FINAL REPORT

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Analysis of Auto Industry and Consumer Response to Regulations and Technological Change, and Customization of Consumer Response Models in Support of AB 1493 Rulemaking –

Effect of Emissions Regulation on Vehicle Attributes, Cost, and Price

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ABSTRACT

This report documents the automotive industry's response to federal regulations of light duty vehicle tailpipe emissions, with the intent of identifying lessons learned that might be applicable to future regulation of greenhouse gas emissions. The focus is on 1975 and 1979-1981, when new standards took effect that led directly to the adoption of costly new emission control equipment. The costs were significant during those time periods – with almost all automakers installing new oxidation catalyst technology in the first time period and three-way catalytic converters in the second. However, prices of new vehicles did not appear to reflect the full costs of emissions control. Other cost and pricing considerations seemed to be even more important. The added compliance costs associated with emissions reduction were just one more factor used by companies in setting prices. Aggregate new car sales were affected only in a minor way by emissions regulations.

EXECUTIVE SUMMARY

The regulation of greenhouse gases from motor vehicles follows a long history of state and federal automotive exhaust emission standards. The automotive industry typically opposes such regulation citing high compliance costs, technological infeasibility, and/or widespread economic impacts. In most cases, the final rules are phased in gradually or the effect on vehicle costs have proved rather modest. Indeed, an analysis of vehicle prices over the past few decades could not detect the effect of emissions or safety regulations (Burke et al 2004; Abeles et al 2004). Thus, we chose to analyze in detail two time periods when emission standards were sharply tightened and were known to require costly new emission control technology. These two periods are 1975 and 1979-1981. In both periods, automakers responded to stricter standards primarily with technological solutions, as opposed to modifications in vehicle attributes such as size or performance. Most manufacturers utilized oxidizing catalysts to meet the 1975 standards, and three-way catalytic converters to meet the latter standards. They also made many other complementary technological changes, including the installation of fuel injection, onboard diagnostic, and computer control technologies.

- **A wide range of costs are associated with emissions regulation compliance.** The total cost of compliance can be separated into the costs initially absorbed by the manufacturer and those passed onto the consumer. Doing so is difficult, though. Types of costs born primarily by automakers include research and development expenditures, capital investments in new tooling equipment, and advertising costs to maintain vehicle sales. One study suggests that manufacturers fully absorb the cost of emissions control equipment immediately after the implementation of more stringent standards and then pass on two-thirds of the costs to consumers the following year. In addition to higher vehicle costs, the changes in the vehicles resulting from new standards may also have different operating costs – such as higher or lower fuel and maintenance costs – and changes in drivability. However, equipment costs comprise the predominant cost.
- **Industry and regulator projections of costs often differ.** When standards were being debated and adopted, it is not surprising that cost projections by government regulators typically turned out to be lower than actual costs, while auto manufacturer projections tended to be higher. In general projections by industry turned out to be more inflated than those by regulators.
- **Changes in emissions control costs were not reflected in changes in vehicle prices.** Actual emission control costs were estimated by several analysts. In all cases, emission control costs per vehicle were estimated to increase with time until 1981, and then diminish. The per-vehicle cost estimates for 1981 vehicles range from roughly $875 to $1350 (US$2002). Average vehicle cost estimates camouflage large variation. Costs varied based on production volume, engine size and type, and many other characteristics. Emission control costs diminished slightly from 1981 to 1994, a period when emission standards were static. These cost reductions are evidence of improvements in the design and manufacturing of emission control systems. Comparison of these emissions control costs with changes in new vehicle price reveals that compliance costs were not passed onto

consumers equally across all vehicles and models. In some years, average vehicle price by vehicle class actually declined, suggesting that any additional costs related to air quality regulations for that year were absorbed either by the manufacturer or purchasers of vehicles in other classes. In other years, vehicle price often increased by an amount greater than the estimated emissions control cost.

- **Vehicle prices depend on a variety of considerations, not just cost.** Clearly many other more important factors were affecting vehicle price. We do not document those other factors, but note that pricing is a highly complex and highly confidential art. We do note that a principal constraint when passing along compliance costs is a desire to moderate price increases, especially after production planning has been finalized. Once factories are tooled and manufacturing processes designed, automakers aim to stick to projected sales volumes. Lower sales volumes results in manufacturing costs—most of which are fixed—to be spread over fewer vehicles, which reduces profits. Increases in vehicle prices may reduce sales, which again affects profits. Automakers employ a number of non-pricing strategies to offset or accommodate cost increases resulting from new standards. They make previously standard equipment optional, eliminate some features, or provide rebates.
- **Changes in emissions regulation were concurrent with periods of economic uncertainty.** Another reason it was not possible for us to document the effect of new regulations on vehicle prices was that many other external forces were at play. Most notable were the oil price shocks that shaped consumer preference and the subsequent regulation of vehicle fuel economy that prompted substantial changes in vehicle design and marketing (and pricing). In addition, there were overlapping periods of economic recessions, high interest rates, and low consumer confidence. In the end, even though the cost impact of emissions regulations was significant during the two case study periods, it is not possible to document the exact impact on prices nor consumer and industry behavior.

1. INTRODUCTION

The regulation of greenhouse gases from motor vehicles follows a long history of state and federal automotive exhaust emission standards. The purpose of this report is to analyze both the auto industry's response to emissions regulations and the subsequent product offered to consumers. By better understanding how auto manufacturers have responded to vehicle regulations in the past, rulemakers will be better prepared to propose greenhouse gas emission standards.

Case Study Approach

Two periods of federal regulation will serve as case studies for industry response to technology-forcing emissions regulations: 1) the introduction of the oxidizing catalyst to meet 1975 standards; and 2) the introduction of the three-way catalyst to meet standards phased-in between 1979 and 1981. The case study approach was selected as the significant changes in emission standards during these periods would minimize any confounding effects, such as variations in fuel prices, vehicle safety regulations, or foreign competition. However, these effects are never completely eliminated, especially for the later case study period when fuel economy standards were introduced. For both of the case studies, the following questions will be addressed:

1. What new or altered technologies were offered by manufacturers?
2. Did increased costs induce manufacturers to change the volume and mix of vehicle types offered for sale?
3. How did manufacturers reflect the cost of new or altered technologies in vehicle prices in the short and long run?
4. To what extent were manufacturers able to raise prices to cover the cost increase associated with new or altered technologies in the short run and long run?
5. How did manufacturers overcome consumer resistance to price increases?

Although the California standards differ from the federal ones, the analysis of industry response has been limited to 49-state version vehicles due to data availability. Thus only the federal regulations will be discussed here. In addition, while light trucks comprise a significant portion of the vehicle fleet at present, lack of data and their limited popularity during the time periods of interest render any analysis inconclusive.

Background on California and Federal emission standards

California has been a pioneer in the regulation of automotive emissions. The state's regulations have generally led to similar federal rules, in part by providing a testing arena for new control technologies. [1] Positive crankcase valve systems were voluntarily installed on all new vehicles sold in California in 1961 and then for all vehicles throughout the country in 1963 to control for blowby emissions. Similarly, exhaust emissions were first regulated in California beginning with model year 1966 vehicles; the standards were established by the California State Health Department at 4.3 grams per mile (g/mi) of unburned hydrocarbons (HC) and 44 g/mi of carbon monoxide (CO) with a durability of 12,000 miles. [2] Federal exhaust emissions controls did not begin until two years later with less stringent requirements. Likewise, California began regulation of evaporative emissions and exhaust nitrogen oxides (NO_x) one year prior to the remaining 49 states.

The federal regulations around which our two case studies revolve have more complex histories. Originally, the 1975 emission standards were set at 0.41 g/mi HC, 3.4 g/mi CO, and 2.0 g/mi NO_x, with NO_x emissions further reduced to 0.4 g/mi the following model year. In both cases, the durability of these standards was set at five years or 50,000 miles (or whichever came first). The levels were intentionally established to exceed the capabilities of existing technologies with the goal of promoting the development of new emissions control devices.[1] As could be expected, automakers contended that such advances were unreasonable to achieve in a cost-effective manner and might even put some companies out of business. [3] Although the original legislation required the Environmental Protection Agency (EPA) to analyze the cost-effectiveness of potential control technologies, Congress explicitly set air quality standards based on health considerations and not costs. [4] Nonetheless, EPA had the authority to delay target dates for a year if the automobile industry was unable to meet the deadline in time with good-faith efforts.

Despite concerns that Chrysler was deliberately stalling, based on evidence that it was spending very little on emissions control research and development (10 to 16 percent that of General Motors and Ford) [5], uncertainty about meeting production targets due to costs prompted the original 1975 standards to be delayed [6]. In their place, interim standards were established for model year 1975 vehicles, halving HC and CO levels to 1.5 g/mi and 15 g/mi, respectively, while NO_x standards remained unchanged. Though these were intended as temporary standards, they still represented significant reductions in allowable emissions levels. The 1977 Clean Air Act Amendments delayed the original standards still further. The original HC requirement of 0.41 g/mi was delayed until 1980 and the CO requirement of 3.4 g/mi was delayed until 1981, as was the NO_x requirement which was also loosened to 1.0 g/mi. Again, these standards represented significant reductions from previous levels, reducing targets by 50 percent or more. However, waivers of the CO standard were available for individual models for the 1981 and 1982 model years of up to 7.0 g/mi. EPA granted these waivers to roughly one-third of all 1981 and 1982 gasoline automobiles. [1] Waivers of the NO_x requirement were also available to small domestic manufacturers such as American Motors for these model years of up to 2.0 g/mi. Besides these waivers, though, the emissions standards applied uniformly to all new vehicles and each vehicle sold that violated the standard would be punishable by a fine of up to $10,000. [5] Despite attempts to revise the Clean Air Act to roll back emission standards for model year 1983 vehicles and beyond, regulations remained virtually unchanged until the 1990 Clean Air Act Amendments.

[1] Note that AB 1493 does not intend for the Air Resources Board to establish standards that would exceed the capabilities of existing technologies unlike the standards discussed in these case studies.

Table 1.1 California and Federal Exhaust Emission Standards for Passenger Cars (g/mi)

	Federal			California		
Model Year	HC	CO	NOx	HC	CO	NOx
uncontrolled	8.7	90	3.4	8.7	90	3.4
1966				4.3	44	
1967				4.3	44	
1968	4.1	34		4.3	44	
1969	4.1	34		4.3	44	
1970	4.1	34		2.2	23	
1971	4.1	34		2.2	23	
1972	3.0	28		1.5	23	3.0
1973	3.0	28	3.1	1.5	23	3.0
1974	3.0	28	3.1	1.5	23	2.0
1975	1.5	15	3.1	0.9	9	2.0
1976	1.5	15	3.1	0.9	9	2.0
1977	1.5	15	2.0	0.41	9	1.5
1978	1.5	15	2.0	0.41	9	1.5
1979	1.5	15	2.0	0.41	9	1.5
1980	0.41	7.0	2.0	0.41	9	1.0
1981	0.41	3.4	1.0	0.41	7	1.0
1982	0.41	3.4	1.0	0.41	7	0.4
1983	0.41	3.4	1.0	0.41	7	0.4
1984	0.41	3.4	1.0	0.41	7	0.4
1985	0.41	3.4	1.0	0.41	7	0.4
1986	0.41	3.4	1.0	0.41	7	0.4
1987	0.41	3.4	1.0	0.41	7	0.4
1988	0.41	3.4	1.0	0.41	7	0.4
1989	0.41	3.4	1.0	0.41	7	0.4
1990	0.41	3.4	1.0	0.41	7	0.4
1991	0.41	3.4	1.0	0.41	7	0.4
1992	0.41	3.4	1.0	0.41	7	0.4
1993	0.41	3.4	1.0	0.41	7	0.4
1994	0.41	3.4	0.4	0.25[†]	1.7-3.4[‡]	0.2-0.4[‡]
1995	0.41	3.4	0.4	0.231[†]	1.7-3.4	0.2-0.4
1996	0.41	3.4	0.4	0.225[†]	1.7-3.4	0.2-0.4
1997	0.41	3.4	0.4	0.202[†]	1.7-3.4	0.2-0.4
1998	0.41	3.4	0.4	0.157[†]	1.7-3.4	0.2-0.4
1999	0.41	3.4	0.4	0.113[†]	1.7-3.4	0.2-0.4
2000	0.41	3.4	0.4	0.073[†]	1.7-3.4	0.2-0.4
2001	0.075[†]	1.7-3.4[‡]	0.2-0.4[‡]	0.07[†]	1.7-3.4	0.2-0.4
2002	0.075[†]	1.7-3.4	0.2-0.4	0.068[†]	1.7-3.4	0.2-0.4
2003	0.075[†]	1.7-3.4	0.2-0.4	0.062[†]	1.7-3.4	0.2-0.4

[†] Fleet average of Non-methane Organic Gases (not Total Hydrocarbons)
[‡] Emission standard varies depending on certification levels TLEV, LEV, or ULEV
SOURCES: U.S. Environmental Protection Agency, California Air Resources Board, California Code of Regulations

