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

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ACKNOWLEDGEMENTS

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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\textsubscript{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\textsubscript{x}, with NO\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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.
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\[ \text{†} \text{ Fleet average of Non-methane Organic Gases (not Total Hydrocarbons) } \]

\[ \text{‡} \text{ Emission standard varies depending on certification levels TLEV, LEV, or ULEV} \]

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.


**Facts about the 1975-’76 Federal Emissions Standards**

This is running out.

The automobile industry is already focusing designs, buying materials and manufacturing facilities for emission control systems to meet federal standards set for 1975 and 1976 cars. We can't wait that long.

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 pollution problem. But we believe the 1975 and 1976 federal standards are too stringent and more expensive than necessary.

The control systems for meeting them will cost you a sizable increase in the price of your car. That means higher payments 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 emission controls:

- Go beyond what is necessary to protect our health
- Will cost you more than it is worth

We call on you to be a catalyst. We urge you to demand:

- Will waste both money and natural resources
- Could undermine the National Health SERC’s scientific standards for considerate national health.

We urge you to be a catalyst. For it is precisely in the proposed California standards that we are in a position 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.

![Image of Chrysler advertisement](image)

Reducing emissions by these last few percent allows necessary to meet the 1975-76 standards and would mean the loss of a few days of driving time in the summer. If you get out of your car when the sun is hot, you find that it is just as hot in the car. The sun acts as the烧烤, heating the car to the same temperature as if you were out in the sun.

The sun’s heat is not the only factor that affects air quality. There are also other factors that contribute to air pollution. These include industrial emissions, vehicular exhaust, and natural sources such as wildfires and volcanic eruptions.

Both the federal government and the states have set standards for air quality. These standards are designed to protect public health and welfare. The federal standards are more stringent than many state standards. However, states are allowed to adopt their own standards, as long as they are at least as strict as the federal standards.

The federal government has set standards for carbon monoxide, hydrocarbons, nitrogen oxides, and sulfur dioxide emissions. These standards are designed to limit the amount of these pollutants that can be emitted into the air.

In addition to setting standards, the federal government also has the authority to regulate emissions from motor vehicles. This includes setting standards for fuel economy, which is measured in miles per gallon (mpg). The federal government requires that new cars meet certain fuel economy standards to reduce the amount of gasoline that is consumed and the carbon dioxide that is emitted into the atmosphere.

According to government data, California has a larger share of emissions than any other state. This is because it has a larger population and is more industrialized than other states. However, the federal government has the authority to set national standards for emissions, and these standards apply to all states.

**WHAT THE LOWEST**

Very little more than you already have.

![Image of car on road](image)

BURLINGTON, Mich., (Motor News, 4-23). Well and you the information.

- 10% fuel efficiency improvement
- 80% of the cars on the road will be able to reach this level of emission reduction.
- The cost to the consumer will be minimal, and the benefits will be significant.

However, it is important to note that these standards are still higher than what is necessary.

The federal government is under pressure to reduce the amount of emissions from motor vehicles. This is due to concerns about the impact of these emissions on public health and the environment.

The federal government is considering whether to adopt even more stringent standards in the future. This could have a significant impact on the cost of new cars. However, it is important to remember that the benefits of cleaner air are worth the cost.

According to government data, California has the most stringent air quality standards in the country. This is due to concerns about the impact of these emissions on public health and the environment.

The federal government is currently in the process of setting new standards for emissions. These standards will be announced in the near future.
The $66 billion mistake

In 1973, Congress passed a series of amendments to the Clean Air Act. One of them said that all cars must meet the federal standards by 1977. This was a major new law. However, it was not clear how much more pollution would be reduced by the more stringent standards. Some experts thought that the new standards would save lives and save money. But others thought that the costs of compliance would be too high.

The Clean Air Act of 1970 was intended to reduce air pollution. It was the first major federal law to address this problem. The act required states to develop plans to control emissions of pollutants. It also established national standards for air quality. The standards were based on the idea that air quality should be protected for future generations.

The Clean Air Act Amendments of 1970 were passed by Congress and signed into law by President Richard Nixon on July 9, 1970. These amendments expanded the Act's scope and increased its provisions for regulation of air pollutants. The amendments directed the Environmental Protection Agency (EPA) to develop and implement a national air quality program.

The amendments established a national air quality standard for sulfur dioxide, a gas emitted by coal-burning power plants and industrial sources. The standard required that the average annual concentration of sulfur dioxide not exceed 0.1 parts per million (ppm) in most areas of the country.

