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

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ABSTRACT

On July 22, 2002, Governor Gray Davis signed AB 1493 into law. This law requires that the California Air Resources Board (CARB) propose rules that would reduce greenhouse gas emissions of light duty vehicles in California. The goal of this study was to provide insight into industry and consumer response to government regulations, especially as they might relate to future regulations that reduce greenhouse gas emissions from vehicles. This report addresses industry and consumer behavior with respect to emissions, safety, and energy use in the U.S. and Europe over the past few decades.

We created and analyzed a large data set of vehicle characteristics, sales, and prices, vehicle financing practices, and exogenous factors such as income, for the period 1975-2003, and supplemented the data analysis with case studies of the introduction of oxidation and three-way catalysts, air bags, and hybrid electric vehicles in the US; and diesel cars in Europe.

We found that costs imposed on vehicles due to US emissions and safety regulations have been significant – somewhere between $2500 and $4000 per vehicle. These costs represent up to 1/3 of vehicle price increases since the 1970s. Whether one considers these costs to be large or small, they had little discernible effect on industry performance and activities. The cost increases have been largely accommodated within normal business and market planning processes of companies.

BACKGROUND

On July 22, 2002, Governor Gray Davis signed AB1493 into law. This law requires that the California Air Resources Board (CARB) propose rules that would reduce greenhouse gas emissions of light duty vehicles in California. These rules must be technology based. This study has two goals: 1) provide insight into industry and consumer response to government regulations, especially as they might relate to future regulations that reduce greenhouse gas emissions from vehicles; and 2) provide a modeling tool that CARB can use to investigate customer responses to greenhouse gas vehicle rules in a systematic and rigorous fashion. Two sets of reports are prepared. The second goal is addressed in a report by Dr. David Bunch et al. (2004).

This report is a synthesis of six background reports that address the first goal (Abeles et al, 2004; Burke, 2004; Burke et al, 2004; Chen et al, 2004a; Chen et al, 2004b; and Kurani and Turrentine, 2004a). Together with the background reports, this synthesis report documents regulatory experiences and industry and consumer behavior with respect to emissions, safety, and energy use in the US and Europe over the past few decades. Together, these reports provide insight into how the automotive industry responds to new regulations, how consumers respond to new "green" technology, and the extent to which the cost of compliance is passed through to consumers.

Study Approach

To understand industry response to regulations, we examined historical experiences. We studied relationships between vehicle prices, costs of complying with vehicle regulations, and automotive marketing strategies. We created a large data set of vehicle characteristics, sales, and prices, vehicle financing practices, and exogenous factors such as income, for the period 1975-2003 (Burke et al, 2004). To provide further insight and to control for these external influences, we supplemented the data analysis with more focused studies of cases where government regulations had sharp impacts in a short period of time, or where new vehicle technologies were introduced that significantly reduced greenhouse gas emissions. The following case studies were conducted:[1]

- Oxidation catalytic converters and three-way catalysts introduced in the US in the mid 1970s and early 1980s, respectively, in response to sharp reductions in emission standards (Chen et al, 2004a). These two cases were chosen because the incurred cost increases were much greater than for any other change in vehicle emission standards.
- Air bag requirement in the US in 1980s (Abeles et al, 2004). This passive restraint requirement was analyzed because it was the single most contentious and costly safety requirement imposed on the auto industry.
- Diesel cars in Europe (Chen et al, 2004b). This case study examines the voluntary adoption of a carbon dioxide emission standard and the industry's principal response: diesel cars.

[1] Battery electric vehicles were not included because they were never introduced on a large scale. Total BEV sales never exceeded a few hundred in any year, excluding small neighborhood electric vehicles.

- Hybrid electric vehicles in the US (Burke, 2004). The voluntary introduction of this energy efficient and low-emitting technology, beginning in the US in 2000, provides insight into how companies introduce unique new technologies, and how consumers respond.

These various studies of industry behavior are based on original analyses of published data, and draw upon the remarkably extensive public record of these regulatory interventions (i.e., transcripts of public hearings and coverage by mass media and trade publications) and the more modest professional and scientific literature. The analysis and interpretation of data were informed and guided by discussions with current and retired automotive executives and analysts. Analyses of consumer response to new regulations and technologies draw in part from these case studies as well as the extensive market research experience of the UC Davis research team and the broader literature on consumer response to energy and environmental vehicle attributes. The overall findings on consumer behavior are summarized in this report, and documented in Kurani and Turrentine (2004a).

Context and Caveats

This report addresses the relationship between very large and complex governments, a very large industry, and a highly diverse consumer population. The relationships are complex, often private, and evolving. The findings of this summary report and the accompanying volumes are subject to many caveats and need to be understood in context. Three broad contexts and caveats are highlighted here.

First, this study relates to current industry dynamics. The current automotive industry is very different from 40 years ago. In the early 1960s, three domestic companies dominated the US automotive market, accounting for nearly 100% of light duty vehicle sales. Now those three companies account for only about 60% of national sales (and less than 50% in California). The three companies have been steadily losing market share to automakers based in Asia and Europe, with Chrysler even purchased by a European company. The oligopoly of three firms has evolved into a highly competitive market. One outcome is less unified industry negotiating positions with regulators, more diverse responses to regulatory initiatives, and more diverse product offerings and pricing strategies.

Second, the history and experience of government regulation of the automotive industry is relatively recent. It is not a mature process. Government began seriously regulating motor vehicle attributes in the 1960s, beginning with safety. This "social" regulation, now addressing safety, pollution, and energy use, has evolved considerably. It is inherently a conflict-based process. Companies are called upon to develop and adopt new technologies that often have unknown costs and uncertain consumer responses, while regulators are adopting rules often with limited knowledge of what technological improvements are possible at what cost. This relationship between regulators and automakers has been steadily evolving. Both sides are becoming more knowledgeable about what is possible and desirable. At the same time, though, the focus of problems and the structure of the industry continue to shift.

Third, this report focuses on the large international automakers that dominate the industry. These companies have the capabilities and resources to invest in new products and technologies. But there are cases of small specialized manufacturers, and unprofitable companies of all sizes that can and have failed, or been bought by stronger companies, in part because of their difficulty in responding to increasingly stringent requirements. These cases are not well documented and are usually complicated by many other factors -- and are not addressed in this report.

HISTORICAL OVERVIEW OF REGULATIONS, TECHNOLOGY, PRICES, AND SALES IN US

As a first step in addressing how government regulations affect vehicle offerings and prices, we created a large database of vehicle prices, attributes, and sales from 1975 to 2003, by vehicle class and manufacturer, and supplemented it with historical data on income, economic conditions, fuel prices, and consumer financing factors (see Burke et al, 2004 for sources and details). Data were analyzed using SPSS, ACCESS, and EXCEL software to analyze historical trends of vehicle, price, and sales parameters in response to changes in government vehicle regulations. An overview of the various changes is provided below.

Vehicle emissions were first regulated in the early 1960s, beginning with the control of crankcase emissions. As indicated in Table 1, emission standards have been tightened over the years, and continue to be so – with new vehicles sold in 2003 having tested emissions 90- 99% below 1960s pre-controlled levels (though actual on-road emissions are higher).

The tightening of fuel economy standards has been more modest in magnitude and more controversial. It is also instructive in demonstrating the powerful but not always straightforward role of standards in influencing innovation. CAFE standards for cars, adopted in 1975, required automakers to increase fuel economy of their cars from about 13 mpg to 18 mpg in 1978, and then to 27.5 mpg by 1985. The standards were met. But since then, the overall fuel economy of cars and light trucks has not improved at all – even though technical fuel efficiency improvements were being made and implemented. Indeed, tremendous improvements were made in engine efficiency, use of lightweight materials, and lighter designs, even during the last 20 years. But these improvements were not used to reduce fuel consumption; as indicated in Figure 1 they were used to increase horsepower (93% increase from 1981 to 2003), improve power (0-60 mph times dropped 29% from about 15 to 10 seconds), and increase weight (+24%), as well as add energy-consuming accessories such as all-wheel drive and air conditioning. If performance and size had been held constant from 1985 to 2001, fuel economy would have improved about 2% per year -- over 30% during this period -- instead of not at all (Hellman and Heavenrich, 2003). Fuel economy standards thus play an important role in motivating technical fuel-efficiency innovations, but how those innovations are used is

part of a more complex story related to market dynamics, consumer behavior, and company positioning.