2. INDUSTRY RESPONSE TO EMISSIONS REGULATIONS

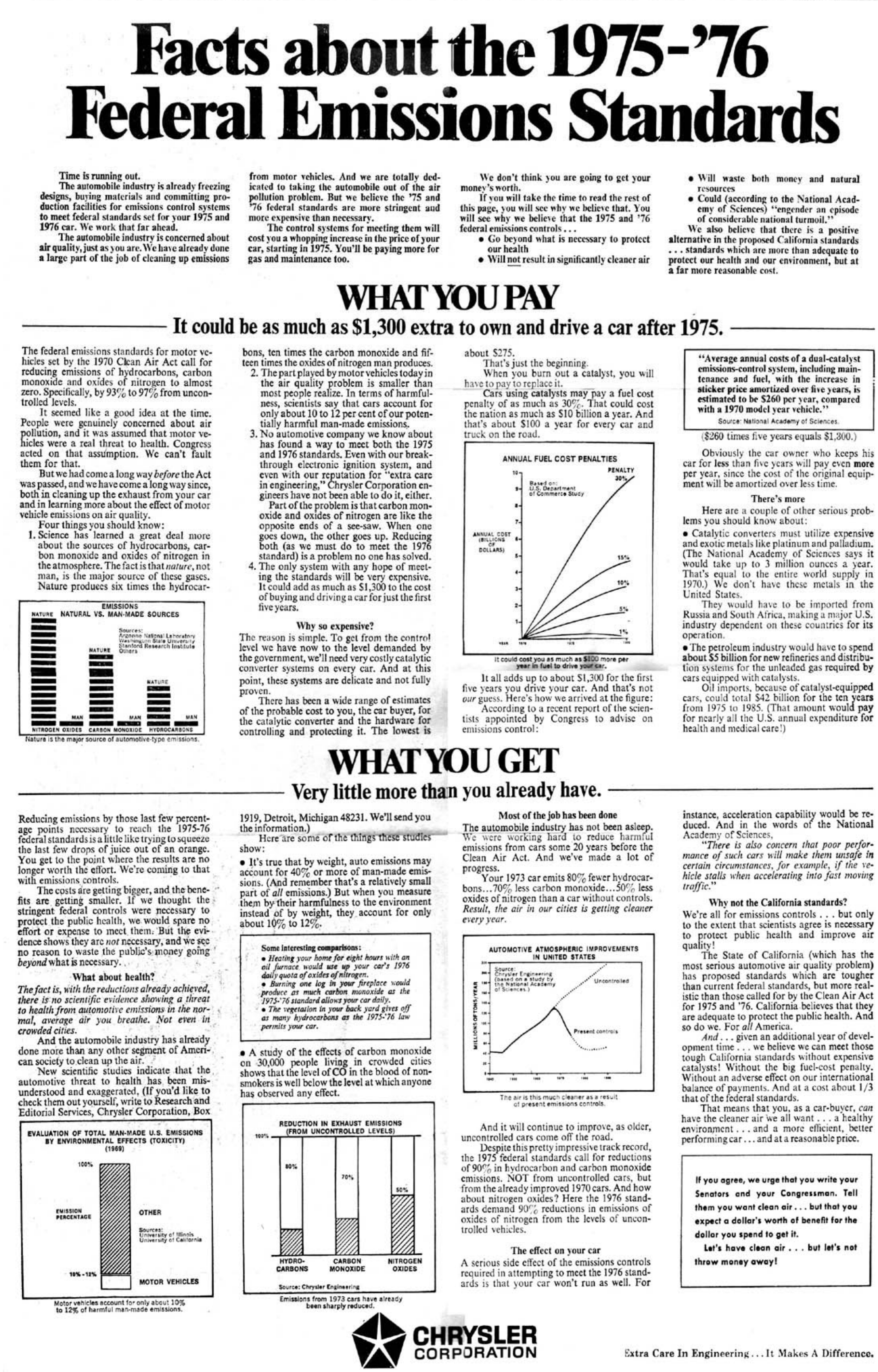
The auto industry's response to emissions regulations can be divided into its actions prior to the standards taking effect and its subsequent compliance actions. Publicly, manufacturers wanted to assure that their opposition to more stringent standards would not damage their public image with consumers. Once the proposed standards became required, each automaker needed to comply with the regulation while still catering to consumer preferences.

Public response to proposed regulations

Not surprisingly, automakers were largely resistant to proposed regulations to increase the stringency of exhaust emissions levels. Ernest Starkman, General Motors' vice president of environmental affairs, testified during a Senate hearing in 1972, "The very stringent levels prescribed [by the proposed 1975 standards]…do not appear to be warranted, either to protect health, prevent plant damage, or to provide aesthetic quality of the air in even the most severely stressed communities of this nation." [7] In general, though, the standards were challenged more on the basis of unreasonable compliance costs (including reduced fuel economy and drivability as well as reduced consumer choice) as opposed to being technologically infeasible or inessential. [8] Of the Big Three companies, Chrysler was the most outspoken against pollution standards due to its smaller size and limited investment capabilities. Figure 2.1 clearly outlines Chrysler's position that such regulation would be costly with little additional direct benefit to consumers. Mobil oil company ran advertisements the same year touting a similar message (Figure 2.2). Though less forthright in its protest, GM was equally concerned that the increased manufacturing costs would do little to increase vehicle quality or a consumer's desire to purchase a vehicle.

An additional issue of contention was the increasing regulation of the industry *per se*. Eugene Cafiero, President of Chrysler stated, "An industry that had very few government restrictions a dozen years ago, now finds almost every action and decision subject to the control of some government agency." [9] The need to constantly redirect research and engineering efforts towards compliance was believed to stifle innovation within the industry. [10]

GM also argued that the abrupt, revolutionary changes required by regulation might disrupt the balance between vehicle supply and demand, and would incur high additional costs. The disruption was relatively greater during the case study period than it would be now because the usual product planning cycle in the industry at that time ranged between five and seven years, depending on the extent of new technology incorporated into the vehicle. [10] (It is now about 2-3 years.) Ford reported at the time that its typical seven-year product cycle required between 44 and 60 months to make significant design changes. [9] Given the regulatory uncertainty, companies faced the prospect of making late changes in factories and vehicle designs, thereby incurring high additional costs. In addition, smaller companies such as Chrysler also felt that the uniform standard unfairly burdened companies with more limited resources and reduced their competitiveness.



THE NEW YORK TIMES, TUESDAY, MARCH 13, 1973 C

Facts about the 1975-'76 Federal Emissions Standards

Time is running out.

The automobile industry is already freezing designs, buying materials and committing production facilities for emissions control systems to meet federal standards set for your 1975 and 1976 car. We work that far ahead.

The automobile industry is concerned about air quality, just as you are. We have already done a large part of the job of cleaning up emissions from motor vehicles. And we are totally dedicated to taking the automobile out of the air pollution problem. But we believe the '75 and '76 federal standards are more stringent and more expensive than necessary.

The control systems for meeting them will cost you a whopping increase in the price of your car, starting in 1975. You'll be paying more for gas and maintenance too.

We don't think you are going to get your money's worth.

If you will take the time to read the rest of this page, you will see why we believe that. You will see why we believe that the 1975 and '76 federal emissions controls . . .

- **Go beyond what is necessary to protect our health**
- **Will not result in significantly cleaner air**
- **Will waste both money and natural resources**
- **Could (according to the National Academy of Sciences) "engender an episode of considerable national turmoil."**

We also believe that there is a positive alternative in the proposed California standards . . . standards which are more than adequate to protect our health and our environment, but at a far more reasonable cost.

WHAT YOU PAY

It could be as much as $1,300 extra to own and drive a car after 1975.

The federal emissions standards for motor vehicles set by the 1970 Clean Air Act call for reducing emissions of hydrocarbons, carbon monoxide and oxides of nitrogen to almost zero. Specifically, by 93% to 97% from uncontrolled levels.

It seemed like a good idea at the time. People were genuinely concerned about air pollution, and it was assumed that motor vehicles were a real threat to health. Congress acted on that assumption. We can't fault them for that.

But we had come a long way *before* the Act was passed, and we have come a long way since, both in cleaning up the exhaust from your car and in learning more about the effect of motor vehicle emissions on air quality.

Four things you should know:

1. Science has learned a great deal more about the sources of hydrocarbons, carbon monoxide and oxides of nitrogen in the atmosphere. The fact is that *nature*, not man, is the major source of these gases. Nature produces six times the hydrocarbons, ten times the carbon monoxide and fifteen times the oxides of nitrogen man produces.
2. The part played by motor vehicles today in the air quality problem is smaller than most people realize. In terms of harmfulness, scientists say that cars account for only about 10 to 12 per cent of our potentially harmful man-made emissions.
3. No automotive company we know about has found a way to meet both the 1975 and 1976 standards. Even with our breakthrough electronic ignition system, and even with our reputation for "extra care in engineering," Chrysler Corporation engineers have not been able to do it, either.

   Part of the problem is that carbon monoxide and oxides of nitrogen are like the opposite ends of a see-saw. When one goes down, the other goes up. Reducing both (as we must do to meet the 1976 standard) is a problem no one has solved.
4. The only system with any hope of meeting the standards will be very expensive. It could add as much as $1,300 to the cost of buying and driving a car for just the first five years.

EMISSIONS NATURAL VS. MAN-MADE SOURCES

Sources: Argonne National Laboratory, Washington State University, Stanford Research Institute, Others

NATURE / MAN — NITROGEN OXIDES, CARBON MONOXIDE, HYDROCARBONS

Nature is the major source of automotive-type emissions.

Why so expensive?

The reason is simple. To get from the control level we have now to the level demanded by the government, we'll need very costly catalytic converter systems on every car. And at this point, these systems are delicate and not fully proven.

There has been a wide range of estimates of the probable cost to you, the car buyer, for the catalytic converter and the hardware for controlling and protecting it. The lowest is about $275.

That's just the beginning.

When you burn out a catalyst, you will have to pay to replace it.

Cars using catalysts may pay a fuel cost penalty of as much as 30%. That could cost the nation as much as $10 billion a year. And that's about $100 a year for every car and truck on the road.

ANNUAL FUEL COST PENALTIES

Based on: U.S. Department of Commerce Study

ANNUAL COST (BILLIONS OF DOLLARS) — PENALTY 30%, 15%, 10%, 5%, 1%

It could cost you as much as $100 more per year in fuel to drive your car.

It all adds up to about $1,300 for the first five years you drive your car. And that's not *our* guess. Here's how we arrived at the figure:

According to a recent report of the scientists appointed by Congress to advise on emissions control:

> **"Average annual costs of a dual-catalyst emissions-control system, including maintenance and fuel, with the increase in sticker price amortized over five years, is estimated to be $260 per year, compared with a 1970 model year vehicle."**
>
> Source: National Academy of Sciences.

($260 times five years equals $1,300.)

Obviously the car owner who keeps his car for **less** than five years will pay even **more** per year, since the cost of the original equipment will be amortized over less time.

There's more

Here are a couple of other serious problems you should know about:

- Catalytic converters must utilize expensive and exotic metals like platinum and palladium. (The National Academy of Sciences says it would take up to 3 million ounces a year. That's equal to the entire world supply in 1970.) We don't have these metals in the United States.

  They would have to be imported from Russia and South Africa, making a major U.S. industry dependent on these countries for its operation.
- The petroleum industry would have to spend about $5 billion for new refineries and distribution systems for the unleaded gas required by cars equipped with catalysts.

  Oil imports, because of catalyst-equipped cars, could total $42 billion for the ten years from 1975 to 1985. (That amount would pay for nearly all the U.S. annual expenditure for health and medical care!)

WHAT YOU GET

Very little more than you already have.

Reducing emissions by those last few percentage points necessary to reach the 1975-76 federal standards is a little like trying to squeeze the last few drops of juice out of an orange. You get to the point where the results are no longer worth the effort. We're coming to that with emissions controls.

The costs are getting bigger, and the benefits are getting smaller. If we thought the stringent federal controls were necessary to protect the public health, we would spare no effort or expense to meet them. But the evidence shows they are *not* necessary, and we see no reason to waste the public's money going *beyond* what is necessary.

What about health?

The fact is, with the reductions already achieved, there is no scientific evidence showing a threat to health from automotive emissions in the normal, average air you breathe. Not even in crowded cities.

And the automobile industry has already done more than any other segment of American society to clean up the air.

New scientific studies indicate that the automotive threat to health has been misunderstood and exaggerated, (If you'd like to check them out yourself, write to Research and Editorial Services, Chrysler Corporation, Box 1919, Detroit, Michigan 48231. We'll send you the information.)

EVALUATION OF TOTAL MAN-MADE U.S. EMISSIONS BY ENVIRONMENTAL EFFECTS (TOXICITY) (1969)

EMISSION PERCENTAGE — 100% — OTHER — 10%-12% — MOTOR VEHICLES

Sources: University of Illinois, University of California

Motor vehicles account for only about 10% to 12% of harmful man-made emissions.

Here are some of the things these studies show:

- It's true that by weight, auto emissions may account for 40% or more of man-made emissions. (And remember that's a relatively small part of *all* emissions.) But when you measure them by their harmfulness to the environment instead of by weight, they account for only about 10% to 12%.

> **Some interesting comparisons:**
> - *Heating your home for eight hours with an oil furnace would use up your car's 1976 daily quota of oxides of nitrogen.*
> - *Burning one log in your fireplace would produce as much carbon monoxide as the 1975-'76 standard allows your car daily.*
> - *The vegetation in your back yard gives off as many hydrocarbons as the 1975-'76 law permits your car.*

- A study of the effects of carbon monoxide on 30,000 people living in crowded cities shows that the level of CO in the blood of non-smokers is well below the level at which anyone has observed any effect.

REDUCTION IN EXHAUST EMISSIONS (FROM UNCONTROLLED LEVELS)

100% — HYDROCARBONS 80% — CARBON MONOXIDE 70% — NITROGEN OXIDES 50%

Source: Chrysler Engineering

Emissions from 1973 cars have already been sharply reduced.