The most significant new provision of the 1970 Amendments was the requirement for states to develop plans to control emissions of lead from vehicles. Lead is a toxic metal that is released into the air when gasoline is burned in internal combustion engines. The lead content of gasoline was reduced over time, and the ban on leaded gasoline was phased in nationwide by 1978.

The Clean Air Act Amendments of 1977 were passed by Congress and signed into law by President Jimmy Carter on October 1, 1977. These amendments further strengthened the nation's air quality laws and expanded the EPA's authority to regulate air pollution.

The amendments established new emission standards for a range of pollutants, including nitrogen oxides, carbon monoxide, and volatile organic compounds. They also required states to develop plans to control emissions of particulate matter and toxics.

The amendments mandated the use of technology-based standards, which set limits on the amount of pollutants that new vehicles could emit. These standards were intended to encourage manufacturers to develop cleaner technologies and to reduce the costs of compliance.

The amendments also established the National Ambient Air Quality Standards (NAAQS), which set limits on the levels of pollutants in the nation's air. The NAAQS are designed to protect human health and the environment and to ensure that the nation's air is clean and safe.

The amendments directed the EPA to publish a report on the costs and benefits of the 1970 Amendments. The report was due in September 1973 and was to be submitted to Congress. The report was not completed on time, and the EPA did not publish it until 1974. The report estimated that the costs of the amendments would range from $15 billion to $50 billion over a 10-year period.

The report's conclusions were based on a review of the available data and a modeling exercise. The modeling exercise estimated the costs and benefits of the amendments using a variety of assumptions and techniques. The report's findings were controversial and led to a debate about the costs and benefits of the amendments. The report was not followed by any action, and the amendments were eventually repealed by Congress in 1987.

The study also provided a framework for future research on the costs and benefits of air quality policies. It highlighted the importance of considering the full range of costs and benefits when designing and implementing environmental regulations.

The study's findings were later used in other studies and in the development of subsequent air quality policies. The study's methodology and conclusions have been criticized, but it is still considered an important contribution to the field of environmental economics.

The study was funded by the U.S. Environmental Protection Agency (EPA) and was conducted by the Resources for the Future (RFF) and the Institute for Research on Geographic Information (IRGi). The study was directed by Donald J. Anderson and co-directed by Robert D. Kates and John A. List.
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 NOx. 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 NOx 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>
<thead>
<tr>
<th>Manufacturer</th>
<th>Compliance Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMC</td>
<td>Oxidation catalyst, three-way catalyst</td>
</tr>
<tr>
<td>Chrysler</td>
<td>Electronic lean-burn system, oxidation catalyst, three-way catalyst</td>
</tr>
<tr>
<td>Ford</td>
<td>Oxidation catalyst, three-way catalyst</td>
</tr>
<tr>
<td>GM</td>
<td>Oxidation catalyst, three-way catalyst</td>
</tr>
</tbody>
</table>
| 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\textsubscript{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\textsubscript{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


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]

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, NOx 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 example, 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”:

\[ C = \text{investment cost/vehicle} = 350 - 110 \left(1 - e^{-0.33t}\right) \] (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
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 average. 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
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

![New Car Loan Terms](http://www.federalreserve.gov/releases/g19/hist/cc_hist_tc.html)

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](image)

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.
REFERENCES


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.

