STEERING WITH PRICES:
Fuel and Vehicle Taxation as Market Incentives for Higher Fuel Economy

John DeCicco[1] and Deborah Gordon[2]

December 1993

Presented at the Transportation and Energy Conference
Asilomar, California, August 22-25, 1993
Revised Manuscript for Conference Proceedings
December 10, 1993

[1]American Council for an Energy-Efficient Economy, Washington, DC
[2]Union of Concerned Scientists, Berkeley, CA

American Council for an Energy-Efficient Economy
1001 Connecticut Avenue NW, Suite 801, Washington, DC 20036
2140 Shattuck Avenue, Suite 202, Berkeley, CA 94704

STEERING WITH PRICES: Fuel and Vehicle Taxation as Market Incentives for Higher Fuel Economy

ABSTRACT

This paper examines the likely effectiveness of pricing policies as a way to reduce light vehicle fuel consumption in the United States. Fuel pricing policies include higher gasoline taxes, which could be energy or emissions based. Vehicle pricing policies include the Gas Guzzler Tax, other taxes or registration fees based on vehicle fuel consumption rates, and feebates (which would also provide rebates for vehicles of lower than average fuel consumption). Our literature review indicates that the dominant response to fuel price increases is higher fuel economy, which depends largely on the cost of technology-based improvements to new vehicle fuel economy. The more limited literature on vehicle pricing policies also indicates that technology improvements are the major component of response. Behavioral changes, such as reduced driving in response to a fuel tax increase and shifted vehicle purchase choices in response to a feebate, are consistently found to be smaller in effect. Generally, the effects of either type of pricing policy are uncertain and there will be a degree of poor response when fuel economy standards constrain the market to higher average fuel economy than would occur in an unregulated market. However, fuel economy standards provide a greater degree of certainty that desired reductions in fuel consumption will be achieved.

To put the effects in perspective, we examine a hypothetical goal of holding 2010 light vehicle consumption to the 1990 level. Achieving this goal through fuel pricing alone would involve fuel tax increases amounting to a 100%-200% increase in consumer gasoline price. By contrast, this goal might be achieved with feebates averaging 5%-10% of vehicle price (although fees and rebates on some vehicles would be larger). Vehicle pricing approaches such as feebates therefore have a greater potential for successful control of light vehicle fuel consumption. Nevertheless, uncertainties in response suggest that a regulatory approach will still be needed to achieve reliable reductions in nationwide fuel consumption. Developing a effective and equitable vehicle pricing policy will require active participation by the automakers, since its effectiveness hinges on how the policy will impact their product development and marketing plans.

CONTENTS

FIGURES

INTRODUCTION

It has been twenty years since King Faisal of Saudi Arabia cut his country's oil output by 25% and ordered an embargo of oil supply to the United States and several other Western nations. By the time the embargo ended in March 1974, Saudi Arabia and other members of the Organization of Petroleum Exporting Countries (OPEC) had increased their profits to $10 per barrel from under $2 per barrel six months earlier (Stobaugh and Yergin 1979). The sharp turns in energy-related markets such that for as automobiles and automobile transportation which have happened in the past two decades are clear evidence that one can "steer with prices." However, the question we still have to face is, "who's in the driver's seat?" It seems that policy makers in the U.S. are at best in the front passenger seat, speaking in the driver's ear while listening to a chorus of back-seat drivers such as those of us gathered at this conference.

Perhaps this last quip is stretching the analogy. Nevertheless, we can use what we know about transportation in the U.S. to look ahead at the direction this country is headed under current policy. The broad direction is, quite literally, already paved with the billions of dollars of asphalt and concrete which this country has poured into automobile supportive infrastructure in the past forty years. The conformity provisions mandated by the Clean Air Act Amendments (CAAA) of 1990 and the new flexibilities in the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 offer hope that future development patterns and infrastructure spending will support a shift to alternative travel modes, at least in urban areas. However, new development alters only a small fraction of the settlement patterns already laid down, and so the geographic determinants of travel demand will only be transformed over rather long time scales, 30-40 years or more.

Neither the Alternative Motor Fuels Act (AMFA) of 1988 nor the Energy Policy Act (EPACT) of 1992 will make much of a difference in the rising trend of U.S. transportation petroleum use over the next twenty years. The Clinton Administration's Clean Car Initiative has a lofty goal but is restricted to research; it does nothing to affect the fuel consumption of the millions of vehicles to be sold and used while the research is being pursued. A major gap remaining in U.S. energy policy today is the absence of measures for meaningful control of rising gasoline use. The Climate Action Plan announced in October 1993 begins to take some new steps through the proposed parking subsidy reform and some accelerated transportation demand management efforts; while meaningful, the effects of these measures will be limited. This is acknowledged in the Administration's Climate Plan follow-up process, which explicitly articulates a focus on how to control greenhouse gas emissions from personal transportation vehicles. As policy makers turn their attention to this issue they will be looking for assurance that the strategy they choose will make a meaningful difference within the next twenty years or so.

Figure 1 shows the light vehicle fuel economy, vehicle miles of travel (VMT), and oil use since 1970, along with our projections through 2010. Behind these projections are economic growth and oil price projections of EIA (1993). Gasoline prices are assumed to rise slowly, reaching about $1.50/gallon by 2010--neglecting here the possibility of another oil crisis like the 2½ we've had since 1973. Without policy change, our best projection is for frozen rated fuel economy of new light duty vehicles (DeCicco 1992)--we will elaborate on this shortly. The top curve is the past new light vehicle average, with the total light duty stock average being the dashed line just below. We can see that currently there is very little gain occurring in stock fuel economy from turnover of the stock, since new vehicle fuel economy peaked five years ago. Thus, light vehicle oil consumption will soon again be rising in lockstep with VMT. The question we address here is, what is the potential for pricing policies to alter the course sketched here in Figure 1?