Table 1 California and Federal Exhaust Emission Standards for Passenger Cars (g/mi)

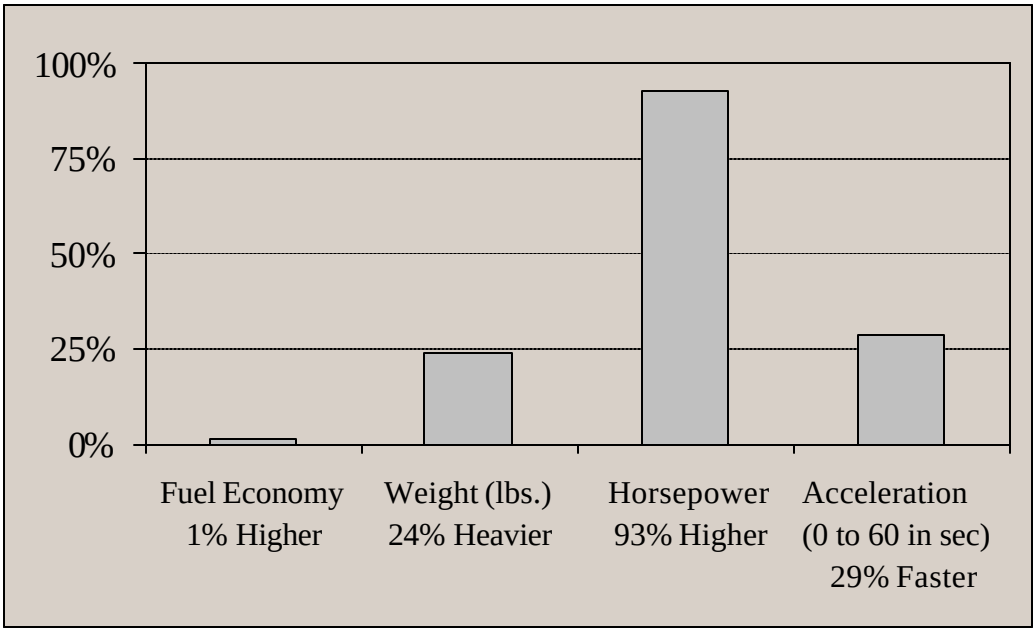
	Federal			*California*		
Model Year	**HC**	**CO**	**NOx**	**HC**	**CO**	**NOx**
uncontrolled	8.7	90	3.4	8.7	90	3.4
1966				4.3	44	
1967				4.3	44	
1968	4.1	34		4.3	44	
1969	4.1	34		4.3	44	
1970	4.1	34		2.2	23	
1971	4.1	34		2.2	23	
1972	3.0	28		1.5	23	3.0
1973	3.0	28	3.1	1.5	23	3.0
1974	3.0	28	3.1	1.5	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

Notes: [†] Fleet average of non-methane organic gases

[‡] Emission standard varies depending on certification levels (e.g., LEV, ULEV)

Sources: U.S. Environmental Protection Agency, California Air Resources Board, California Code of Regulations.

Figure 1 Percent Change from 1981 to 2003 in Average Vehicle Characteristics



Source: Hellman and Heavenrich, 2003

The light duty market evolved considerably over the past few decades, and continues to evolve. One underlying change was improved safety, emissions, and energy efficiency, all related to government rules and regulations. As indicated in Finding #1 below, the costs associated with these improvements are significant, but a modest part of overall cost increases. Other changes – improvements in reliability, durability, "fit-and-finish" quality, and power, and the addition of many new accessories – incurred even greater costs, and therefore were responsible for a larger proportion of increased vehicle prices.

Cost increases are difficult to quantify. The best indicator of changes in costs are transaction prices estimated by the Bureau of Economic Analysis (BEA) of the US Department of Commerce through extensive surveys (with responses weighted by sales). The problem is that cost data are confidential and not available.

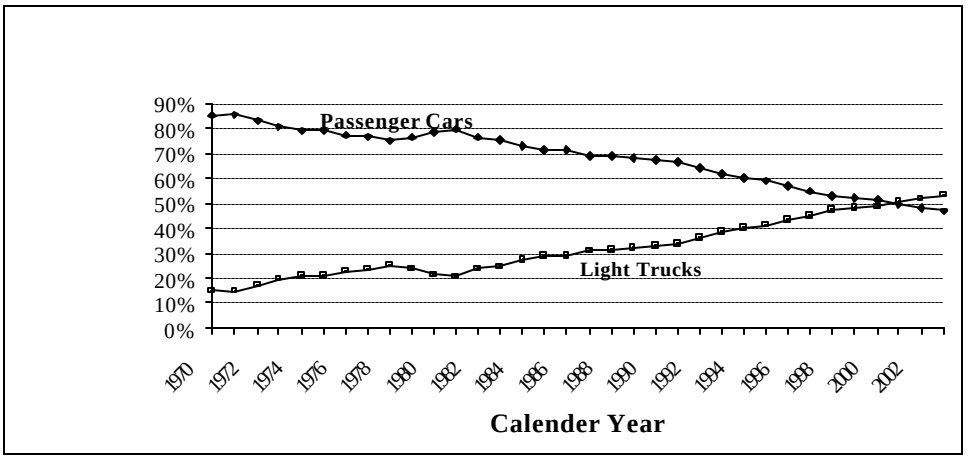
Many analysts use manufacturer's suggested retail prices (MSRP) as an indicator of prices, but these are not good indicators. They are not sales weighted and it is very difficult to procure sales figures by model for the 1970s and '80s. Moreover, automakers often increase MSRP intermittently over a year. Most importantly, consumers do not pay the MSRP. They pay more for extra features and accessories, or less if they negotiate a lower price or receive financing incentives. And special loan conditions alter the effective price they pay. And then there is the problem of adjusting for inflation. Two price indices are often used: the consumer price index and the vehicle price index. They are very different. For instance, the consumer price index (CPI) for all goods and services

increased 105% between 1985 and 2003, but for new vehicles only 50%. If one is analyzing changes in vehicle prices over time, one should use the vehicle CPI, which produces smaller increases in vehicle prices than the general CPI. (One would use the general CPI when analyzing consumers' ability to buy new vehicles.)

In any case, as documented later, by any measure vehicle prices have increased considerably. In Finding #1, we examine what proportion of vehicle price increases were due to regulatory requirements.

Another profound shift over the past three decades has been the shift from cars to light trucks. As indicated in Figure 2, cars as a share of light duty vehicles dropped from 85% in 1971 to less than 50% in 2001 -- the remainder being light trucks. In 1975 most light trucks were pickups; by 2001, sport utility vehicles (SUVs) were the largest light truck category, accounting for 20% of all light duty sales.

Figure 2 Sales of Cars and Light Duty Trucks by Percentage, 1970-2003, US



Sources: American Automobile Manufacturers Association (1998), Ward's Communication (2003).

In a larger sense, though, the shift from cars to light trucks, and other shifts between vehicle classes are related to changes in vehicle prices, fuel prices, household income, economic conditions, and consumer financing costs. For instance, the large annual fluctuations in annual vehicle sales indicated in Table 2 closely tracked economic conditions (Ward's, 2003; US Dept of Commerce, 2003). In depressed economic times, consumers sharply reduced purchases of new vehicles, and in good times, increased purchases.

In summary, the automotive market is highly complex, with different companies pursuing different strategies and facing different market circumstances. Overall, vehicle prices in real dollars have increased significantly over the years due to both technology and quality changes in the vehicles, but consumers have continued to purchase the vehicles even at the higher prices. Much can be learned from the past, in terms of industry and consumer response to regulations, but those findings must be interpreted in terms of evolving

circumstances if they are to provide useful lessons for the future. In the remainder of this report, we report the findings from our case studies and consumer research, and interpret them in terms of our understanding of evolving circumstances.

PROJECT FINDINGS

#1: Government regulations have accounted for about 1/3 of overall vehicle price increases.