Most of the job has been done

The automobile industry has not been asleep. We were working hard to reduce harmful emissions from cars some 20 years before the Clean Air Act. And we've made a lot of progress.

Your 1973 car emits 80% fewer hydrocarbons...70% less carbon monoxide...50% less oxides of nitrogen than a car without controls. *Result, the air in our cities is getting cleaner every year.*

AUTOMOTIVE ATMOSPHERIC IMPROVEMENTS IN UNITED STATES

Source: Chrysler Engineering (based on a study by the National Academy of Sciences.)

MILLIONS OF TONS/YEAR — Uncontrolled — Present controls

The air is this much cleaner as a result of present emissions controls.

And it will continue to improve, as older, uncontrolled cars come off the road.

Despite this pretty impressive track record, the 1975 federal standards call for reductions of 90% in hydrocarbon and carbon monoxide emissions. NOT from uncontrolled cars, but from the already improved 1970 cars. And how about nitrogen oxides? Here the 1976 standards demand 90% reductions in emissions of oxides of nitrogen from the levels of uncontrolled vehicles.

The effect on your car

A serious side effect of the emissions controls required in attempting to meet the 1976 standards is that your car won't run as well. For instance, acceleration capability would be reduced. And in the words of the National Academy of Sciences,

"There is also concern that poor performance of such cars will make them unsafe in certain circumstances, for example, if the vehicle stalls when accelerating into fast moving traffic."

Why not the California standards?

We're all for emissions controls . . . but only to the extent that scientists agree is necessary to protect public health and improve air quality!

The State of California (which has the most serious automotive air quality problem) has proposed standards which are tougher than current federal standards, but more realistic than those called for by the Clean Air Act for 1975 and '76. California believes that they are adequate to protect the public health. And so do we. For *all* America.

And . . . given an additional year of development time . . . we believe we can meet those tough California standards without expensive catalysts! Without the big fuel-cost penalty. Without an adverse effect on our international balance of payments. And at a cost about 1/3 that of the federal standards.

That means that you, as a car-buyer, *can* have the cleaner air we all want . . . a healthy environment . . . and a more efficient, better performing car . . . and at a reasonable price.

> **If you agree, we urge that you write your Senators and your Congressman. Tell them you want clean air . . . but that you expect a dollar's worth of benefit for the dollar you spend to get it.**
>
> **Let's have clean air . . . but let's not throw money away!**

CHRYSLER CORPORATION

Extra Care In Engineering . . . It Makes A Difference.

Figure 2.1. Full page advertisement published in the New York Times by Chrysler Corporation (1973)

©1973 Mobil Oil Corporation

The $66 billion mistake

In 1970, Congress passed a series of amendments to the Clean Air Act. One of them said that all cars sold in the U.S. after 1974 must be near-zero polluters.

It sounded fine. Near-perfect emission control seemed not only desirable, but imperative. At that time, people widely assumed that the air was getting steadily dirtier because of the automobile. Most people also assumed that industry could solve any technical problems that might be encountered—and at a reasonable cost.

The goal has proved elusive. Despite the expenditure of hundreds of millions of dollars, and uncounted hours of research and development time, no control system that meets all the requirements of the federal standards has yet been proved.

Bad news? Not necessarily. Today both industry and government have the benefit of research results and other information that were simply not available when Congress passed its amendment in 1970.

Today we know that:

• Total air pollution from cars has already been rolled back to the level of about 1960, and is continuing to drop.

• Cars that met the federal standards would probably be poor performers and gasoline-guzzlers. They also could need costlier maintenance than today's cars.

• A less restrictive level of controls on automotive emissions would do very nearly as much for air quality as the federal standards would.

• Meeting the federal standards could cost $100 billion over the ten years starting in 1976; meeting the less restrictive standards could cost $34 billion. The difference could be a $66 billion mistake.

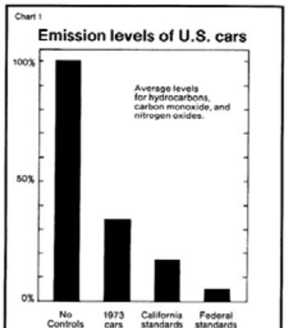
If not perfection, what?

The only way to completely eliminate auto pollution would be to do away with the auto itself. Since this would be neither practical nor desirable, what percentage reduction of emissions should we aim at? By what date? And at what cost?

The goal should be to make the auto as small a contributor to air pollution as technology allows—but without incurring exorbitant costs for dubious results. Since technology does not stand still, this would be a moving goal. Today's impractical dream often can be tomorrow's reality.

Today's reality in automotive pollution control is, in fact, yesterday's dream: As Chart 1 indicates, emissions of hydrocarbons, carbon monoxide, and nitrogen oxides have been drastically reduced from the days (not long ago) when exhaust emissions were uncontrolled. Changes in engine design plus pollution-control devices have reduced emissions by 1973-model cars an average of 66%.

Chart 1



This is quite an achievement. And as a result, total air pollution from automobiles has been declining in the United States since 1968, and is now down to the levels of about 1960. It would continue to decline for several more years even if no further controls were imposed, as old cars with few if any controls are scrapped.

So. How much further should we go? And by when?

California has a better way

The Air Resources Board of the State of California (and who has more auto-related air-pollution problems, or has had more experience dealing with them?) has proposed automotive emission-control levels based on air-quality standards calculated to restore the atmosphere of Los Angeles to its quality of the early 1940s. California proposes to cut the three principal auto emissions by an average of 83%.

Mobil has been engaged in intensive auto-emission research for several years. We were the co-founder (with Ford Motor Company) of the Inter-Industry Emission Control program, or IIEC, which is probably the largest private cooperative research program of its kind in the world. So Mobil knows something about the problem, too. We believe the California standards can be achieved with in-sight technology, at a reasonable cost.

The California standards are similar to those proposed by the federal government's own Department of Health, Education and Welfare in 1970.

The HEW standards were not accepted. Instead, Congress voted for the last bar on Chart 1. The Clean Air Act now mandates that the three emissions be reduced by 97%, 96%, and 93%—for an average of 95%.

These levels must be reached by 1975 for hydrocarbons and carbon monoxide, and by 1976 for oxides of nitrogen, unless the federal government grants an extension.

AUTO EMISSION REDUCTIONS BELOW PRE-CONTROL LEVELS

	Hydro-Carbons	Carbon Monoxide	Oxides of Nitrogen
1973 Cars	80%	69%	50%
California	94	81	75
Federal	97	96	93

A 95% reduction in emissions may not seem much more difficult to achieve than an 83% reduction. But did you ever try to wring the last drop of water out of a wet towel? One good twist and most of the water flows out. Another hard twist and a little more dribbles out. But now the law of diminishing returns sets in. It's just plain impossible to wring the towel dry, and not worth the effort.

Similarly, the last few percentage points of automotive emission control are far costlier and far more difficult to achieve than the first 80 to 85 points.

Almost every day, we read in the newspapers about some sensational new device that will cut auto pollution virtually to zero. Mobil technical people have investigated many of these devices. A few offer exciting possibilities, given time for development. But none has yet demonstrated it will be ready to meet federal requirements in the short time remaining.

Sneak preview: your '76-model car

Mobil's analysis of current technology indicates that if federal-level cars could be built, their emission-control systems would be so complicated and demanding that the cars could:

• Cost several hundred dollars more than present cars.

• Consume considerably more gasoline than today's cars.

• Need frequent and costly tune-ups and maintenance to keep their emission-control systems operating.

• Present difficult driveability problems, with a tendency to stutter, stammer, and stall—which could become a safety hazard.

On the other hand, cars built to the California standards will cost less to buy and to operate, and will perform better, than cars built to the federal standards.

Mobil sells gasoline, but we have no desire to see our products wasted. Cars built to the federal standards could consume as much as 15% more gasoline per mile than cars built to the California standards. That 15% would require refining an extra 30 million barrels of crude oil in 1976, and an extra 150 million barrels a year by 1980. All that crude oil would have to be imported, with a substantial—and unnecessary—drain on our country's balance of payments.

Catalysts would be necessary to meet the federal standards. From 1975 through 1980 the auto industry apparently will have to import some 10,000,000 ounces of platinum and some other noble metals for catalysts—for a cumulative balance-of-payments drain of at least $1,300,000,000, based on present prices.

The motorist also would need to replace the catalyst as it deteriorated—perhaps every 20,000 or 25,000 miles.

About the safety aspect, Dr. Arie J. Haagen-Smit, chairman of the California Air Resources Board, offers this chilling caution: "The driveability problems such cars will present may become clear to a motorist only at the worst possible time—when he comes up the ramp to swing into 70-mile-an-hour freeway traffic. A stumble then may be the last mistake he'll ever make."

The gap between the emission reductions that could be achieved by the California and the federal standards would be very small, for several years at least.

It could turn out to be very small indeed, because the complicated systems needed to meet the federal standards could break down more easily—and if they did, the car's emission-control system could become completely ineffective.

Up the Matterhorn

Which brings us to Chart 2. The one with a curve that looks like the southeastern slope of the Matterhorn.

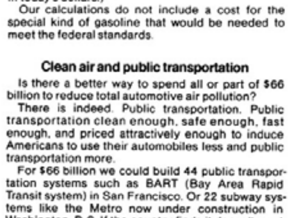
Control equipment to meet the 1973 standards adds about $65 to $100 to the cost of a new car. Not excessive, considering how far the cars have come in reducing harmful emissions.

The price curve turns up to meet the California standards—to a range of $175 to $300 per car for the control equipment. Perhaps still not too expensive, considering the extra gains in pollution reduction.

But to reach the federal standards that are now the law for 1975 and 1976 models, the cost curve heads almost straight up. These systems could cost $500 to $600 a car—and maybe more. We can't determine the exact cost, since systems to meet the 1976 standards have not been proved.

These are just the initial costs of the emission-control systems. Add the extra maintenance, and throw in the additional gasoline, and the grand total for meeting the federal standards comes to $100 billion over the decade starting in 1976.

Chart 2



Add the same expenses for the California standards, and the grand total is $34 billion. (All these figures are Mobil engineers' estimates, expressed in today's dollars.)

Our calculations do not include a cost for the special kind of gasoline that would be needed to meet the federal standards.

Clean air and public transportation

Is there a better way to spend all or part of $66 billion to reduce total automotive air pollution?

There is indeed. Public transportation. Public transportation clean enough, safe enough, fast enough, and priced attractively enough to induce Americans to use their automobiles less and public transportation more.

For $66 billion we could build 44 public transportation systems such as BART (Bay Area Rapid Transit system) in San Francisco. Or 22 subway systems like the Metro now under construction in Washington, D.C. If the country finds it doesn't want or need that many subways or BART-type systems, there are other forms of public transportation to keep in mind. Express bus lanes on freeways are one of the most efficient of all ways to move people. Also, as everyone knows, America's commuter and longer-haul railroads urgently need modernizing.

As we said in October, 1970, "Providing for our future transportation needs will require very large expenditures. We believe there's an urgent need for legislators to re-examine the procedures used to generate and expend transportation revenues."

To achieve this, we said in January, 1972, "Congress should enact a National Master Transportation Program."

What would $66,000,000,000 buy?

The program Mobil outlines in this report could save the American consumer $66 billion over ten years. That's far too much money for most of us to comprehend. But here are a few things $66 billion could do:

• Build the water-treatment plants needed for all the country's household, municipal, and industrial sewage and waste water—and maintain those facilities for more than five years.

• Nearly pay the annual U.S. expenditures for all health and medical care ($67 billion in 1970).

• More than finance all new private and public housing construction in this country for two years (1970 total: $30 billion).

• Almost pay the total cost of all types of education in the U.S., at all levels, for a year (1970 total: $69 billion).

• Buy various combinations of subways, BART systems, commuter trains, longer-haul railroads, and express lanes for buses on freeways.

More and better public transportation can go a long way toward several desirable objectives: Less air pollution. Less waste of gasoline. Less pressure on the U.S. balance of payments as our imports of oil inevitably rise. And maybe less emotional strain on motorists and fewer accidents.

The critical fourth dimension

Companies in various industries are developing emission-control systems and testing them for durability and economy. Some of these systems offer exciting possibilities for reducing emissions to very low levels at a reasonable cost. But the most critical element is time—time to test various devices and systems for thousands of miles and to engineer the systems for mass production.

The dilemma as we see it is that the federal government has legislated results by a specified date without knowing how or at what cost they could be achieved, if at all. Here is a program we believe will get the country off the horns of this dilemma:

1 The Environmental Protection Agency should grant a one-year extension of the present federal standards, as provided in the Clean Air Act.

2 Congress should re-examine that act. We hope a thorough analysis will convince the members to amend the act to mandate emission levels closer to those California proposed.

3 The federal government should continue to monitor air quality levels, and to sponsor research into the impact of emissions from all sources on health and well-being. If car-population trends or other data should indicate a future need for further reductions in auto emissions, new standards should be set.

4 The automotive, petroleum, and related industries should be required to continue at a high level their research and development programs on emission-control systems to reduce costs and increase efficiency.

5 The Congress should proceed forthwith to enact a National Master Transportation Program to enable people (and goods) to move fast, safely, comfortably, and at reasonable cost on a first-class system of public transportation adequately supported by Congressional appropriations.

Under such a program, motorists could drive better-performing, less expensive, and safer cars. A substantial drain on the U.S. balance of payments, for crude oil and platinum, would be avoided. A vital and scarce natural resource—petroleum—would be conserved. And the advance of technology would enable auto makers to meet even stricter control standards—if they were found necessary at some future date—with durable, trouble-free, and reasonably economic systems.

