-downs" between the government and powerful interests can be counterproductive.CP

References

Abernathy, William J. "Innovation and the Regulatory Paradox: Toward a Theory of Thin Markets," in *Government, Technology, and the Future of the Automobile*. New York: McGraw-Hill, 1980, pp. 38-61.

Air Pollution Foundation. *Sixth Technical Report*. Los Angeles, 1960.

Automobile Panel, Committee on Technology and International Economic and Trade Issues of the Assembly of Engineering, National Research Council, and Office of Foreign Secretary, National Academy of Engineering. *The Competitive Status of the U.S. Auto Industry: A Study of the Influences of Technology in Determining International Competitive Advantage*. Washington, D.C.: NAS/NAE/NRC, 1982.

Bryner, Gary C. *Blue Skies, Green Politics: The Clean Air Act of 1990*. Washington, DC: CQ Press, 1993.

Cairncross, Frances. *Costing the Earth: The Challenge for Governments, the Opportunities for Business*. Boston: Harvard Business School Press, 1993.

Committee on Motor Vehicle Emissions, Commission on Sociotechnical Systems, National Research Council. *Report by the Committee on Motor Vehicle Emissions*. Washington, D.C.: NAS/NAE/NRC, 1973.

Ginsburg, Douglas H. "Making Automobile Regulation Work: Policy Options and a Proposal" in *Government, Technology, and the Future of the Automobile*. New York: McGraw-Hill, 1980, pp. 10-37.

Gore, Al. *Earth in the Balance: Ecology and the Human Spirit*. New York: Plume, 1993.

Health, Education, and Welfare, Department of. *Proceedings: The Third National Conference on Air Pollution*. Washington, D.C., 1967.

Jacoby, Henry D. and Steinbruner, John D. *Clearing the Air: Federal Policy on Automotive Emissions Control*. Cambridge, MA: Ballinger Publishing, 1973.

Paul, John A. "Urban Air Quality: The Problem," in *EPA Journal*. Vol. 17, No. 1, January/February 1991, pp. 24-6.

Walsh, Michael P. "Motor Vehicles and Fuels: The Problem," in *EPA Journal*. Vol. 17, No. 1, January/February 1991, pp. 12-14.

Notes

[1]Gore, *Earth in the Balance*, p. xvi.

[2]Cairncross, *Costing the Earth*, p. 9.

[3]As the Supervisor of the Regional Air Pollution Control Agency (RAPCA) in Dayton, Ohio states: "Six out of every 10 people in the United States today live in an area which fails to meet air quality standards that have been set to protect human health." John A. Paul, "Urban Air Quality: The Problem," *EPA Journal*, January/February 1991, p. 24.

4Walsh, "Motor Vehicles and Fuels: The Problem," *EPA Journal*, January/February 1991, p. 12.

[5]A representative of the Automobile Manufacturer's Association stated in 1966 that flame and catalytic afterburners (i.e., catalytic converters) had "proved to be unfeasible." See the speech of B.W. Bogan, p. 81, in the *Proceedings* of the Third National Conference on Air Pollution.

[6]This is inferred from progress in the development of the catalytic converter in the early 1970's. See for instance the reference to "significant advancements" in the cover memorandum for *The Report by the Commitee on Motor Vehicle Emissions.*

[7]Jacoby and Steinbruner, *Clearing the Air: Federal Policy on Automotive Emissions Control*, p. 1.

8 Air Pollution Foundation, *Sixth Technical Report* (1960), p. 41.

9Abernathy, *Government, Technology, and the Future of the Automobile*, p. 46.

10Automobile Panel, Committee on Technology and International Economic and Trade Issues, *The Competitive Status of the Automobile Industry*, (1982), p. 87.

11 Bryner, *Blue Skies, Green Politics: The Clean Air Act of 1990,* (1993), p. 132.

12Ginsburg, "Making Automobile Regulation Work: Policy Options and a Proposal," in *Government, Technology, and the Future of the Automobile*, p. 17.

13Ibid. p. 18.

14 Ibid. pp. 18-19

15Some authors promote technology certification programs as a means to promote the early use of near-term technologies while also encouraging the long-range development of other technologies.