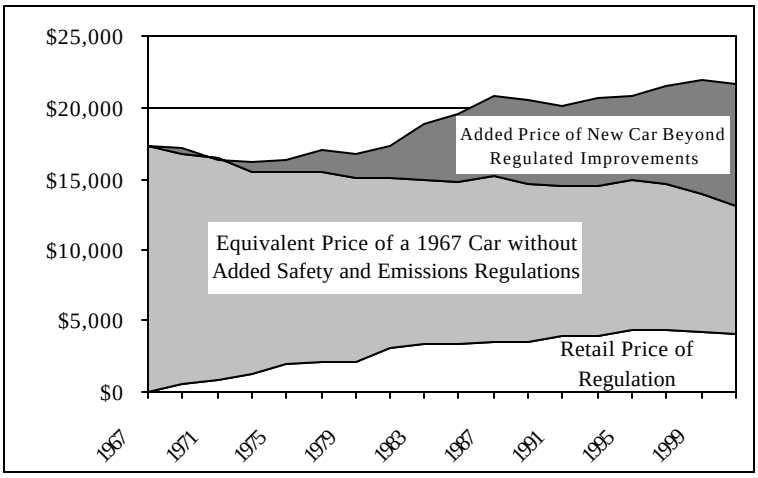
Government regulations to improve safety and reduce air pollutant emissions and oil use have added significant cost to vehicles. But how much – both in absolute terms and relative to the costs of other vehicle improvements?

This question is remarkably difficult to answer, mostly because of paucity of data on costs of complying with government regulations. The best source of aggregate regulatory cost compliance data is from the US Bureau of Labor Statistics (BLS), which annually estimates the cost of "quality improvements" to vehicles. They break these quality improvement costs into regulated and non-regulated improvements. Regulated improvements are for safety and emissions. We compare those cost estimates with average vehicle "transaction" price estimates by US Bureau of Economic Affairs (BEA), published in Ward's Automotive Yearbook (annual) to determine the proportion of vehicle price increases attributable to regulations.

Some analysts add the annual estimates of costs resulting from regulation into a cumulative total. That is incorrect. As noted above, there are sharp learning improvements with emissions and safety technologies, far more than with other non-regulated quality improvements since the non-regulated quality improvements tend not to be new technologies and not to have sharp learning improvements.

A better approach is to analyze data on quality improvements for current vehicles (see Figure 3). According to the BEA data (reported in Ward's), the sales-weighted average price of vehicles sold in 1967 was $3,200 in current dollars, including a very tiny amount (about $11) for regulatory quality improvements, for safety and emissions. If one applies the new vehicle price index (NVPI) to the 1967 price, the price of a car with identical quality would be $9,120 in 2001 in 2001$. But the actual 2001 price (from BEA) was $21,600. Hence, quality improvements and other cost factors between 1967 and 2001 account for $12,480 of the price of the 2001 car.

Figure 3 Average Transaction Price for a New Car in 2001$



Note: The light gray area represents the estimated average transaction price for a 1967 comparable car with no regulated or non-regulated quality improvements. The white area represents the value of added safety and emissions equipment as determined by the U.S. Bureau of Labor Statistics (BLS), all inflated to current dollars. Note that prior to 1980, the cost to improve fuel economy was included with quality improvements "beyond regulated improvements" (in the dark gray category), but since then has been included with the cost of regulation. The dark gray area shows the change in transaction price accounted for by non-regulated improvements plus other quality and price increases.
Source: BEA and BLS data as reported in Ward's (annual).

Separately, Ward's, using BEA data, estimates the total price of improvements due to regulations for 2001 cars to be $4020. Thus, regulations accounted for about 1/3 of the price increase between 1967 and 2001. The ratio between 1975 and the present would also be about 1/3.

We believe that the cost estimate of $4020 per vehicle to meet emissions and safety regulations to be high. One industry expert contends that safety and emissions regulations added about $2,500 to the price of an average new car in 2000 (Weidenbaum, 2000, p. 14). We believe this number to be closer to reality.

As indicated in Finding #2, the cost of emission control is no more than $1000 per vehicle. We did not conduct a similarly comprehensive analysis of safety costs, but did examine airbags, the costliest safety item in the vehicle. Since 1999, dual airbags have been required for all light duty vehicles sold in the US. Additional airbags are beginning to become widespread on vehicles. We consider the cost of dual airbags as automaker responses to regulations, though we note that airbags are now more a response to market demand than regulatory requirements.

There was significant debate over the cost of airbags in the early years. A teardown analysis in 1988 of airbags for the Ford Tempo determined that the cost for a Ford driver-side airbag was $391 at a production rate of 350,000 units, and $1,233 at 25,000 units (2002$) (Khadilka, 1988). Ford offered the airbags on 1987 and 1988 Tempos and Topazes as an option for $815 ($1,233 in 2002$), but sold only about 13,000 and reported that they suffered significant losses (Automotive News, 1988). By 2000, volume was

dramatically higher and costs had fallen accordingly. Another teardown analysis employing the same methodology found that a driver-side airbag on a 2000 Ford Taurus had a cost of about $180 (2000$) at a production volume of 250,000 units (Spinney, 2000). In fact, Ford inserted these airbags in their 382,035 2000 Ford Taurus's and similar versions on all of the company's 4 million 2000 passenger cars and light trucks sold in the US.

Thus, the cost of dual airbags in 2000 was several hundred dollars. Doubling these costs to reflect retail prices, and adding in other safety features is unlikely to boost the average safety cost per vehicle much beyond $1000.

In summary, the BLS estimate of $4018 per vehicle for regulatory compliance seems overstated, and thus the estimate that emissions and safety regulation accounted for 1/3 the cost of vehicles over the past few decades should be treated as an upper limit.

#2: Cost of complying with emission standards peaked in the 1980s.

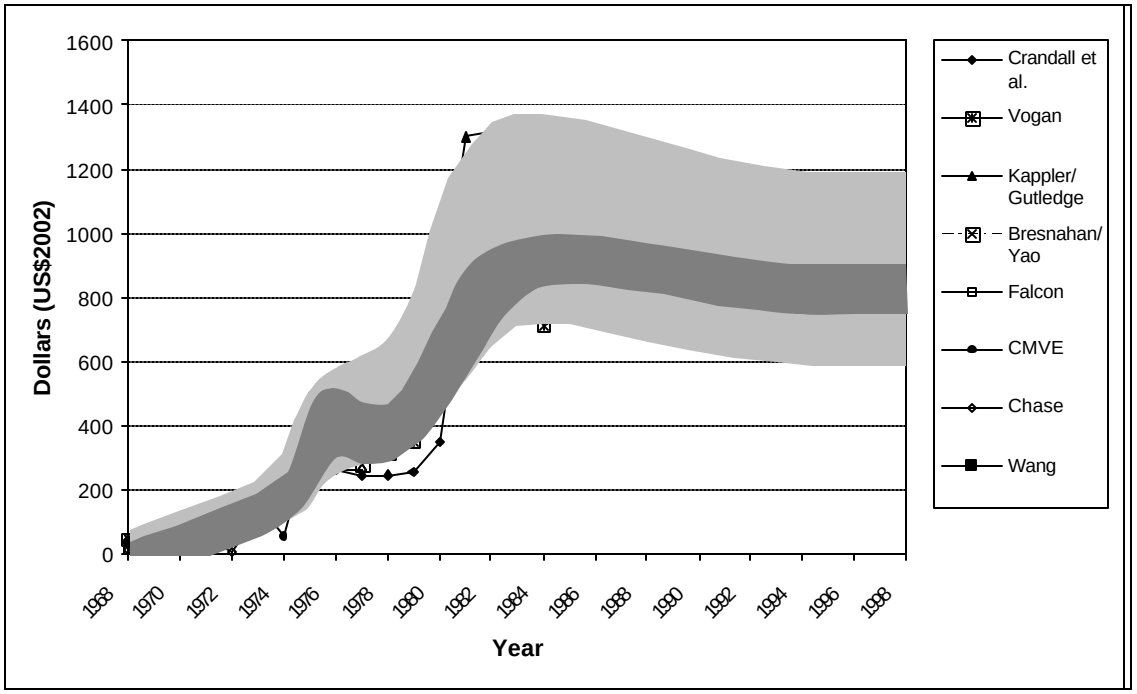
Our detailed analyses of emission control costs suggest that cost per vehicle peaked in the early 1980s and only now in 2004 are starting to approach those levels again.