Not to mention avoiding a $66 billion mistake.

Mobil®

This advertisement appeared in The Chicago *Tribune*, The Los Angeles *Times*, The New York *Times*, *The Wall Street Journal*, and The Washington *Post*.

Figure 2.2. Full page advertisement published in multiple national newspapers by Mobil Corporation (1973)

What new or altered technologies were offered by manufacturers?

Automakers had a number of options to comply with new air quality standards. Arguably, one strategy for meeting emissions targets was to reduce vehicle weight, which would inherently reduce the amount of emissions control necessary, especially NO_x. According to White (1982), though, "very little downsizing occurred because of the

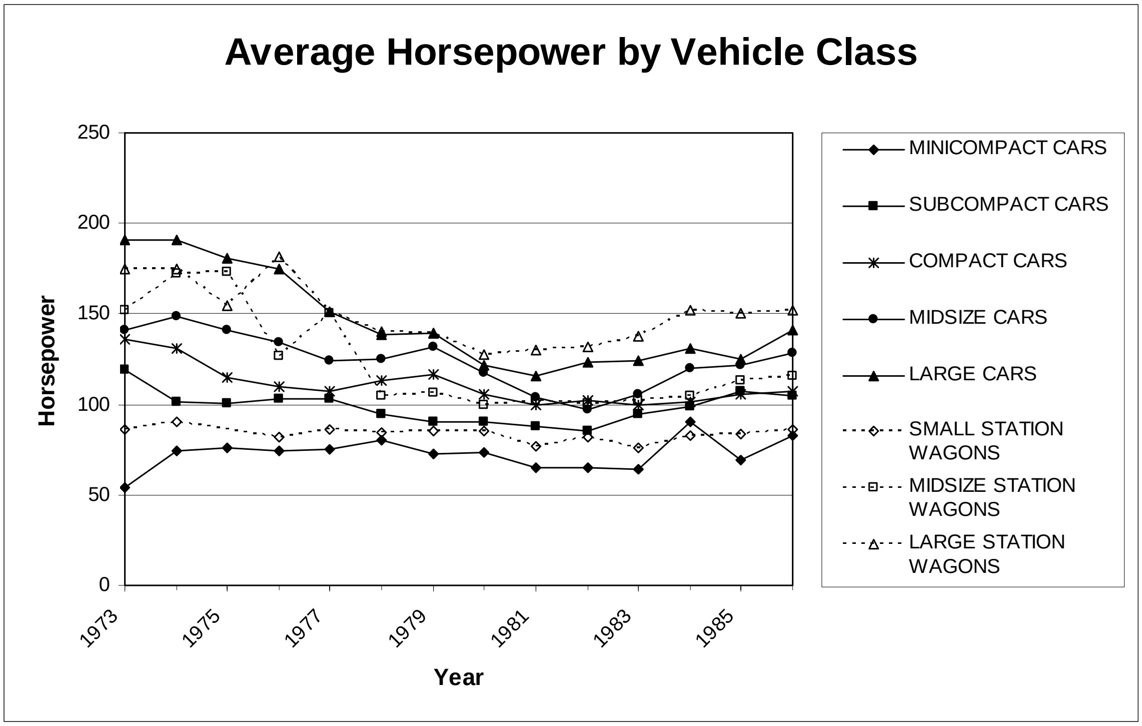


Figure 2.3 Average Horsepower by Vehicle Class

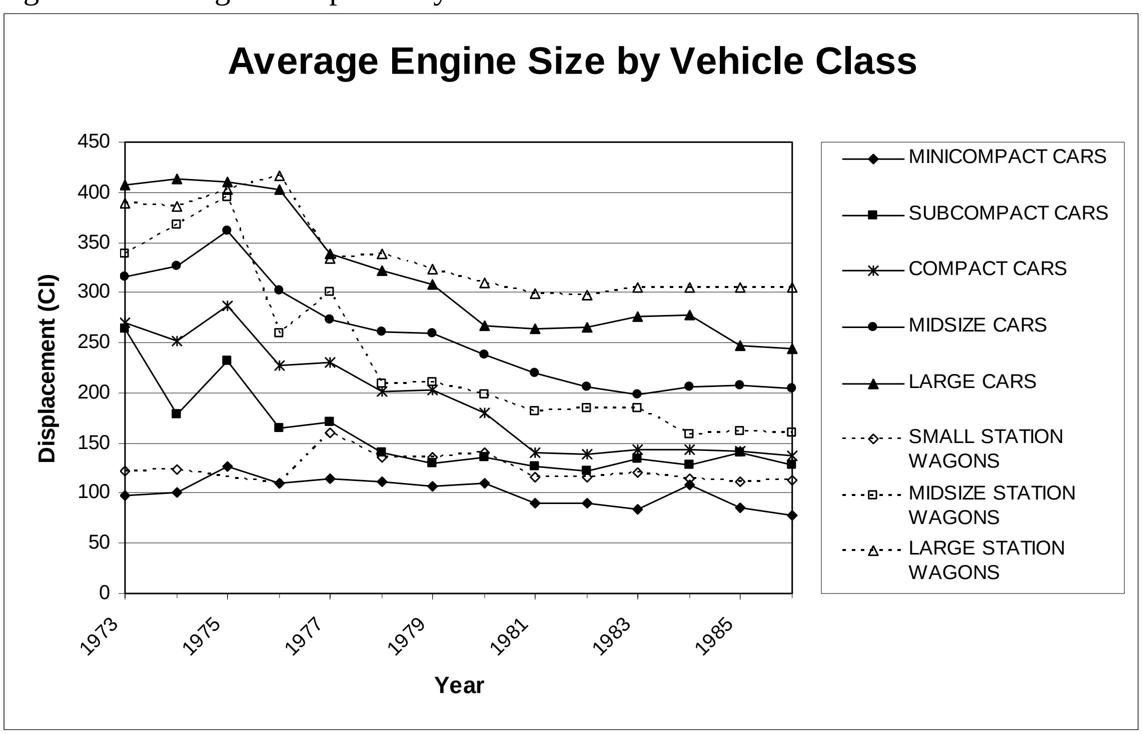


Figure 2.4 Average Engine Size by Vehicle Class

regulations; the American manufacturers appeared to be quite determined to meet he requirements through changes in technology rather than changes in size." [5]

Analysis of the CARBITS vehicle attribute database also reveals minimal impacts on performance indicators such as horsepower and engine displacement. (See Appendix A for description of CARBITS database.) As shown in Figure 2.3 horsepower dropped more substantially for larger vehicles during early regulation; for smaller vehicles horsepower remained fairly stable, perhaps aided by larger engines as seen in Figure 2.4. Over the second period of more stringent emissions requirements, engine size dropped uniformly while horsepower remained fairly stable, suggesting that engines became more efficient per displacement volume.

While modifications to vehicles such as weight and size reductions were potential strategies to help meet new emissions requirements, technological changes were also necessary. Technologies considered for meeting the 1975 standards included: the modified conventional gasoline engine with an oxidation catalyst, the carbureted stratified-charge engine, the Wankel engine with an exhaust thermal reactor, and the diesel engine. [11] Despite some concerns about platinum supplies, the catalytic converter was viewed as the most promising technology as it required no major changes in powertrain technologies and the other strategies appeared riskier since they all increased NOx emissions, and more stringent NO_x standard were forthcoming. The decision to install catalytic converters was also partly influenced by consumer preferences for high fuel economy following the oil embargo; vehicles could meet emission requirements with after-treatment devices other than catalysts but only at the expense of poor fuel economy. [12] Thus, by the 1975 model year, only 15% of vehicles were not equipped with catalysts. [6] By model year 1977, this figure dropped to only 10% of vehicles. [13] The remaining vehicles complied by using rotary or stratified-charge engines. These vehicles were typically produced by small foreign manufacturers (Mazda, the rotary engine, and Honda the stratified charge).

Table 2.1 Compliance Technologies for 1975-1981

Manufacturer	**Compliance Technologies**
AMC	Oxidation catalyst, three-way catalyst
Chrysler	Electronic lean-burn system, oxidation catalyst, three-way catalyst
Ford	Oxidation catalyst, three-way catalyst
GM	Oxidation catalyst, three-way catalyst
Toyota	i.) three way catalyst (>2000 cc engines) ii.) lean air-fuel mixtures and oxidation catalyst (1500-1800 cc engine) iii.) oxidation catalyst (1300 cc engine)
Nissan	i.) three way catalyst (large models) ii.) fast-burn engine (NAPS-Z) (medium-range models) iii.) improved oxidation catalyst (<1500 cc engine)
Honda	CVCC engine with thermal reactor
Volkswagen	Oxidation catalyst, three-way catalyst, diesel engine

Sources: [9, 10]

Additional technologies were considered to comply with the later more stringent NO_x requirement. These included: the modified conventional engine with dual catalysts and a thermal reactor, the modified conventional engine with a reduction catalyst and two thermal reactors, the modified conventional engine with a three-way catalyst and electronic fuel injection, and the stratified-charge engine with fuel injection and an oxidation catalyst. [11] Although reports were initially pessimistic about the feasibility and cost-effectiveness of these technologies, the three-way catalyst—which oxidizes HC and CO while also reducing NO_x—ultimately proved to be an effective and reliable technology. [14]

Although the larger manufacturers could afford to explore multiple alternatives, in the end most settled on similar compliance strategies. (See Table 2.1) Those companies that did diverge, though, were not terminally disadvantaged by their decision. Both Chrysler and Honda were skeptical about the effectiveness of catalytic converters. Chrysler initially believed them to be unreliable and a potential fire hazard from their excessive heat buildup. Thus in 1975 and 1976 Chrysler relied on controlling the air-fuel ratio using an electronic lean-burn system. Chrysler finally installed catalytic converters in 1977 when the electronic lean-burn system proved insufficient to meet stricter standards. Honda's concern regarding catalytic converters revolved around the uncertainty of the products from the chemical reactions, the durability of the device, and doubt about platinum availability and reclamation. In addition, both Toyota and Nissan scaled their strategies based on engine sizes. Larger vehicles required three-way catalysts since the increased vehicle weight complicated the use of lean-burn engines while smaller vehicles only required oxidation catalysts to comply with 1977 and 1978 standards. [10]

However, the installation of emissions control devices alone was not sufficient to comply with both sets of new standards. In addition to engine system modifications, strategies such as more precise carburetion and spark timing, higher compression ratios, and exhaust gas recirculation were also necessary. [15] Fuel injection also appeared in a large number of model year 1975 vehicles which had previously not been fuel-injected. In later years, as fuel injection technology improved, it was combined with computer controls and sensors to improve the performance and reduce the cost of emission control. [13] Future developments in air meters for injection systems also contributed to maintaining precise air-fuel ratios to control emissions. [2] Additionally, the installation of the three-way catalyst depended on the development of more sophisticated electronic control devices as well as elimination of lead in gasoline to prevent significant deterioration of the catalyst.

It is also important to note that emissions control devices produce feedbacks in the design of the vehicle. For example, the addition of control technologies increases the vehicle weight as well as requires auxiliary devices, such as air pumps. These additional parts may require other maintenance or repair costs. The reverse is also true. The introduction of unleaded gasoline increases the life of the exhaust system and spark plugs, thus reducing maintenance costs, while the use of computer controls allows better combustion control and higher energy efficiency. [15]

Did manufacturers change the volume and mix of vehicles types offered for sale?

Although in general the attributes of the vehicles themselves may have remained relatively stable, the mix of vehicle types shifted during the late 1970's. Figure 2.7

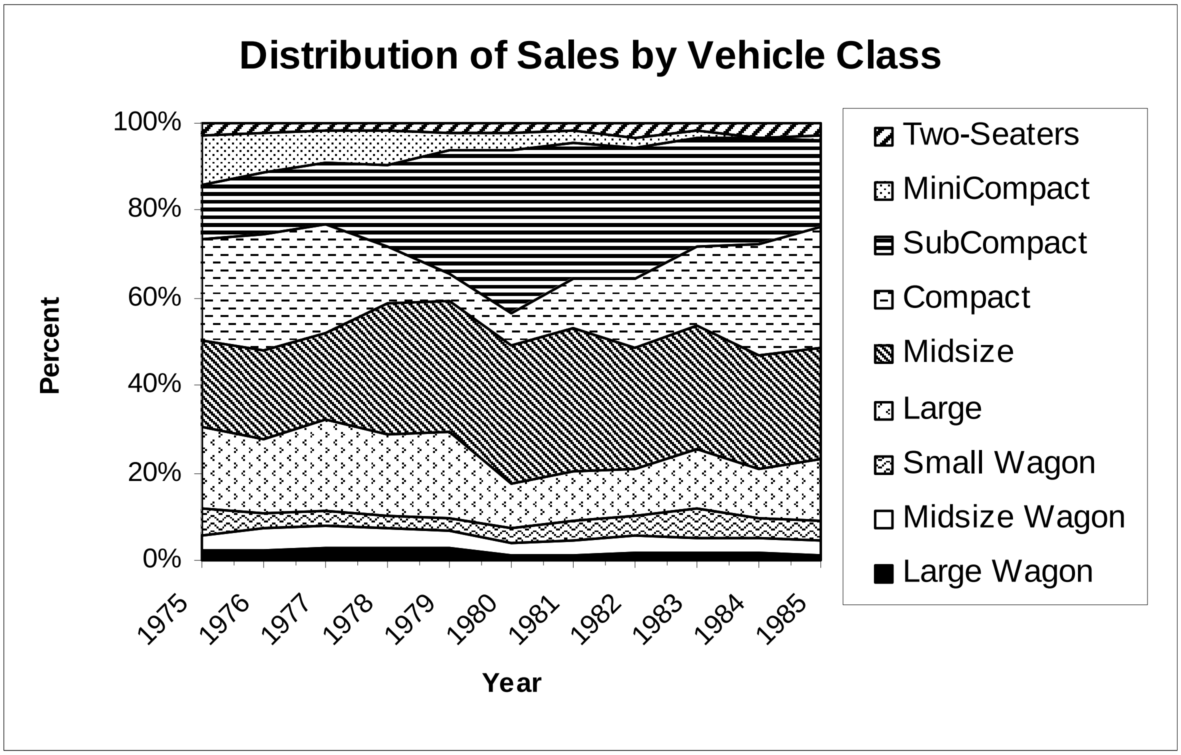


Figure 2.5 Distribution of Sales by Vehicle Class
SOURCE: Hellman, K.H. and R.M. Heavenrich, Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2004. 2004, Office of Transportation and Air Quality, U.S. Environmental Protection Agency. EPA420-R-04-001.