<table>
<thead>
<tr>
<th>Column Header</th>
<th>Description</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>Model Year</td>
<td>EPA X</td>
</tr>
<tr>
<td>Class</td>
<td>EPA Vehicle Class (available only for 1978-2003)</td>
<td>Wards X</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Manufacturer name (note that some manufacturers have been omitted)</td>
<td>CR X</td>
</tr>
<tr>
<td>carline name</td>
<td>Model name (note that vehicle series are not distinguished)</td>
<td>CR X</td>
</tr>
<tr>
<td>wheelbase</td>
<td>Length of wheelbase in inches</td>
<td>CR X</td>
</tr>
<tr>
<td>curb weight</td>
<td>Curb weight in pounds</td>
<td>CR X</td>
</tr>
<tr>
<td>gross vehicle weight</td>
<td>Gross vehicle weight (curb weight + maximum rated load + passenger weight)</td>
<td>CR X</td>
</tr>
<tr>
<td>maximum rated load</td>
<td>Maximum rated load in pounds</td>
<td>CR X</td>
</tr>
<tr>
<td>horsepower</td>
<td>Net horsepower</td>
<td>CR X</td>
</tr>
<tr>
<td>traction</td>
<td>Traction Control: Blank=none; 1=optional; 2=standard</td>
<td>CR X</td>
</tr>
<tr>
<td>abs</td>
<td>Anti-lock Brakes: Blank=none; 1=optional; 2=standard</td>
<td>CR X</td>
</tr>
<tr>
<td>hp-ca</td>
<td>Net horsepower for California vehicles (only early imports)</td>
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</tr>
<tr>
<td>msrp</td>
<td>Manufacturer suggested retail price in nominal dollars</td>
<td>CR X</td>
</tr>
<tr>
<td>airbag</td>
<td>Airbags: Blank=none; 1=driver; 2=dual; 3=side; 4=rear/side; 5=ceiling</td>
<td>CR X</td>
</tr>
<tr>
<td>Towing Capability (lb.)</td>
<td>Towing capability in pounds (mostly light trucks)</td>
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</tr>
<tr>
<td>0-30</td>
<td>Acceleration 0-30mph in seconds</td>
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</tr>
<tr>
<td>0-60</td>
<td>Acceleration 0-60mph in seconds</td>
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<tr>
<td>45-65</td>
<td>Passing acceleration in seconds</td>
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<td>Consumer Reports road trip test fuel economy in mpg</td>
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<td>Fuel Econ City Driving</td>
<td>Consumer Reports city test fuel economy in mpg</td>
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<tr>
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<td>Consumer Reports highway test fuel economy in mpg</td>
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<td>convertible?</td>
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<tr>
<td>veh type</td>
<td>1= luxury or sports car; 2= SUV; 3= minivan; 9=crossover</td>
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</tr>
<tr>
<td>cyl</td>
<td>Number of cylinders</td>
<td>CR X</td>
</tr>
<tr>
<td>DISP CI</td>
<td>Engine displacement in cubic inches</td>
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<td>fuel system</td>
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<td>EPA [X] Wards [X] CR [X]</td>
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<td>Optional displacement in liters</td>
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<td>OD=overdrive, EOD=electronic overdrive; AEOD=automatic overdrive</td>
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<td>Y=catalyst; N=no catalyst</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>drv</td>
<td>Drive axle type: FWD, RWD, 4WD</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>cty</td>
<td>Adjusted city fuel economy</td>
<td>EPA [X] Wards [X] CR [X]</td>
</tr>
<tr>
<td>hwy</td>
<td>Adjusted highway fuel economy</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<tr>
<td>cmb</td>
<td>Adjusted combined fuel economy</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>Unadjusted city fuel economy</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<tr>
<td>uhwy</td>
<td>Unadjusted highway fuel economy</td>
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<tr>
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<td>Unadjusted combined fuel economy</td>
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</tr>
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<td>Fuel type: L=leaded gasoline; U=unleaded gasoline; D=diesel</td>
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<td>G</td>
<td>Gas guzzler vehicle</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>Turbocharger</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>Supercharger</td>
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<td>2-door passenger volume</td>
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<td>4lv</td>
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<td>Hatchback passenger volume</td>
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<td>hlv</td>
<td>Hatchback luggage volume</td>
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<tr>
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<td>EPA [X] Wards [X] CR [X]</td>
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<td>Engine description 1</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>Engine description 2</td>
<td>EPA [X] Wards [X] CR [X]</td>
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<td>Engine description 3</td>
<td>EPA [X] Wards [X] CR [X]</td>
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## APPENDIX B: VEHICLE CLASS DEFINITIONS FOR PASSENGER CARS

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<tr>
<th>SEDANS</th>
<th>Passenger and Cargo Volume</th>
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<tr>
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</tr>
<tr>
<td>Subcompact</td>
<td>85 to 99 cubic feet</td>
</tr>
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<td>Compact</td>
<td>100 to 109 cubic feet</td>
</tr>
<tr>
<td>Midsize</td>
<td>110 to 119 cubic feet</td>
</tr>
<tr>
<td>Large</td>
<td>120 or more cubic feet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STATION WAGONS</th>
<th>Passenger and Cargo Volume</th>
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</thead>
<tbody>
<tr>
<td>Small</td>
<td>Under 130 cubic feet</td>
</tr>
<tr>
<td>Midsize</td>
<td>130 to 159 cubic feet</td>
</tr>
<tr>
<td>Large</td>
<td>160 or more cubic feet</td>
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