Emission control cost calculations are difficult and uncertain. Emission control costs should include research and development expenditures as well as new tooling machinery in factories to build the new control devices, but untangling those costs from other R&D and manufacturing costs is difficult because vehicles are designed as integrated systems and a single vehicle part may serve multiple functions (e.g., electronic fuel injection improves performance and energy efficiency, as well as emissions). Moreover, costs vary depending on vehicle weight, engine design, and engine calibration, and also by manufacturer.

A number of cost estimates have been made of emissions control systems, each using different methods (Figure 4). They indicate that the cost per vehicle for emission control jumped in 1975, mostly because costly catalytic converters were needed to respond to tightened hydrocarbon and carbon monoxide standards, and again in 1981, this time with three-way catalysts and electronic controls, motivated by the need to meet tightened nitrogen oxide standards. Estimates of emission control costs per vehicle for 1981 range from $875 to $1350 (US$2002).[2] These costs subsided thereafter, well into the 1990s as continuing improvements were made in design and manufacturing (see Finding #4 regarding innovation effects).

[2] Strictly speaking, these emission control "cost" values are actually retail values – that is, cost to the consumer – and thus are directly comparable to vehicle prices.

Figure 4 Emissions Equipment Control Costs, 1968-1998



Note: Compliance costs associated with emissions regulation vary widely depending on manufacturer and vehicle size. The lightly shaded area represents uncertainty in average control costs. The darker shaded area represents our best assessment.
Source: Chen et al, 2004a (based on cited studies)

Beginning in the early 1990s emission control costs began to increase once again, the result of new (Tier 1 and LEV I) standards adopted in 1990 by California and the US EPA. Retrospective analyses by the California Air Resources Board staff suggest that the cost of reducing emissions from 1990 levels to "ultralow" levels (California's ULEV standard) was about $200.

The net result is that about $1000 of the retail cost of today's vehicles is incurred to meet emission standards -- roughly the same cost that was incurred in the early 1980s, when emission standards were far less stringent.

One study provides additional insight and detail. Wang et al. (1993) used a parts-pricing approach on model year 1990 vehicles to find that emissions control costs vary widely depending on vehicle class and manufacturer. For example, US manufacturers spent only $250 (US$2002) on average for emission control per compact car, while European manufacturers spent $1680 per vehicle for large cars.[3] In general, that study found costs were less for smaller vehicles, more for Japanese manufacturers presumably because they were more risk averse and aimed for a larger buffer below the standard, and more for Europeans automakers who supplied a greater share of luxury cars with presumably

[3] These costs are costs to the manufacturer. To convert them into costs to the consumer (and to make them comparable to other emission costs presented elsewhere in this report), they should be inflated about 40% to represent manufacturer and dealer markups.

smaller economies of scale and higher quality. Since 1990, circumstances have changed, but significant cost differences presumably still exist across engines and vehicles, and probably manufacturers as well.

#3: Cost increases associated with regulations have been swamped by year-to-year variability in vehicle price.

Because of long time lags in implementing new government rules (often due to industry challenges) and continuing R&D, and in some cases strong consumer demand for new safety devices, automakers have not experienced large cost shocks in any single year. Having said this, we are not endorsing delay; long delays and uncertain requirements are not a model of good rule-making. In many cases, regulatory delays and uncertainty resulted in inefficient investments by industry as they tried to gauge uncertain market demand and uncertain implementation of government rules. The result was more pollution and more fatalities over those years.

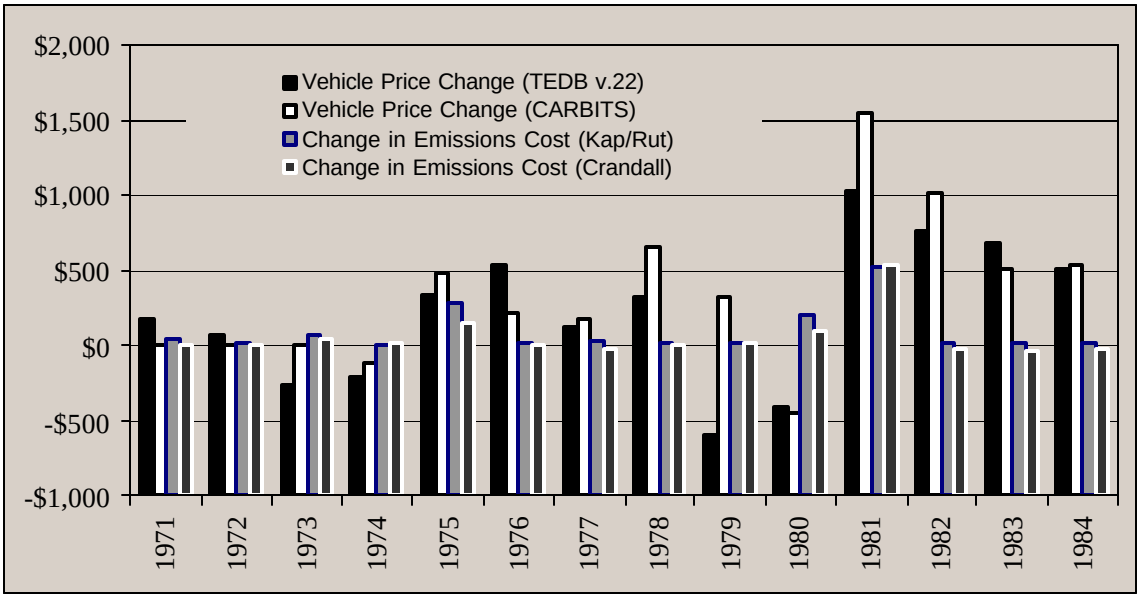
The more specific point here is that, while regulatory compliance costs have been substantial and influential, they have not played a significant role in the pricing of vehicles. Vehicle prices have steadily increased over time, far exceeding the costs of emission control and safety equipment. These price increases have fluctuated considerably on a year-to-year basis. These two effects, price increases and price fluctuations, tend to swamp typical compliance cost increases for emission control and safety – even, as we have seen, when regulatory compliance costs have been especially large. These cost increases, to the extent they are substantial, are dealt with in the short run by a variety of pricing and marketing strategies and by allocating R&D costs further into the future and over more future models.

Indeed, even during those times when large new emission and safety costs were imposed (for catalytic converters and air bags), prices for particular models and even vehicle classes fluctuated considerably, both up and down. During some years, vehicle prices declined for one class but increased for another. During the volatile 1979-80 period, the average price of a subcompact car increased by $465 while midsize car prices decreased by over $2000 (2002 dollars). In recent years, financing incentives and sales rebates have introduced even more price variation – not necessarily in terms of the manufacturer's suggested retail price (MSRP), but in actual prices paid by customers. For instance, in 2002, GM offered an average of $1500 per vehicle in financial incentives, including $3,855 per vehicle in the third quarter of that year (Automotive News, 2002).

In comparison, annual changes in compliance costs for emission and safety standards over most of the last three decade have been rather small. In only a few years over the past 35 have increases in emission costs exceeded the change in vehicle price (the number of years depending on study method and data used) (Abeles et al, 2004; Burke et al, 2004; Chen et al, 2004a).

The response of automakers in 1975 and 1980-81 is instructive, since this is the time when emission control costs increased most sharply – $300-$500 per vehicle in a single year. Figure 5 compares emission costs to vehicle price for these periods. In those two time periods of interest, vehicle price increases were considerably greater than emission cost increases. Was the intent to completely recover costs immediately? Probably not, for reasons we elaborate below. These were volatile times for the industry, with fuel prices rising sharply and, in the 1980-81 period, aggressive CAFE standards taking effect.