illustrates the number of vehicles sold within each vehicle class. There is significant yearly variation among classes. In 1980 subcompact sales increased dramatically while sales of large cars simultaneously plunged. Shortly after, compact sales grew and reduced the share of subcompact vehicles. These trends demonstrate the industry's ability to modify production volumes within rather short time frames. In only three years during the late 1970's, production of small cars rose from less than a million to approximately 4.5 million. [16]

However, it is difficult to distinguish how much of this shift can be attributed to the auto industry attempting to meet stricter regulations and how much was motivated by fuel economy. [17] In addition, the introduction of CAFE standards complicated manufacturers' decisions about fleet mix. Small cars, while helping to achieve CAFE requirements, were less profitable than larger cars. John Deaver, manager of Ford's economics department, affirmed that "product mix decisions are now determined by the number of large and medium-sized cars the company believes it can sell, and then by the number of small cars it needs to produce/sell in order to meet CAFE requirements." [as cited in 10]

3. COSTS ASSOCIATED WITH EMISSIONS REGULATIONS

New technologies almost always incur additional costs. Whether these additional costs are absorbed by the auto manufacturers or passed onto consumers is somewhat unclear. First, it is important to distinguish between cost and price. Price is what consumers pay. The actual cost is usually less, since a company needs to make a profit. Determining the costs of emissions control can be a fairly complex process as more than just material costs are involved.

A thorough calculation of costs incurred by manufacturers would include the costs of tooling new machinery to accommodate the new control devices, as well as the research and development expenditures invested to develop the devices and to reengineer vehicles to comply with more stringent regulations. Note in Figures 3.1a and b that the larger expenditures tend to occur prior to new regulations taking effect. Both Ford and GM exceeded their typical R&D expenditures of 3 percent of total corporate revenues in 1973 and 1974 to comply with new regulations. [9] However, R&D expenditures cannot be solely attributed to emissions controls. For example, rise in investment spending in 1977 and 1978 is largely due to the reengineering of smaller vehicles with front-wheel drive to meet new fuel economy standards. [18]

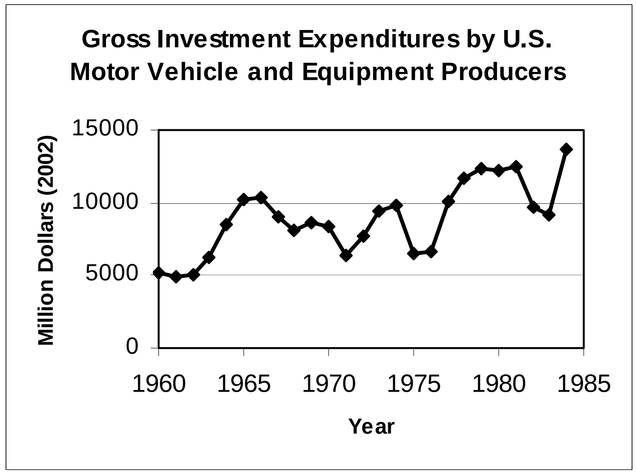


Figure 3.1a

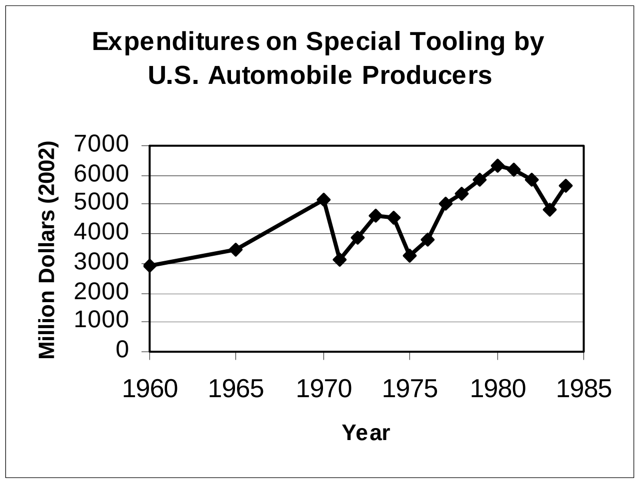


Figure 3.1b
SOURCE: [18]

In addition to the difficulties of accounting for all costs, further complexities arise as vehicles are designed as integrated systems and a single vehicle part may serve multiple functions. Thus, accurately apportioning the costs of emissions control systems to only actual emissions control can be difficult. For example, Bresnahan and Yao found that increases in capital costs resulting from regulation were partially offset by corresponding increases in quality related to developments in emissions technology. Technologies such as electronic controls and fuel injection significantly increase vehicle quality while simultaneously contributing to emissions reductions. [13]

Costs are also difficult to calculate as they vary depending on vehicle weight, engine design, and engine calibration. [6] Furthermore, costs will differ by manufacturer. For example, American Motor Company's (AMC) fleet was heavily dominated by smaller vehicles, thus reducing the need to make significant modifications to meet emission standards. In addition, as a smaller firm AMC tended to depend on outside suppliers for new technologies, allowing them to forego major research and development investments. With mandatory technology, though, AMC lost some of its negotiating powers and usually had to accept whatever price suppliers requested. In contrast, GM as the largest manufacturer enjoyed much more control in its product development.

Emissions control system cost estimates

A number of cost estimates were made prior to and during the regulatory process to assess the feasibility and cost-effectiveness of more stringent emissions standards. These estimates are difficult to compare, though, as they reflect different vehicle configurations and may also include costs besides just hardware (such as maintenance costs or fuel penalties). In addition, many estimates are presented as incremental costs from previous (or sometimes ambiguous) years, which make comparisons impossible unless the baseline years are identical. For example, Grad et al. estimated the cost of compliance with the 1975 interim standards using various engine configurations with and without catalysts ranging from $207 to $352 (2002 dollars), presenting the costs as the increase in sticker price over the 1974 model equivalent. [19] *Automotive News Annual 1978* calculated $435 (2002 dollars) as the price increase since 1968 for emissions control equipment in 1978 cars. [as cited in 10] One widely cited estimate of $860 (not specified if this is real or current dollars) reflects the cost to consumers for vehicles complying with the original 1976 standard over the 1970 vehicle cost at a durability of 85,000 miles. This estimate includes the cost of dual HC/CO, NO_x catalytic converters, a low-grade rich thermal reactor, and exhaust gas recirculation. [15] Other studies simply

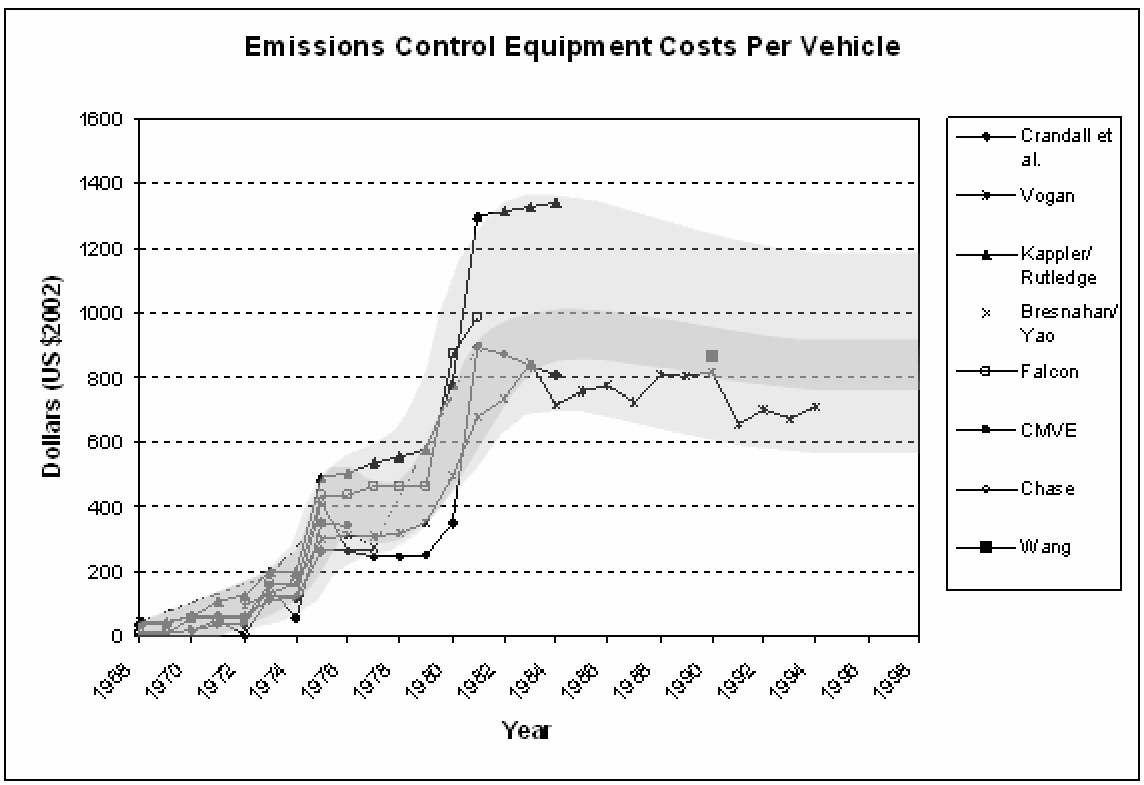


Figure 3.2 Emissions Control Equipment Costs per Vehicle

report costs per new vehicle for control hardware without reference to a base year. These types of isolated cost estimates are less informative than longitudinal analyses of compliance costs.

There are a few studies with estimates of equipment costs to consumers through time, though. (Figure 3.2) These assessments, while somewhat varied also show remarkable similarities, especially until 1981. The earliest two studies projected compliance costs before the regulations took effect. [20, 21] The remaining studies all performed their analyses retrospectively. [12, 13, 18, 22-24] All of these estimates peak in 1975 and then again in 1981. During this second peak, Kappler and Rutledge estimated that consumer spending on catalytic devices increased by 21 percent in 1980 (constant dollars) and then by 18 percent the next year, mostly attributable to the popularity of three-way catalysts. Meanwhile spending on noncatalytic equipment rose by 23 percent in 1980 and then by 51 percent the following year, largely due to the installation of expensive electronic controls. [12]

One potential drawback of these estimates is that they reflect the average for all vehicles and do not make any distinctions for the various vehicle models or producers. Wang et al. used a parts-pricing approach on model year 1990 vehicles to calculate emissions control costs. They found that compliance costs do indeed vary widely depending on vehicle size and manufacturer ($254-$1684 adjusted to 2002 dollars). [24] The higher costs were for luxury vehicles from Europe. The differences among size classes were not as extreme, with emission control costs averaging $504 for compact cars (2002 dollars) and $586 for large cars (2002 dollars), not weighted by sales.

Whether a similar distribution in costs across vehicle sizes exists for earlier model years, particularly when technologies were still maturing, is unclear. Overall, Wang et al. estimated the average cost to consumers for 1990 vehicles to be $862 (2002 dollars). However, this value includes an apportionment of all components for emissions control, even those that serve multiple functions, such as fuel injection and electronic controls (e.g., one-fourth of the cost of fuel injection was apportioned to emission control). Accounting for only equipment dedicated fully to emissions control, the cost was $627 per vehicle (2002 dollars).

One note of caution when analyzing compliance costs is that some estimates include both the hardware costs as well as the additional operating costs. Consumers may be expected to incur costs through increased fuel consumption, fuel prices (for unleaded gasoline) or maintenance and repair requirements. Thus, total costs associated with emissions regulation can significantly exceed the cost of equipment alone. In some cases, though, consumers may experience cost savings through secondary benefits that reduce maintenance needs or fuel consumption. For instance, the installation of the catalytic converter to comply with interim 1975 standards resulted in a net consumer savings of $65 [14] to $310 [13] depending on the source of the estimate.

Variations in estimates by source

Cost estimates of emissions controls prior to the regulation taking effect often vary depending on the source of the projection. Government agencies assigned the responsibility of evaluating the cost-effectiveness of a standard may feel pressured to project optimistic estimates while industry sources have an incentive to project pessimistic estimates in hopes of derailing the regulation. For example, EPA estimated that compliance with the 1981 emission standards would cost $388 (in 2002 dollars) more than the 1979 vehicle. In contrast, Ford projected a cost of $596 while GM estimated $529 (both 2002 dollars) [1] As another examples, cumulative costs through 1976 were estimated by EPA to be $837 (in 2002 dollars) while industry estimates ranged from $761 (-9 percent different from EPA's) to $1093 (+31 percent). [11] Even a committee of the National Academy of Sciences estimated cumulative costs for emissions controls through 1974 to be 39 percent higher than EPA projections. [11]

However, few studies have been conducted to assess the accuracy of projected emissions costs to actual costs, and even fewer of those have been specifically on vehicle exhaust emissions standards. [25] In part, these types of analyses are difficult to conduct not just because of the complicated nature of estimating costs as discussed in previous sections, but also because actual compliance costs are generally regarded as proprietary information by auto manufacturers and therefore not publicly available for comparison. One study does exist by Anderson and Sherwood (2002) that compares projected and actual costs of reformulated gasoline programs. According to their findings, industry projections of fuel price changes prior to the program taking effect substantially exceeded the actual price increase, in some cases two to four times higher. [25] The only other comparison was performed by EPA, specifically assessing vehicle emissions control costs. This study showed that EPA's estimates tended to range between plus or minus 20 percent of actual costs, while estimates from manufacturers ranged from minus 50 percent to as much as 140 percent above the actual costs. [1] Thus, industry estimates tend to have much wider error ranges.

Changes in compliance costs over time

When any technology matures, costs can be expected to fall as manufacturers learn to design and manufacture the product better, and as increased production volumes create economies of scale. Failure to consider these manufacturing improvements would lead to overestimates of emissions compliance costs. Bresnahan and Yao found compliance costs to be extremely high immediately following the initial regulation as manufacturers are given limited time to come into compliance. During this period, control costs are high because tooling costs for transitional technologies are spread over a short time span. The costs then fall with the introduction of new improved and longer-lasting technology. [13] Costs may also fall with time because a change in vehicle design only needs to be developed once but can be used again in following years at no additional cost. [10]

Quantifying the changes in compliance costs due to these factors is complicated. The Office of Science and Technology's report on cumulative regulatory effects on automotive transportation costs uses the following equation to calculate learning curves for vehicle production, defined as "increased production efficiency, which will reduce the initial investment costs as experience is gained in production":

$$\mathbf{C = investment\ cost/vehicle = 350 - 110\ (1 - e^{-0.33t})}\ \text{(in 1970 dollars)},$$

where *t* represents the time elapsed since 1976 and 350 represents the initial per vehicle investment cost. Based on this formula, production costs would stabilize at $633 (2002 dollars) after 1985. [26] Comparison with Figure 3.2 shows that this value is slightly below the actual costs, though costs per vehicle do appear to have stabilized.

The effects of economies of scale on costs are difficult to determine for the entire emissions control system as the configuration of these systems is frequently changing. Ideally, analysis could be performed on individual components of emissions control systems, such as catalytic converters or exhaust gas recirculation systems. However, cost estimates of these components are limited and therefore cannot provide any definitive evidence. Also, in the case of catalytic converters, their cost may vary depending on the price of precious metals which would be unrelated to any developments in the technology.

4. COST IMPACT OF EMISSIONS REGULATIONS ON CONSUMERS

The nature of business is to make a profit. Thus, the goal of any company would be to pass any new costs, such as those incurred in complying with regulations, along to consumers. Eventually, one would expect most or all compliance costs to be passed along, otherwise a business would fail. However, there are many reasons related to strategic planning, market competition, cost management, and external market circumstances that might lead to absorbing the additional cost temporarily and across certain products.

How did manufacturers reflect the cost of new or altered technologies in vehicle prices in the short and long run?

Additional costs resulting from emissions regulations can either be absorbed by auto manufacturers, passed onto consumers through increased prices, or both. Real vehicle prices have historically increased sharply during periods of engine innovation. [27] Although the manufacturer's suggested retail price does not generally reflect the price paid by the consumer, this is typically the only information available and is a good indicator. Analysis of the CARBITS database reveals that vehicle retail prices have varied significantly over time and across vehicle classes. While the averages presented in Figure 4.1 represent the average price of vehicles offered, and are therefore not weighted for vehicle sales, they illustrate the variation between vehicle classes over time. Also, unweighted averages better reflect the response of the manufacturer while sales-weighted averages would be more representative of consumer response. Note during some years that the average vehicle price declined for one class but increased for another. For example, between 1979 and 1980, the average price of a subcompact car increased by $465 while midsize car prices decreased by over $2000 (2002 dollars).

The Bureau of Labor Statistics (BLS) annually calculates the amount of retail price increases attributable to quality improvements. Average retail price increases resulting from emissions improvements are shown in Figure 4.2. Marked spikes occurred in 1975 and 1980-1981, corresponding to the changes in emissions regulations. From 1981 to 1984, though, the emissions value includes both fuel economy and emissions control changes, which overstates the cost of compliance with emissions regulations. Another important aspect of these estimates is that they reflect only the price increases for changes made during that model year and therefore do not account for any reductions associated with learning or scale economies of changes that had been implemented in previous years. Thus, simply aggregating these price changes over time would also overestimate emissions control costs.

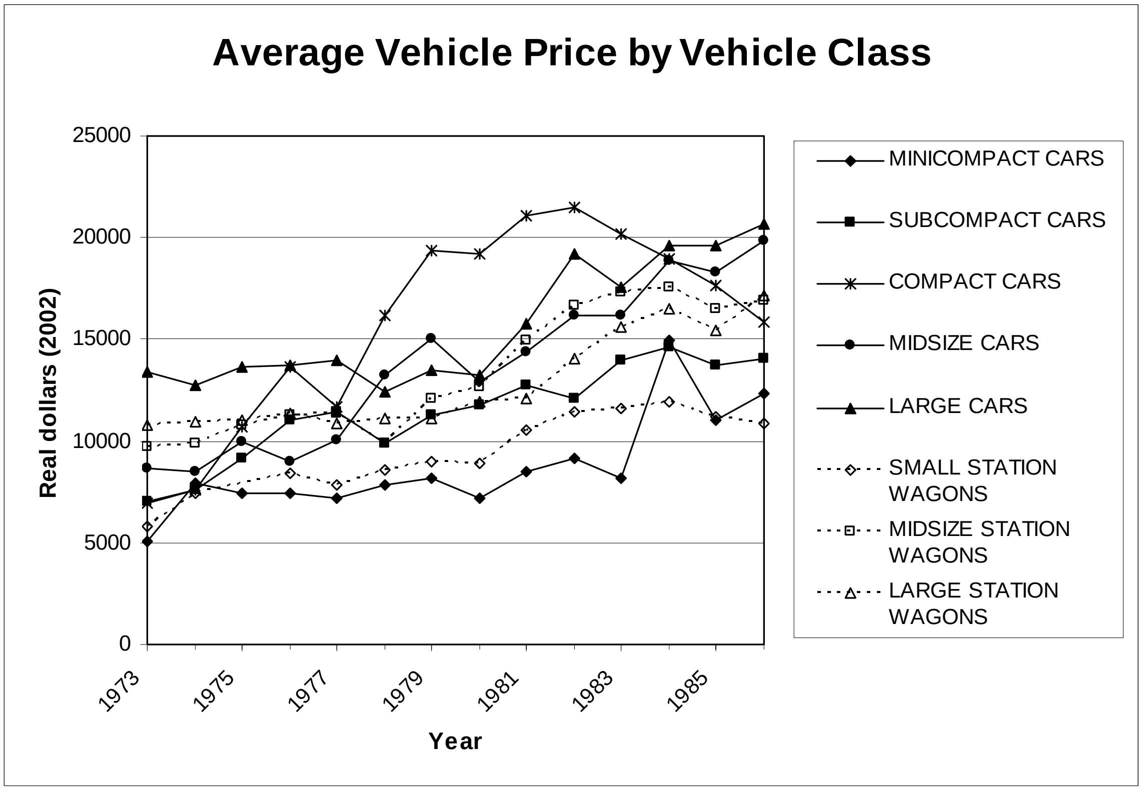


Figure 4.1 Average Vehicle Price by Vehicle Class

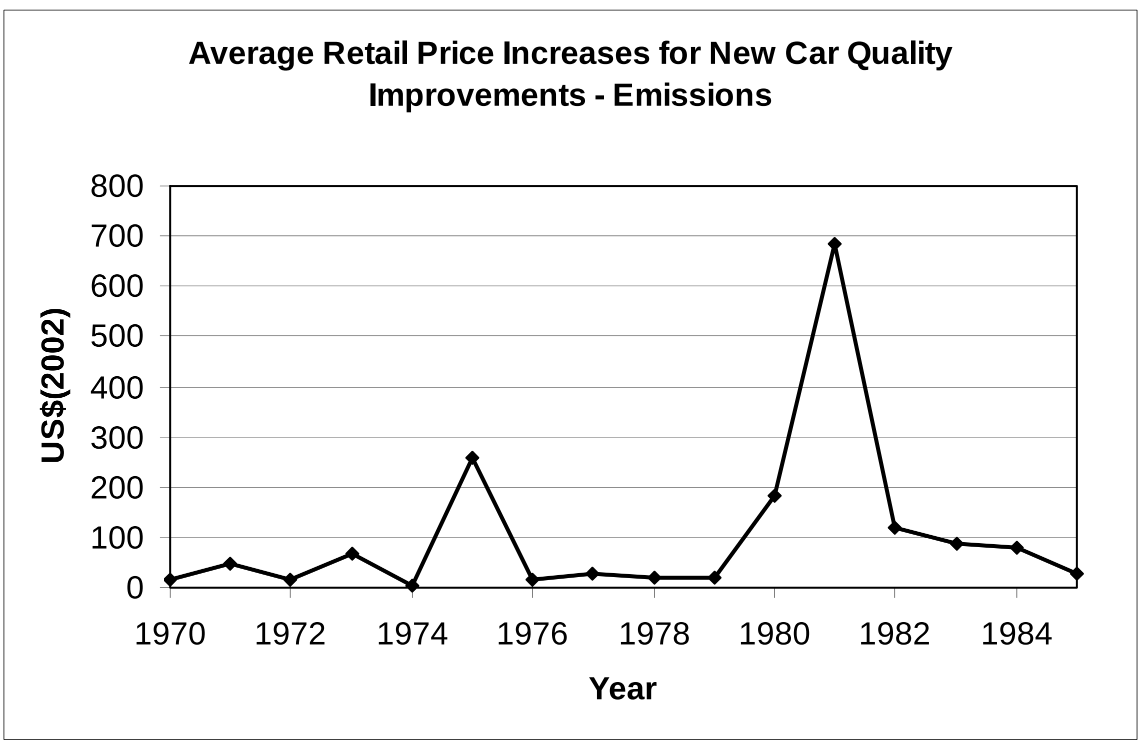


Figure 4.2 Average Retail Price Increases for Quality Improvements

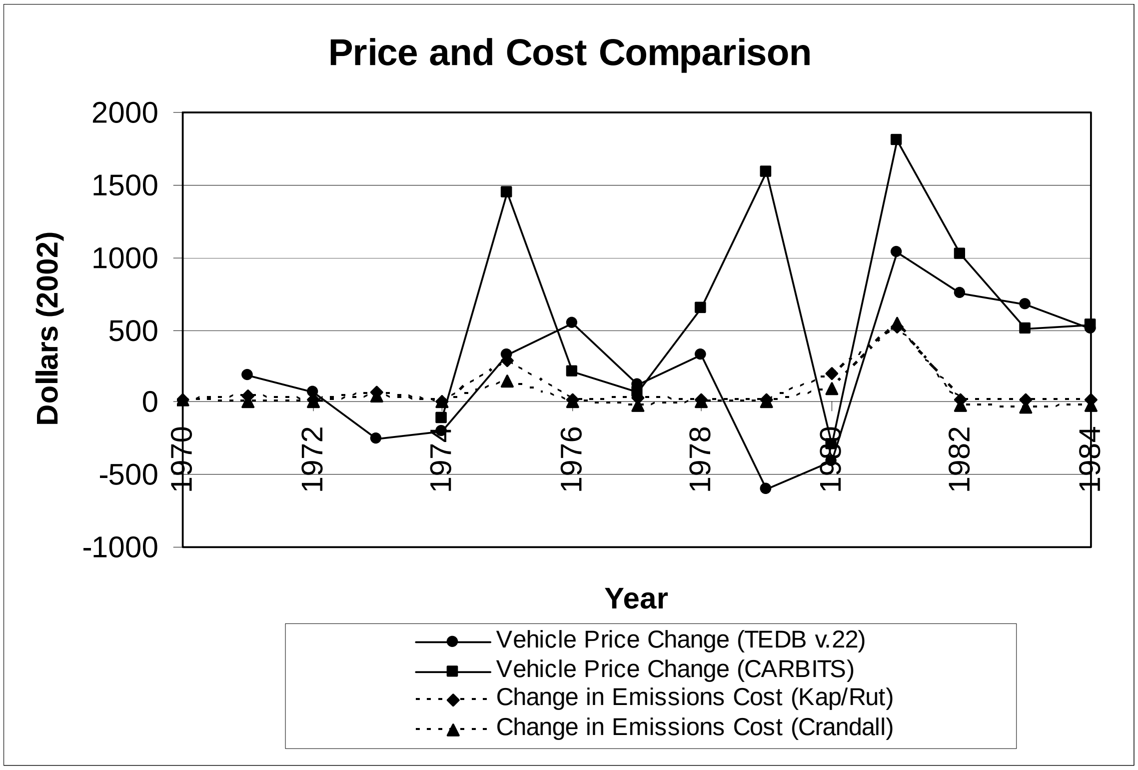


Figure 4.3 Price and Cost Comparison

However, price changes for emissions do not necessarily reflect changes in vehicle price, which would be what the consumer sees. Figure 4.3 shows these changes in vehicle prices and compares them to emission control costs. Compared to a sales-weighted average of passenger car prices (TEDB), the change in compliance cost exceeded the change in vehicle price for four years. However, compared to an unweighted average of prices for all passenger cars offered during the model year (CARBITS), the change in cost exceeded the change in price for only two years, though possibly three years if data for 1973 were available. The difference in 1979 could be attributed to the weighting, so that although the change in prices for vehicles offered by automakers increased, consumers heavily favored the less expensive models which lowered the weighted averaged. The fact that vehicle prices decreased during periods when emission control costs were estimated to have increased suggests that manufacturers were either absorbing the costs of compliance or reducing the cost of vehicles using other strategies. Whether these costs were fully passed on to consumers in the remaining years depends on what other changes were made to the vehicles for competitive purposes.