Figure 5 Change in Vehicle Price vs. Change in Emission Control Costs, US, 1970-84



Source: Chen et al, 2004a

In summary, in most years, the effects of emission standards on vehicle prices cannot 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 are just one more factor used by companies in setting prices. And thus, aggregate new car sales have been affected only in a minor way by safety and emissions regulations.

Finally, the effect of emissions and safety regulations on overall vehicle sales is speculative. Emissions and safety regulations clearly added cost to vehicles, but they also added value. Without those rules, vehicles would be more dangerous and more polluting – but less costly. Without the government regulations, it is unknown whether overall demand for vehicles would be more or less.

#4: Technological innovation dampens the cost of complying with new regulations.

New regulations that improve vehicle safety and environmental and energy performance also impose additional costs. But these additional costs are not permanent nor cumulative. As with any new products or technologies, with time and experience engineers learn to

design the products to use less space, operate more efficiently, use less material, and facilitate manufacturing. They also learn to build factories in ways that reduce manufacturing cost. This has been the experience with semiconductors, computers, cell phones, DVD players, microwave ovens – and also catalytic converters and airbags, and will certainly be the case with future technologies such as fuel cells.

Experience curves, sometimes referred to as "learning curves," are a useful analytical construct for understanding the magnitude of these improvements. Analysts have long observed that products show a consistent pattern of cost reduction with increases in cumulative production volume. In essence, manufactured products tend to decline in cost by 10-30% with each doubling of *cumulative* production volume (see Lipman and Sperling, 2000). This logarithmic effect means that cost reductions are achieved rapidly early in a product's history, when doublings in cumulative production occur relatively quickly, and then more slowly as the doublings take longer to achieve. Thus, if a product can gain an initial foothold in the market due to some competitive advantage – or government regulation -- this triggers a cycle of innovation that results in continuing cost reductions.

Innovation tends to reduce costs over time, as is the case with emissions and safety improvements -- though continuing tightening of standards can introduce more cost. In the case of emissions, learning improvements have been so substantial, as indicated earlier, that emission control costs per vehicle (for gasoline internal combustion engine vehicles) are no greater, and possibly less, than they were in the early 1980s, when emission reductions were far less (see Table 1).

In practice, the relationship between regulations and innovation is complex and far reaching, with substantial positive indirect effects. Tightened emissions and fuel economy standards played a central role in motivating the development of an impressive array of new and improved technologies that were rapidly introduced in passenger cars starting in the mid 1970s, continuing to the present time. Many of these innovations would have eventually been introduced without the standards, and many provided a wide array of benefits and enhancements. These innovations included engine and fuel sensors, computers, electronic ignition control, lightweight materials, four valves per cylinder, variable timing, cylinder deactivation, and rapid engine stop-start. Indeed, the adoption of aggressive emissions, energy, and safety requirements in the 1970s is often credited with accelerating innovation in the automotive industry (Maynard, 2003). Those standards may also have aided the competitiveness of the domestic auto industry by forcing it to innovate earlier than otherwise, giving it more time to respond to the newly competitive foreign competitors (Kawahara, 1998). In any case, the rate of innovation in the auto industry began accelerating in the 1970s (Santini, 1985 and rapid innovation continues to the present day, with a host of innovations, including hybrid-electric powertrains, aimed at improving energy and environmental performance.

#5: Compliance costs are not immediately converted into higher price and are recovered with a variety of ad hoc tactics.

As a general principle, companies want to pass costs through to consumers as fast and fully as possible. In practice, though, the costs of complying with regulations are not immediately passed through to customers in higher prices, nor are costs passed through equally to all new vehicles and classes.

Using a model of vehicle prices and profits they developed, Robert Crandall of Brookings Institution and his colleagues (1986) found that automotive manufacturers fully absorb additional regulatory costs in 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. 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" (Schnapp, 1978, p. I-91). Economists, viewing compliance costs as analogous to a unit sales tax on the industry, assert that competitive firms should be expected to pass on as much of this "tax" as possible, since subsidizing consumers indefinitely would reduce profit margins.

One phenomenon mitigating the rapid pass-through of costs are innovation effects, as indicated in Finding #4. With time and experience, the cost of making and installing catalytic converters, sensors, airbags, and so on is reduced.

Another phenomena, a deliberate strategy used by automakers to restrain price increases, is decontenting. In this case, automakers convert standard equipment into optional equipment, replacing materials such as tires, fabric, and carpet with inferior substitutes, or eliminating some features altogether, such as vent windows or arm rests (Braden et al, 1979, p.100).

More broadly, vehicle pricing is a complex art in which prices are only loosely connected to costs. In setting prices, automakers consider not only production costs, but also overall return on investment, sunk costs, expected sales, shifting consumer demand, prices of competing new and used cars, long term buyer loyalty, and market conditions.

Pricing strategies generally fall into three categories: cost, image, and competitive 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. Base vehicle prices and option prices fall within a narrow margin among the manufacturers (Braden et al, 1979, p.30; Kawahara, 1998). This approach was dominant until the 1970s. Image pricing bases the price of a vehicle on its appeal within the market. Luxury models and, more recently, SUVs are typically priced using this method.

The SUV phenomenon, along with light duty trucks more generally, are particularly instructive in highlighting the complexity of pricing – and, by extension, the small role of regulatory compliance costs. In 2000, a fully loaded Lincoln Navigator was estimated to

earn as much as $15,000 profit per vehicle (Bradsher, 2002, 85). One single factory, where the large Ford Expedition and Navigator SUVs were assembled, generated $2.4 billion in after-tax profits in 1998, one third of the company's entire profit for the year (Bradsher, 2002: 89).[4] Similarly, while it cost Ford about the same amount to build their Taurus sedan as their full-sized pick-up, they priced the pick-up $5000 higher (Rubenstein, 2001, 241).

A third approach is competitive pricing. This broad category encompasses the many other tactics used in pricing. One tactic is to lower prices of entry-level vehicles so as to attract new customers, with the hope they will become loyal to the brand and move up later to more profitable models. Another tactic is to price vehicles with high fuel economy lower so that they can sell more high-profit luxury cars (with low fuel economy).

Another competitive issue affecting pricing has to do with what have become known as legacy costs. The historical US companies -- General Motors, Ford, and Chrysler -- have a legacy of many manufacturing plants, longstanding labor contracts, and a large number of retirees. They are burdened by the high cost of health insurance and pensions for these many retirees, find it difficult to dispose of existing facilities, and are limited by labor contracts that require them to continue paying laid-off workers (Bradsher, 2002: 91). As a result, these three companies have a large incentive to resist further erosion of their market share, and to price their product accordingly – that is, to price vehicles low enough to ensure high sales (Rubenstein, 2001).

Neither the literature nor industry analysts provide a framework that explains automaker pricing behavior, and nowhere did we find evidence of formal quantitatively based scientific strategies. Our interpretation of the case studies and various discussions with executives and analysts suggests that companies pursue the following general guidelines:

- Restrain price increases
- Increase prices for products where demand is less sensitive to price increases
- Maintain sufficient sales volume for vehicles with good fuel economy so as to avoid CAFE fines
- Design (and fine tune) vehicle prices to achieve sales targets, which had been used to design and retool factories for that product and to manage labor needs.
- Pass costs upstream to parts suppliers as much as possible.
- Identify regulatory and policy "loopholes" to avoid costs and enhance profits.

Of course, companies might employ a wide variety of tactics in responding to these guidelines. They might increase the price of after-market parts, reduce the number of options available, "decontent" vehicles, and offer longer term financing to customers.

In a broader sense, companies may increase prices across their fleet or for selected makes and models, introduce costly changes only on certain vehicles or in certain markets, and

[4] Auto manufacturers do not publish profits broken down by individual model or assembly plant. They do, however, give special briefings to Wall Street analysts on costs and profits, and these analyses sometimes find there way to journalists, such as Keith Bradsher of the New York Times, who disclosed these analyses in his book.

change the mix of vehicles offered. Indeed, as a means of pursuing profits in a highly competitive and shifting market, automakers are constantly readjusting their vehicle mix, vehicle options, pricing, and financing incentives.