According to a recursive two-equation model of vehicle prices and profits by Crandall et al., manufacturers fully absorb the additional regulatory costs for the first year and then pass on approximately two-thirds of the costs to consumers the following year. They note that the full costs of regulation may eventually be included in the price of the vehicle. [18] Figure 4.4 shows that corporate profits fell dramatically during our case study periods but rebounded afterwards, suggesting that manufacturers are only

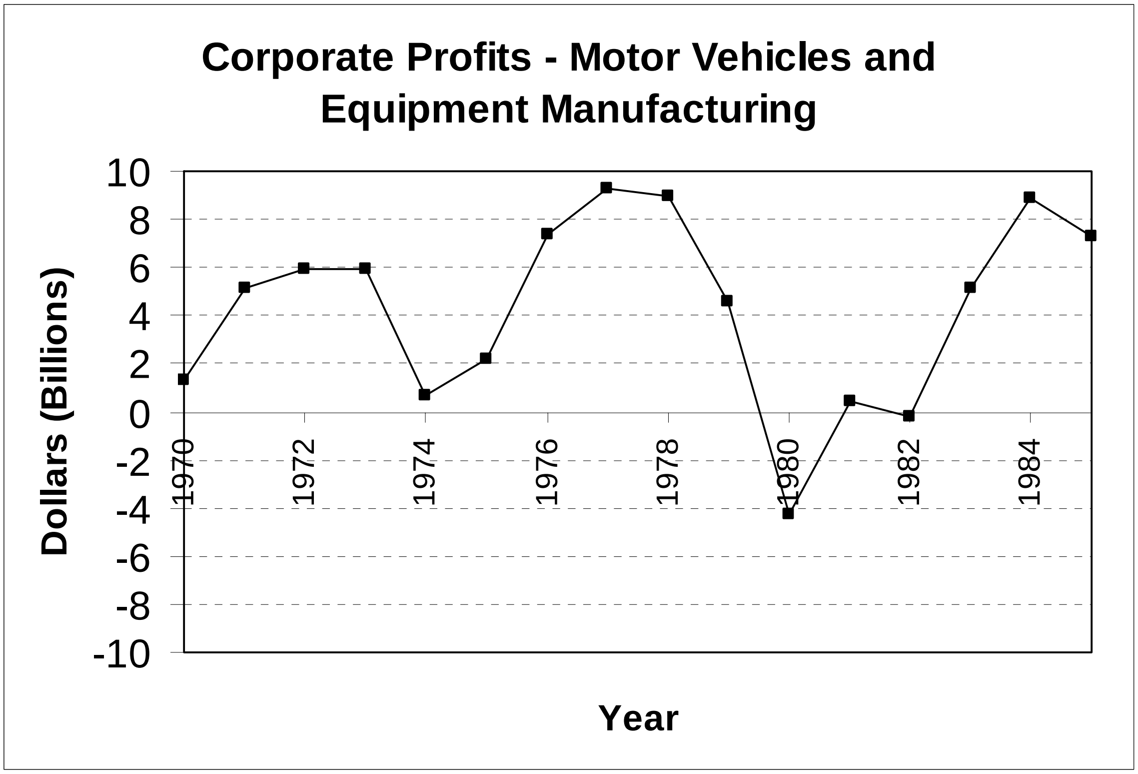


Figure 4.4 Corporate Profits
SOURCE: Bureau of Economic Analysis, Corporate Profits National Income and Product Accounts (NIPA) Tables

temporarily absorbing some of the costs. In his report on corporate strategies of automakers, Schnapp writes, "[t]here will be an inevitable tendency to pass through regulatory cost increases despite automaker concerns about possible adverse consumer behavior." [10] Economists view compliance costs as analogous to a unit sales tax on the industry. Thus, competitive firms will attempt to pass on as much of this tax as possible since subsidizing consumers indefinitely would reduce profit margins.

Another reason to expect that full costs will be passed on is that the costs fall with time as discussed in Section 3. Thus, a smaller amount—and presumably more tolerable to consumers, particularly if the increases are gradual—would be passed on. However, each manufacturer differs in their ability to absorb costs, which in turn influences what share of the costs are passed onto consumers. Larger automakers have more resources to absorb costs and consequently lower vehicle prices, allowing them to increase market share and outcompete the smaller manufacturers. [10] Passing on costs does not necessarily imply increased vehicle prices, though. More subtle strategies include converting standard equipment into optional equipment while simultaneously increasing the price of options, replacing materials (tires, fabric, carpet, etc.) with inferior substitutes, or eliminating some features all together such as vent windows or arm rests. [28]

To what extent were manufacturers able to raise prices to cover the cost increase associated with new or altered technologies in the short run and long run?

Although manufacturers tend to pass on regulatory costs to consumers, their ability to pass them on in the form of vehicle price increases is constrained by a number of factors. Most importantly, automakers preferred to keep vehicle price increases below the rate of inflation for fear that consumers would delay their purchases or downgrade to less luxurious (and less expensive) models. Especially during our case study periods, manufacturers were skeptical that consumers would not value the costs associated with emissions regulation; thus, any subsequent price increases could reduce both consumer demand and vehicle sales. In contrast, options such as power steering and power brakes could be installed as standard equipment at roughly list price without consequence. [17]

Industry profits are highly dependent upon unit volume. During the 1970s, Arvid Jouppi, an industry analyst, estimated that GM profits fell 2.5 times faster than unit sales, while Ford and Chrysler profits fell 3 and 4 times faster, respectively. [10] Thus, manufacturers are careful not to overprice their products in order to maintain market share and profitability. Another constraint on price changes was the increasing competition from foreign producers, which limited the extent to which domestic makers could transfer these compliance costs. An additional consideration when increasing vehicle prices is that prospective buyers often consider the change in price from their last vehicle purchase several years ago and not necessarily the change in price from the previous model year.

The initial pricing of a vehicle is a highly subjective and complex process. In addition to production costs, manufacturers also consider the return on investment, the return on sales, vehicle attributes (physical and psychological), market conditions, and used car prices. [28] Pricing strategies generally fall into two categories: cost pricing and image pricing. Cost pricing bases the price of a vehicle on the price of other models in the same vehicle segment with any necessary adjustments made for actual production costs. As the largest manufacturer with the ability to set the lowest prices, GM had most of the control over vehicle prices since models with similar attributes had to be priced equivalently to compete. Thus, both base vehicle prices and option prices fall within a narrow margin among all manufacturers. [17]

Image pricing bases the price of a vehicle on its appeal within the market and is the preferred pricing strategy as it tends to be more profitable. Luxury end models are typically priced using this method to capitalize on the status they confer to their owners. For instance, the Cadillac Seville and Lincoln Versailles were priced with more than $4500 (2002 dollars) of profit. [17] Although profit margins will vary for each model, manufacturers believe these variations are needed to capture all segments of the market. [10] For instance, automakers deliberately price the base model to have little profit in the hopes that consumers will purchase profitable options or else become brand loyal and upgrade to a more expensive model next time.

5. MANUFACTURER INCENTIVES DURING PERIODS OF CHANGING REGULATION

From 1975 through the early 1980's, auto manufacturers needed to employ creative marketing strategies to maintain sales volume given the overall increase in vehicle costs and prices that resulted from investments in fuel economy improvement and other performance and amenities enhancements as well as emissions improvements. Conventional marketing tools such as heavy advertising can be successful in overcoming the public's resistance to a product. For example, the sluggish sales of the downsized 1978 Chevrolet Malibu eventually exceeded sales of its predecessor by 50 percent with the aid of a national advertising campaign. [10] The success of Ford's MPG campaign, GM's downsizing effort, and AMC's Buyer Protection Plan were all the result of effective advertising. However, underlying any successful campaign is the need for a quality product that appeals to consumers. Advertising can do little for a product that is perceived as inferior or a poor value. For instance, sales of GM's Vega compact car were slow despite heavy promotion, as consumers believed it to be of poor quality. [29] Incidents such as Ford's recall of 3.7 million cars in 1977 for product liability reasons also hurt consumer confidence in vehicle quality. [9] Furthermore, although effective advertising has the power to generate demand, it can only do so when the product is in line with consumer preferences. In the case of fuel efficient cars, miles-per-gallon-type advertising could not prevent consumers from purchasing larger, less fuel efficient cars when the fear of oil shocks subsided. [29]

Another strategy employed by automakers and dealers was the use of creative financing. Roughly two-thirds of new car were purchased with credit during the late 1970's. [10] In response to lackluster sales, auto dealers believed that reducing loan rates to below ten percent would boost demand. [30] Loan rates of course are related to

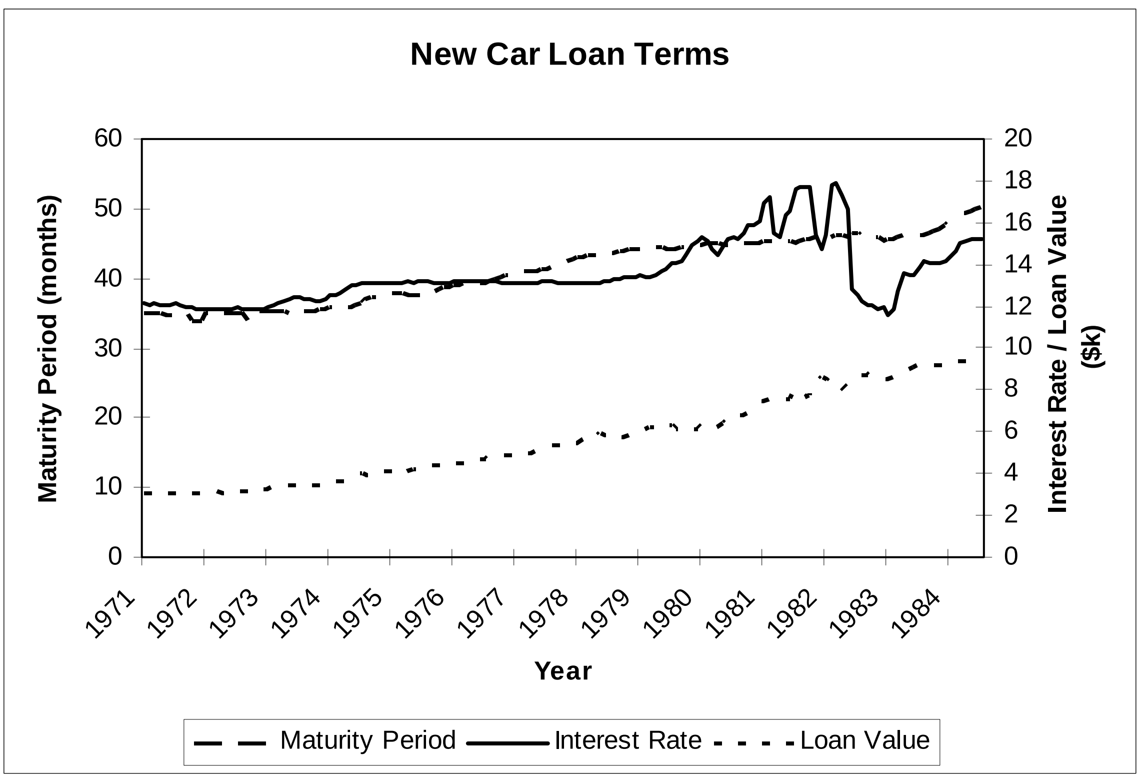


Figure 5.1 New Car Loan Terms
[Source: Federal Reserve Bank http://www.federalreserve.gov/releases/g19/hist/cc_hist_tc.html]

market interest rates. Although car loan interest rates have recently fallen well below ten percent, they remained well above that level during our case studies, peaking in 1982 at almost 18 percent. (See Figure 5.1) Thus, as interest rates remained high and vehicle prices increased, the maturity period of the loans were extended so that monthly payments would not change drastically. In 1974, financial institutions offered 48 month loans for the first time on a widespread basis. Monthly payments in 1974 averaged $132, with four percent of buyers financing their cars with loan periods of 36 to 48 months. By 1976, this percentage was over 30 percent, and by 1978, 60 percent of buyers secured loans for 36 to 48 months, with average monthly payments of $174. [3, 10] While longer loan periods help mask increased vehicle sales prices, they are less effective when interest rates are high. Particularly during the early 1980's when interest rates peaked, higher monthly payments appear to have deterred consumers, with high interest rates accounting for 8 percent of lost sales. [31]

When advertising or financing strategies fail, manufacturers typically turn to dealer incentives or customer rebates to stimulate sales. Rebates are preferable to direct price reductions when inventory levels are high as they can be offered intermittently as opposed to more permanent price cuts. Although such programs are generally viewed as last resorts since they reduce profits, they are preferable to plant shutdowns or lost market share. Manufacturers also hope that increased sales can bring production back to more efficient levels. [29] The costs of incentives are not negligible, though. In 1975, the industry spent a total of $100 million (1975 dollars) on an incentives program that only raised monthly sales by 8 percent. [29] Chrysler was the only manufacturer to view the program as successful in light of the savings from reduced inventory. However, the effects of the rebates were short-lived and inventories rose again when the program ended.