It is well known that automotive companies cross-subsidize certain vehicles on a sustained basis -- to attract new customers to their entry-level cars in anticipation that they will later move up to more profitable vehicles, to create a vehicle mix that will help meet the company's CAFE standards, and to boost sales and recoup huge upfront investments for products not meeting planned sales targets.

Pricing is also influenced by the huge upfront investment required to launch new models -- upwards of a billion dollars. To maintain profitability in a complex business environment of high fixed costs, unpredictable economic conditions, and varying consumer tastes, companies employ a wide variety of manufacturing, marketing, advertising, and financing strategies.

In summary, vehicle pricing is only loosely connected to costs. As a general principle, automakers try to recover costs of complying with regulations as quickly as possible. But cost recovery strategies vary according to a wide variety of circumstances, and are generally dwarfed by other considerations. It is instructive to note that in some years, vehicle prices actually dropped when emission costs increased (see Figure 5).

#6: Manufacturers spread the cost of new technologies across a broad range of models and markets.

During the intermittent and often contentious zero emission vehicle debates in California, automakers sometimes asserted that the high cost of producing battery electric cars, well above what customers would be willing to pay, would obligate them to raise the prices of all vehicles sold in California to compensate them for the extra cost. The more general question is whether automakers try to recover cost increases in the same regions where they sell the new costly products, whether sold voluntarily or not? It is a relevant question when the new product has high R&D and/or upfront tooling expenses. This question might apply to a wide range of products, such as hybrid vehicles sold disproportionately in Japan and California, cold weather features designed for Alaska and Canada, and emission controls designed for Denver and other high elevation locations.

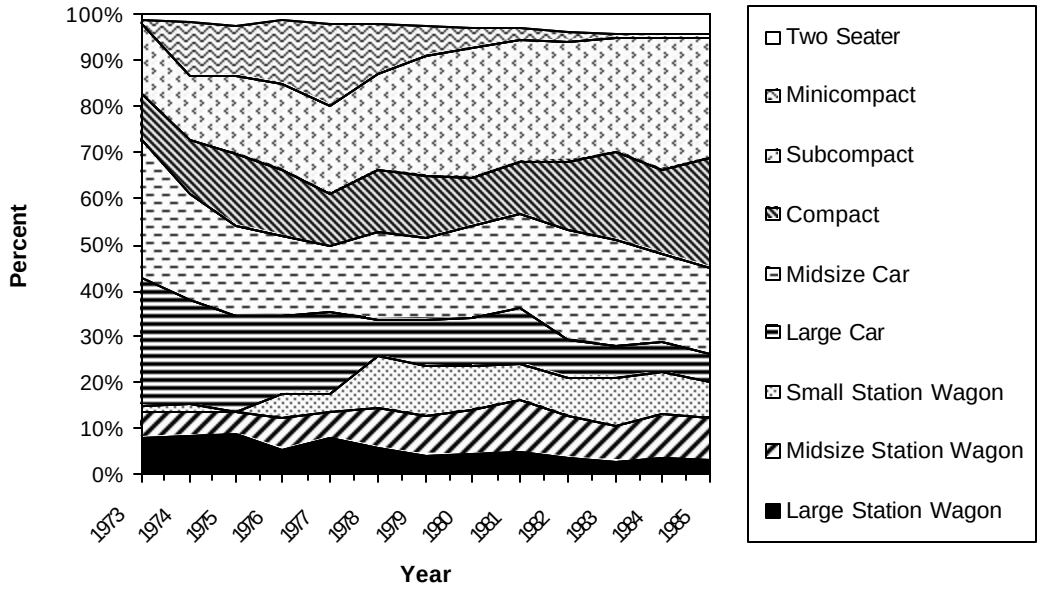
We found no evidence that automakers make a strong effort to recover costs of new expensive products in the same regions where they sell them, at least initially. For instance, vehicle prices in California in 2003 had the same MSRP as vehicles sold elsewhere in the country, even though cars sold in California had to meet more stringent emission standards (though the differential was not great). One exception highlights the point. Ford sells a version of the Focus in California that meets stringent PZEV (partial zero emission vehicle) requirements. They offer the same vehicle elsewhere in the country, but with the PZEV option priced $115 extra. The actual cost increment is much greater. The additional cost for emission control is estimated by CARB to be about $100,

but this PZEV car not only has extra emission control, but also is fitted with a more powerful engine. Jim Cain, a spokesperson for Ford, said, "We only charge $115 for several hundred dollars' worth of improvements… The Focus competes in a very price-sensitive segment of the market. If we charge too much money, we might not achieve our volume objective" (Wired, 2003). And thus, even if customers buy the PZEV model, Ford is not recovering the extra cost of emission control, and is essentially spreading the cost increment broadly across its customers (and stockholders).

#7: Regulations sometimes induce manufacturers to alter their volume and mix of vehicles.

Vehicle attributes and vehicle mix are not static (see Figure 6). Large station wagons virtually disappeared in the late 1970s, minivans emerged as a new vehicle class in the early 1980s, sport utility vehicles increased their share from near zero in the early '90s to almost 20% in 2002, and in the early years of this century, a variety of crossover car-truck models are being launched. Clearly, the automotive industry has a history of being able to transform their product offerings in periods of less than a decade (though companies generally prefer more stability).

Figure 6 Distribution of Carlines by Vehicle Class



Source: Chen et al, 2004a.

We found only three cases where regulations clearly altered the volume and mix of vehicles. The first is in the late 1970s and early '80s. In Figure 6, one can see the continuing shifts in vehicle mix during this period. Subcompact and compact cars increased from ¼ of all cars in 1970 to half in 1981. During this period, stringent

emission standards were adopted. But it also the period when fuel prices more than quadrupled and were expected to continue increasing, and fuel economy standards were imposed. CAFE standards played an important, though controversial role in this shift to smaller cars, along with large fuel price increases (Greene, 1990). During that time, John Deaver, manager of Ford's economics department, noted 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" (quoted in Schnapp, 1978, p.I-123). There is no evidence that the shift to small cars took place because of the newly stringent emission standards. -- even though emissions can be reduced more easily and less expensively in smaller cars (Wang et al, 1993).

CAFE standards played a role again, later, in influencing product mix, this time encouraging the introduction of minivans, pickup trucks, and SUVs. In this case, safety and emission standards also played a small complementary role. This time period was the 1980s and thereafter.

In 1980, cars accounted for 80% of light duty vehicles; by 2001 the share was less than 50% -- the remainder being light trucks. In 1980 most light trucks were pickups; by 2001, sport utility vehicles (SUVs) were the largest light truck category, accounting for 20% of all light duty sales. Regulations played some role in this shift, though no rigorous analysis has ever been conducted. Emission and safety standards were less stringent for light trucks than cars throughout this time period, and perhaps played some role in encouraging a shift to light trucks (Kockelman, 2000). But the more important effect was CAFE standards. Aggressive CAFE standards for cars, along with high fuel prices, played a central role in the demise of large station wagons in the late 1970s, while the more lenient CAFE standard for light trucks, along with dropping fuel prices,[5] encouraged manufacturers to emphasize minivans in the 1980s, and then SUVs in the 1990s

CAFE standards certainly played an important role in the emergence of light duty trucks. But other policy and market factors played an even stronger role. Perhaps the strongest indicator of these other factors was the huge profitability of SUVs in the 1990s. As indicated earlier, Ford's SUVs and large pick-up trucks were far more profitable during this era than cars. This high profitability was an outcome of industry dynamics and government policy. Japanese and European automakers did not have large markets for light trucks in their home markets (because of high fuel prices, dense cities, and so on) and thus were slow to enter this market. And a variety of policies helped created this market and high profitability. Less stringent CAFE, emission, and safety standards for light trucks played a role (larger SUVs are not even covered by CAFE and some safety standards). But also important was the US government adopted protectionist policies that discouraged the importation of these vehicles, creating the potential for high profits. The

[5] Gasoline prices increased from $1.14 per gallon (for leaded regular) in 1972 (in 1996 dollars) to $2.21 in 1981 (for unleaded regular), dropping steadily to $1.23 in 1986, and then continuing along with small fluctuations to $1.23 in 2002. (U.S. Department of Energy, cited in Burke et al, 2004).

US government imposed a 25% tax on all light trucks in 1964, and did not reduce it until 1989, to 2.5% for SUVs and minivans, leaving the 25% tariff in place on pickups.

A third case where regulations had an effect on product mix is the emergence of diesel cars in Europe. Diesel vehicle sales in the European Union (EU) increased from 23% of all light duty vehicles sold in 1994 to 41% in 2002. This rapid increase in market penetration was due to four related factors: a voluntary agreement by European automobile manufacturers in 1998 to reduce CO_2 emissions from new light duty vehicles by 25% from 1995 levels by 2008; significant advances in diesel technology; preferential fuel and vehicle pricing in most European countries; and preferential European Union regulation of diesel emissions (Chen et al, 2004b).

The voluntary agreement and the preferential emission standards were key. It was explicitly understood that if automakers did not meet the goals of the voluntary agreement, then firm enforceable rules would be put in place. Automakers determined from the outset that the easiest and cheapest way to meet the goals was largely by switching vehicles to the more efficient diesel engines. The EU supported these corporate plans by accelerating the introduction of clean diesel fuel (thereby allowing diesel cars to meet emission standards more easily) and permitting diesel cars to meet less stringent emission standards. As documented in Chen et al (2004a), light duty diesel emission standards in the EU are several times higher than gasoline standards for both nitrogen oxide and particulate emissions (per vehicle kilometer). In contrast, in the US and California, diesel cars and light trucks must meet the same stringent emission standards as their gasoline counterparts. The result of these aggressive CO_2 and diesel-friendly policies and rules is the transformation to diesel cars. Diesel cars are widely expected to exceed 50% of light duty sales in the EU by the end of this decade.

These three cases are instructive. They highlight the few but influential cases where government regulations and related policies have significantly impacted the mix of offerings by automakers. But it is instructive to note that in each case, the government regulations and policies were operating in unison with shifts and differences in fuel prices. In the shift to small cars, fuel prices were soaring. In the shift to light trucks, fuel prices were dropping. And in Europe, diesel fuel prices were much lower than gasoline prices.

#8: Manufacturers have used non-pricing strategies to overcome consumer resistance to price increases resulting from regulations.

When a new product or attribute has perceived value in the marketplace, that company will try to take advantage of it. When Chrysler became the first non-luxury automaker to offer airbags across their entire vehicle line, the move was supported by a memorable print and television advertising campaign. TV ads included:

- A live stunt driver crashing into a barrier with him hitting the airbag in slow motion, and then getting out of the car nonchalantly as if he had just stopped at the grocery store.

- Lee Iacocca sitting with survivors of horrific crashes that attributed their survival to the airbag in their Chrysler vehicle.
- A re-enactment of the post-crash scene of two Chrysler LeBarons that had suffered the first known head-on collision between two airbag-equipped cars.

Advertising can be effective to a point. It can help generate sales when the product is in line with consumer preferences, as with SUVs and airbags in the 1990s, but not when consumers are fundamentally disinterested, as with fuel efficient cars during the same time period. And when the product is perceived as inferior or poor value, as with GM's Vega in the 1970s, even heavy promotion is ineffective.

Another non-pricing strategy is lengthening of loan payback periods, making increasingly expensive cars more affordable. The average maturity rate for auto loans has nearly doubled, from 35 months in 1971 to 60 months in 2003. A number of independent finance companies in the western United States have recently offered loans as long as 96 months (Automotive News, 2003).

More broadly, automakers and dealers have increasingly turned to financing incentives to maintain high sales volumes during economic downturns. Since September 11th, 2001, General Motors has led the industry in expanding the use of zero percent financing and rebates. By October 2002, GM, Ford, and DaimlerChrysler were spending an average of $3,764 per vehicle, or 14 percent of the selling price, on all types of incentives (Automotive News, 2002).

Cut-rate financing and cash rebates are not new for the auto industry. These measures began in the mid-1970s as a means to move end-of-the-year inventory and particularly slow-selling models. Such marketing approaches have remained a way to reduce inventory and maintain market share. The excess capacity in the auto industry, particularly for GM, Ford and Chrysler, explains the need for those companies to maintain sales. Utilization of US automotive plant capacity has dropped from around 60% in the late 1980s to the high 40s in the early years of this century. Bill Lovejoy, V.P. of GM, stated in October 2002 that, "incentives will stay in place until demand is more aligned to capacity" (Automotive News, 2002). With the Japanese and European companies building new plants in the US, but total vehicle sales remaining flat, pressure on GM, Ford, and Chrysler to maintain sales and market share becomes more severe.

#9: Industry behavior toward new technologies is not related to whether or not they were the result of government regulation.

Companies adopt and promote new products and attributes based on their marketability, profitability, and market positioning strategy. If they are required to adopt it, and they perceive no market value in it, they will of course do whatever they can to minimize their investment and losses, short of tarnishing the brand. Thus, GM purchased slightly retrofitted golf carts and gave them away in California in 2002 as a way of meeting their ZEV requirements at least cost. They did not associate their name with the product in any

way. Likewise, companies aggressively resisted airbag requirements for years because they believed the cost would be large and the perceived customer benefits small. When consumers began to value safety in the 1990s (and costs came down), car companies warmed to airbags and aggressively advertised and promoted them.

In the early years of this century, Toyota widely promoted its Prius hybrid electric car in print media and billboards, even though demand continued to exceed supply. They did so because it gave the company a halo effect – an image of environmentalism and advanced technology.

#10: The effect of fuel cost savings on vehicle purchase decisions is poorly understood.

Using an economic model to explain consumer behavior, the automotive industry and various studies have concluded that car buyers demand a three-year payback for fuel-saving investments (see Kurani and Turrentine 2004a for elaboration). Sometimes these findings are couched in terms of "discount" rates (a three-year payback being equivalent to a 30-40% implied discount rate). The underlying theory is consumers calculate how long it will take to get back money they spend on buying an alternative fuel or fuel-efficient vehicle. For example, suppose the consumer estimates that a more economical vehicle will cost $600 more to buy, but that he or she will save $200 per year in fuel costs. Their payback period would be three years. A more sophisticated approach would use discount rates, to analyze the opportunity costs of the additional upfront expenditure for the more expensive but economical vehicle, or even to consider differences in maintenance costs, refueling inconvenience, and other related factors.

This idea that consumers use payback periods or discount rates in making decisions is not widely accepted outside economics. Even the idea of payback calculations is seldom observed in household decision-making. Consumer researchers, particularly those looking at energy using appliances have argued that such calculations are beyond most consumer decision capabilities (Stern, 1992; Chater et al, 2003) and do not fit with cultural models of behavior (Kempton et al, 1995). In practice, consumers do not expect financial payback on vehicle attributes. Few vehicle attributes seem to be viewed in this rational economic way, and few consumers think this way. For example consumers do not expect financial payback on leather seats, acceleration or safety. A possible exception is reliability, but even here, consumers are more likely to search for a reliable brand or reputation than they are to make any calculations.

In a detailed study of vehicle purchases by over 50 households currently underway at ITS-Davis, we find that few households know their annual fuel costs, fewer still could or would make comparisons between vehicles based on payback, and none characterized purchase decisions in terms of opportunity costs over time (Kurani and Turrentine, 2004b). Many participants do not know the fuel consumption (miles per gallon) of their current vehicle and few households budget the cost of fuel. The one thing most car buyers

do know is the cost of a filling their fuel tank (though many do not know how many gallons are in a tank nor how many miles they travel with a tank full of fuel).

Much of this inattention to fuel use may be due to the relatively small cost of fuel for most households. When pressed to state a payback period related to higher fuel economy, many households have been unable to estimate or even imagine one. Most commented that they had never thought about payback periods, and imagined that they would have to "do some math." One financial analyst responded to our questions about the possible role of fuel savings in his household's vehicle purchases, saying, "Oh, you mean the payback period. I never thought about it (fuel economy) that way."

What is clear is that no household in their sample, not even those who understand the calculations to find a payback period, ever actually made such calculations about fuel costs for their automotive purchases. If they do offer a payback period, they arrive at a number in one of a number of ways, including the following:

- Length of time they financed a recent vehicle (typically three to five years)
- Length of a lease of a current vehicle (often five years)
- Length of ownership of a vehicle (depends on household and vehicle)

Some are optimistic, imagining they spend much more on fuel per year than they really spend and that paybacks are possible within one or two years. None mention discount rates for future fuel savings.