This result is consistent with most other rebate programs, as incentives generally shift the timing of a vehicle purchase rather than generate sales that would not have occurred without incentives. The Congressional Budget Office estimated that a $1,300 rebate in 1980 would have generated only 0.8 million "new" sales for the year (possibly diverted from the used car market), while accelerating 1.7 million purchases that would have occurred within the next year or two and subsidizing the remaining 5.8 million purchases that would have occurred regardless of the rebate. [31] Figure 5.2 supports this finding with sales unresponsive to incentives by the end of the year, presumably because all demand had been

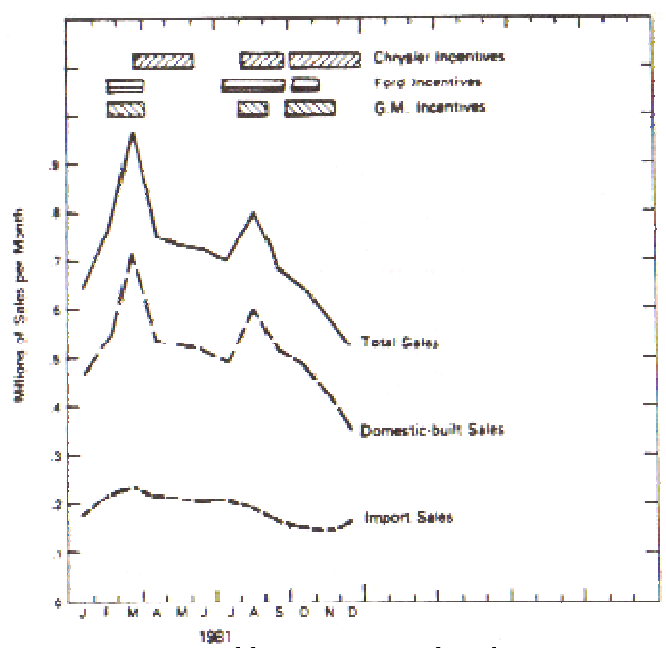


Figure 5.2 Monthly U.S. Auto Sales Showing Impact of 1981 Price Incentives
[Source: Reference 29]

fulfilled. [16]

Similar to advertising, though, the success of a rebate program also depends on the quality of the product being discounted. Offering of rebates does not automatically translate into increased sales, as some manufacturers that offer rebates actually fare worse than their competitors who did not offer rebates. [29] Some of the variation in effectiveness could be due to dealers who raise prices, either by reducing list price discounts or lowering the trade-in value, so that they profit from the rebate as well. [31]

Factors confounding sales volumes

Price alone is not the only factor affecting sales volume, though. While interest rates play an important role in a vehicle purchase decision, a survey by the National Automobile Dealers' Association in May of 1980 found that almost half of auto credit applications were refused compared to a typical rate of 10 to 15 percent. [as reported in *29*] The other major factor affecting sales volume is the general health of the economy. Vehicle sales generally change in accordance with the gross national product. Between 1973 and 1975, GNP declined by two to three percent while vehicle sales dropped by almost one-fourth. [31] 1980 and 1981 were similarly poor years in terms of both economic health and vehicle sales, with sales down by one-third compared to their peak in 1978. [18] Figure 5.3 also shows changes in vehicle sales to be highly correlated with the Conference Board's consumer confidence index, which gauges consumers' outlook on economic conditions. Both case study periods overlap with slumps in consumer confidence, confounding the effect of price increases on vehicle sales. However, given

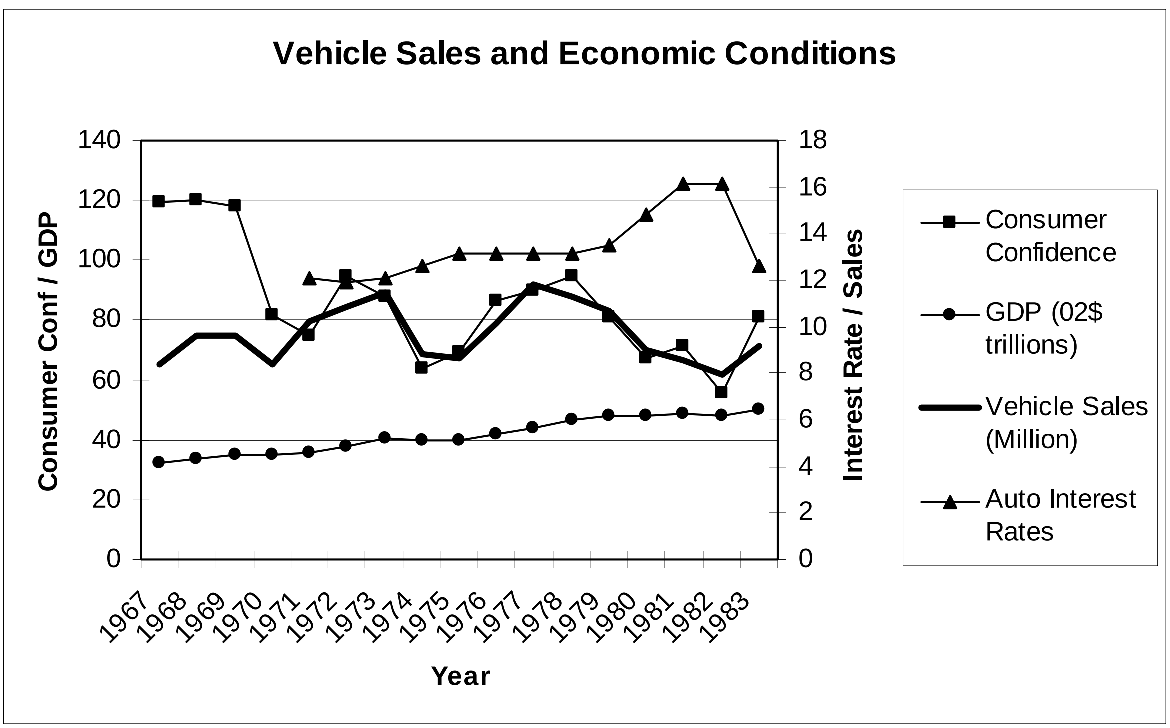


Figure 5.3 Vehicle Sales and Economic Conditions
SOURCES: Bureau of Economic Analysis, Federal Reserve Bank, The Conference Board, Transportation Energy Databook Volume 22

that emissions control equipment contributed only partially to vehicle price increases, aggregate vehicle sales were affected just in a minor way by the tightened emissions standards.

6. SUMMARY AND CONCLUSIONS

During both case study periods, automakers appeared to have responded to tightened emission standards by seeking technological solutions, as opposed to modifying vehicle attributes or changing in fleet mix. Thus, most manufacturers utilized oxidizing catalysts and three-way catalytic converters to meet the stricter standards. However, other factors such as engine system modifications, fuel injections, and onboard diagnostics and computer controls were important contributors to achieving compliance.

The cost of emissions control systems peaked in the early 1980s, at costs estimated to range from $875 to $1350 per vehicle (US$2002). Costs declined through the 1980s as manufacturers learned to design and manufacture the technology better. Still, these compliance costs were not fully passed onto consumers in the form of increased vehicle prices, at least immediately. In some years when emission control costs increased substantially, average vehicle prices actually declined, confirming that other more important factors are at play. Those other factors influencing pricing include the desire to smooth sales over time and across models so as to balance planned production volumes with shifting demand. They also include myriad smaller goals, such as using pricing to boost sales of vehicles with high fuel economy so as to achieve the company's CAFE standards, or making entry-level cars attractive to first-time buyers (who, it is hoped, will become brand loyal and later upgrade to more expensive and profitable vehicles). In addition, automakers use other non-pricing tactics to respond to regulatory changes and market shifts – including advertising and financing incentives.

Automaker response to new emissions regulations was not straightforward, uniform, nor transparent. We found, though, that even with aggressive new emission standards that imposed large cost increases, the effect on vehicle prices could not be detected. When the costs were significant, other cost and pricing factors seemed to be even more important. The added compliance costs associated with emission reduction were just one more factor used by companies in setting prices. Aggregate new car sales were affected only in a minor way by emissions regulations.

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APPENDIX A: DESCRIPTION OF CARBITS VEHICLE ATTRIBUTE DATABASE

A comprehensive database has been compiled for model years 1975-2002 for vehicle attributes at the make, model, and series level (though data at the series level are incomplete). EPA Fuel Economy Guide Reports provide the foundation for the database for model years 1978-2002. Additional attributes were added from Ward's Automotive Yearbooks, matching vehicles based upon engine displacement and fuel economy. Ward's also provided the basis for model years 1973-1977, during which period EPA data were not collected. Other vehicle characteristics were included using Consumer Reports tests of select vehicles. Because the number of vehicles tested by Consumer Reports is significantly fewer than the vehicles listed in Ward's, regression analysis will be used to devise a formula to obtain values for acceleration and maximum rated load for the remainder of the vehicles. The table below describes the variables currently included in the database and their sources.

		Data Source		
Column Header	**Description**	**EPA**	**Wards**	**CR**
Year	Model Year	X		
Class	EPA Vehicle Class (available only for 1978-2003)	X		
Manufacturer	Manufacturer name (note that some manufacturers have been omitted)	X		
carline name	Model name (note that vehicle series are not distinguished)	X		
wheelbase	Length of wheelbase in inches		X	
curb weight	Curb weight in pounds		X	
gross vehicle weight	Gross vehicle weight (curb weight + maximum rated load + passenger weight) in pounds for light trucks only		X	
maximum rated load	Maximum rated load in pounds			X
horsepower	Net horsepower		X	
traction	Traction Control: Blank=none; 1=optional; 2=standard			X
abs	Anti-lock Brakes: Blank=none; 1=optional; 2=standard		X	
hp-ca	Net horsepower for California vehicles (only early imports)		X	
msrp	Manufacturer suggested retail price in nominal dollars		X	
airbag	Airbags: Blank=none; 1=driver; 2= dual; 3=side; 4=rear/side; 5=ceiling		X	
Towing Capability (lb.)	Towing capability in pounds (mostly light trucks)			X
0-30	Acceleration 0-30mph in seconds			X
0-60	Acceleration 0-60mph in seconds			X
45-65	Passing acceleration in seconds			X
195-mile trip fuel economy	Consumer Reports road trip test fuel economy in mpg			X
Fuel Econ City Driving	Consumer Reports city test fuel economy in mpg			X
Fuel Econ Express-wayDriving	Consumer Reports highway test fuel economy in mpg			X
convertible?	blank=no; 1=yes		X	
veh type	1= luxury or sports car; 2= SUV; 3= minivan; 9=crossover		X	
cyl	Number of cylinders	X		
DISP CI	Engine displacement in cubic inches	X		

		Data Source		
Column Header	**Description**	**EPA**	**Wards**	**CR**
fuel system	Number of carburetor barrels or type of fuel injection: MPFI=multiport fuel injection; SFI=sequential fuel injection; IDI=indirect fuel injection; TBI=throttle-body injection; EFI=electronic fuel injection; VV=variable venture	X		
displ (liters)	Engine displacement in liters	X		
optional disp	Optional displacement in liters	X		
trans	Transmission type (A=automatic; M=manual; L=lockup)	X		
overdrive	OD=overdrive, EOD=electronic overdrive; AEOD=automatic overdrive	X		
catalyst	Y=catalyst; N=no catalyst	X		
drv	Drive axle type: FWD, RWD, 4WD	X		
cty	Adjusted city fuel economy	X		
hwy	Adjusted highway fuel economy	X		
cmb	Adjusted combined fuel economy	X		
ucty	Unadjusted city fuel economy	X		
uhwy	Unadjusted highway fuel economy	X		
ucmb	Unadjusted combined fuel economy	X		
fl	Fuel type: L=leaded gasoline; U=unleaded gasoline; D=diesel	X		
G	Gas guzzler vehicle	X		
T	Turbocharger	X		
S	Supercharger	X		
Type 2 Door	2-door vehicle passenger and luggage volume	X		
2pv	2-door passenger volume	X		
2lv	2-door luggage volume	X		
Type 4 Door	4-door vehicle passenger and luggage volume	X		
4pv	4-door passenger volume	X		
4lv	4-door luggage volume	X		
Type Hbk	Hatchback passenger and luggage volume	X		
hpv	Hatchback passenger volume	X		
hlv	Hatchback luggage volume	X		
fcost	Annual fuel cost in nominal dollars	X		
eng dscr 1	Engine description 1	X		
eng dscr 2	Engine description 2	X		
eng dscr 3	Engine description 3	X		
trans dscr	Transmission description	X		
cls	Valves per cylinder (2000 and later)	X		

APPENDIX B: VEHICLE CLASS DEFINITIONS FOR PASSENGER CARS

	PASSENGER AND CARGO VOLUME
SEDANS	
Minicompact	Under 85 cubic feet
Subcompact	85 to 99 cubic feet
Compact	100 to 109 cubic feet
Midsize	110 to 119 cubic feet
Large	120 or more cubic feet
STATION WAGONS	
Small	Under 130 cubic feet
Midsize	130 to 159 cubic feet
Large	160 or more cubic feet