Similarly, attempts to "measure," and therefore to establish, consumer payback calculations or discount rates for diesel markets in the 1980s in the US or 1990s in Europe are off the mark in a similar way, and lack direct investigation of consumer decisions.

Based on this new research, we believe that consumers do not use the concept of an average payback period in making purchase decisions. It is not a valid measure of consumer awareness, knowledge, or use of fuel economy information, and probably represents a diverse set of unformed and *ad hoc* responses to an unfamiliar and inappropriate question. And there is no grounded behavioral evidence that a three year payback period describes behavior in an aggregate manner nor for an individual.

Similarly, attempts to measure and calculate consumer payback periods or discount rates for diesel car buying in the US in the 1980s or in Europe in the 1990s are off the mark in a similar way. They lack direct investigation of consumer decisions.

Improved understandings of buyer behavior are critical to predicting consumer response to new greenhouse gas emission standards, since new technologies and attributes will often be tested and introduced sequentially into particular vehicles in particular geographic markets to particular buyer segments. It is especially critical to the formulation of policy and regulations.

#11: Demand for environmental attributes in vehicles is weak -- and poorly understood.

Currently, little is understood about demand for environmental attributes of vehicles. Surveys show strong policy support for air pollution (Public Policy Institute, 2002), but how might that air pollution concern evolve into demand for cleaner vehicles? And how might other even less salient environmental and energy concerns -- for energy security and climate change -- evolve into stronger policy and buyer demand? The answers are entangled in deeper values and preferences related to consumer sovereignty, collective choice behavior, and environmental quality that vary across regions, social groups, and even nations. The problem is that these values, beliefs, and behaviors are not well understood, and thus it is difficult to assess how governments might best intervene – for instance via laws such as California's AB 1493.

The analytical difficulty is that vehicle buyers have rarely faced the choice between products offering *only* different levels of performance on environmental measures. Those cases in which it appears consumers may have had such a choice typically do not involve the choice of *which* new vehicle to buy, but *whether* to buy a new vehicle. The massive switch to unleaded gasoline (and catalytic converters) in the US in the 1970s is one example. With only minor exceptions, consumers could not choose which new car or truck to buy based on their "preference" for leaded fuel or the effectiveness and maintenance cost of their car's emission system. If they preferred leaded gasoline, their only choice was to not buy a new vehicle.

In still other cases, distinct environmental differences, such as emissions of criteria pollutants, were simply never marketed—even in the case of cars versus light trucks. No one—not federal or state governments, not environmental advocacy groups, and certainly not motor vehicle manufacturers—engaged in a systematic effort to educate and inform the public about the fact that light-duty trucks were allowed to be more polluting than were cars for over 30 years (though new rules now require all light duty vehicles in California to meet the same standards, with similar national rules to take effect soon).

The case of airbags is instructive in demonstrating the changing nature of preferences. Interest in safety regulation gradually increased over time, initially aroused by Ralph Nader's 1965 book, *Unsafe at Any Speed*. Support for government intervention eventually evolved into a willingness to pay extra for safety features. This evolution took over 25 years in the US.

The hybrid electric vehicle experience may provide valuable new insights. Preliminary results from a UC Davis study indicates that buyers of the Toyota Prius value low air pollutant emissions equally with the high gas mileage (Kurani and Turrentine, 2004b). Many Prius buyers would have otherwise purchased larger and more expensive vehicles, and have been willing to downsize to the Prius because of its progressive technology. Many buyers speak of wanting to be part of a change, a movement. Who are the hybrid vehicle buyers, how are they making choices, and how representative are they of current

and evolving desires and beliefs? These are key questions that remain largely unanswered.

CONCLUSIONS

The era of vehicle regulation is rather short, but rich in experience. Government regulations in California, US and elsewhere have played a large role in the evolution of vehicle technology. Vehicles are now much safer and lower emitting, and consume less fuel (per mile) than several decades ago. Government regulations played a central role in reducing emissions and improving safety. Emissions improvement occurred almost exclusively because of persistent and aggressive government regulation. Market factors and consumer behavior played almost no role. These improvements initially were quite expensive, but government persisted because air quality retained strong public support. Eventually, technical innovation resulted in continuing improvements at little or no extra cost. Current vehicles are cleaner burning than ever and yet the cost of emission control per vehicle is no greater than it was in the early 1980s.

Safety regulation was more complex and protracted. Automakers effectively resisted passive restraints, and especially airbags, for many years. By the time aggressive airbag requirements were adopted in 1991, consumer demand for safety had grown so strong that automakers willingly incorporated airbags well before the statutory deadlines of 1998 for cars and 1999 for light trucks.

Energy regulation has been the most controversial and most complex. The adoption of the Corporate Average Fuel Economy (CAFE) standards in 1975, taking effect in 1978, had a galvanizing effect on the auto industry. Car fuel economy doubled between 1973 and 1985. But fuel prices also soared during this period. CAFE played an important role, but so did fuel prices. Since then car CAFE standards have remained static, and light truck CAFE standards have increased only minimally.

We reviewed one other enlightening experience: the "voluntary" adoption of carbon dioxide (CO_2) emission standards in Europe by automakers. While voluntary, it was made clear that firm enforceable standards would be adopted if the industry failed to attain large CO_2 emission reductions – on the order of 25% per vehicle for a the ten year period from when they were adopted in 1998 until 2008. They are nearly on track to do so. The principal strategy has been to switch from gasoline to diesel engines, which have inherently lower fuel consumption but higher emissions of oxides of nitrogen and particulates. This diesel strategy has been successful because it has been embraced by most of the European countries. The European Union has maintained less stringent emission standards for diesel cars and most countries tax diesel fuel and diesel cars less.

In summary, the success of government regulation depends on some mix of political and consumer support, and consistent market incentives and signals. There is no formula to predict the necessary mix. But the case studies conducted as part of this overall study and summarized here provide the insights and lessons to guide new proposals.

The history of automotive regulation is remarkable in how little it disrupted the industry. Many changes in product mix and industry organization did occur in parallel with the imposition of new government requirements. The market share of light trucks, first minivans and then SUVs, increased dramatically. The industry became much more competitive, with many more large companies from Japan and later Europe gaining considerable market share. And in the past two decades, vehicles have become larger and more powerful. Government regulations clearly played some role in these transitions. The stringent emissions and fuel economy standards in the 1970s gave Japanese automakers the opening to crack the US market, though the rapidly improving and expanding Japanese industry was likely to do so eventually anyway. And the shift to light trucks was encouraged by the less stringent CAFE standards applied to light trucks (and also less stringent safety and emissions standards), providing an incentive to automakers to shift production to minivans and SUVs.

In the end, though, vehicles prices increased much faster over the past decades than did costs associated with regulations, reflecting the considerable improvements in vehicle quality and performance that have taken place over this time. Indeed, we found that even when costly changes were required in a short time – as with the introduction of oxidation and three way catalysts -- the impact on vehicle prices was barely discernible. Vehicle markets have not been perturbed significantly by government regulation in the US, excepting perhaps the perverse effect of CAFE standards encouraging light trucks (pickups, minivans, and SUVs). In Europe, the situation is somewhat different, but in that case it was a not a single regulatory initiative that led to diesel cars, but rather a cluster of coherent policies and rules.

The fact that government regulations did not cause major automotive industry disruptions is due in large part to the many advertising, marketing, financing, and pricing tools available to companies. For instance, even with rising prices, automakers have maintained the affordability of vehicles by providing financial incentives and doubling the length of financing periods. In the short run, automakers can use these tools to adjust to perturbations, whether imposed by government or external market conditions. And in the long term, they respond with technological innovation and product planning changes – building vehicles that last longer, are more reliable, safer, and more environmentally desirable.

The challenge for government regulators as they formulate new regulatory initiatives is to understand shifting market dynamics, anticipate technological innovation, and forecast likely near and long term cost impacts. Easier said than done.

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