The recent policy debate on light vehicle energy consumption is characterized by a polarization between those who favor higher fuel taxes and those who place greater emphasis on regulating new vehicle fuel economy. The former point of view is represented, for example, by Leone and Parkinson (1990), CRA (1991), DRI (1991), and Congressional testimony by auto industry representatives, who emphasize the efficiency of market forces and the broad influence afforded by fuel taxation. The other point of view is taken by the environmental and energy conservation advocacy community, including ourselves, emphasizing the importance of regulatory incentives directed specifically toward new vehicle fuel economy. Market incentives in the form of vehicle pricing interventions--such as the gas guzzler tax--have also been long discussed (Difiglio 1976, Davis and Gordon 1993, DeCicco et al. 1993, and others). Of course, many point out the need for a combination of approaches, differences often being one of degree and emphasis on a given policy.

The Efficiency Gap

Answering the question of policy choice depends on first answering some questions about goals. Why should we care about reducing oil use? How much should it be reduced? A number of reasons are cited, since oil use entails environmental damage including greenhouse gas emissions, risks to national security, a chronic component of the U.S. trade deficit, and other economic losses. Here, we focus on the last reason, namely, economic losses other than various externalities and the trade imbalance. Since the present degree to which our transportation system relies on the petroleum resource is very much a "status quo," it is perhaps more clear to say "forgone opportunities" (for greater economic welfare, in terms of national income and employment) rather than "losses." Thus, behind the polarization of views on how to address rising transportation oil consumption, there are differing answers to a question about the efficiency of current market conditions. To the extent that there is an "efficiency gap," closing the gap provides a rationale for how much we should seek to reduce light vehicle energy consumption. The concept of an efficiency gap relates the technical (physical) and economic notions of efficiency.

Technical efficiency, for motor vehicles, is the ratio of the useful transportation of a vehicle's occupants and cargo to the energy available in the fuel. Technical efficiency may be defined in a number of ways, but there is no need here to digress on this topic. For our purposes, fuel economy (e.g, miles per gallon) is a suitable measure of technical efficiency. Increasing fuel economy without sacrificing the ability to transport occupants and cargo clearly raises the technical efficiency of transportation. Therefore, this paper focuses on policy instruments for improving fuel economy. Further support for this focus will be revealed below, when we review estimates of the potential for travel demand reductions (which can involve higher vehicle occupancy) as compared to the potential for vehicle efficiency improvements.

Economic efficiency is a measure of the extent to which resources are allocated optimally. The concept of Pareto optimality is used to judge economic efficiency: an allocation of resources is economically efficient if no one can be made better off without making someone else worse off. For the case at hand, the U.S. spends a certain amount of money on vehicle technologies that has resulted in a light vehicle stock averaging about 20 mpg (on-road) and having numerous other attributes valued by consumers and society (Davis and Strang 1993). We also spend a certain amount of money for the approximately 6 million barrels per day (Mbd) of gasoline consumed by those vehicles. It is possible to transform our resource allocations to spend relatively more on technology for technical vehicle efficiency so that we might spend less on fuel. Such transformations do not happen overnight of course, since the vehicle stock takes about 10-12 years to turn over. Moreover, the process by which one resource allocation can be transformed to another can itself involve costs. Nevertheless, if such a transformation can be made at net benefit to the country, then there is an efficiency gap, rooted in the untapped potential for increasing the technical efficiency of motor vehicles. Among the implications of such a gap are forgone opportunties for economic growth and job creation; for example, Geller et al. (1992) projected a net gain of nearly 250,000 U.S. jobs if new light vehicle fuel economy is improved to an average of 45 mpg by 2010.

The magnitude of the efficiency gap is partly estimated by engineering analysis of the potential for improving light vehicle fuel economy. To be most useful, such an analysis must identify the direct costs of improving technical efficiency. If there are changes in other vehicles attributes, these must also be accounted for. Most analysts find it convenient to examine the potential for fuel economy improvement while holding constant such key attributes as size and acceleration ability. Figure 2 shows a way to represent estimates of the potential to improve technical efficiency. Per-vehicle cost is plotted against a degree of automobile fuel economy improvement. Clearly, there is a range of estimates possible depending on one's judgement of engineering possibilities. That discussion is outside the scope of this paper (see OTA 1991; Ross et al. 1991; SRI 1991; Greene and Duleep 1992; NRC 1992; DeCicco and Ross 1993). For reasons described by DeCicco (1992), we assume here the upper range of the estimates of potential fuel economy improvement. Allowing for stock turnover, the resulting 30% to 70% improvement in fuel economy would imply a 20% to 40% reduction in fuel consumption per mile driven.

The fuel economy "supply curve" of Figure 2 makes the efficiency gap quite apparent. But if there is such a gap, why does the market not close it, at least eventually? A partial answer is given in Figure 3, which puts the cost of fuel economy improvement in context. This graph is an update of one developed by Von Hippel and Levi (1983)--it is notable that when this illustration was first published, gasoline prices were 40% higher than they are today. Even if consumers were rational, cost-minimizing utility maximizers, the cost advantage of choosing higher fuel economy is relatively small in the context of the total cost of owning and operating a car. That the few pennies of price difference, which are quite visible at the gasoline pump and lead to such political sensitivity, seem so less relevant in new car show rooms, where the cost of a nicer radio or fancier trim might equal a year's worth of fuel costs, should come as no surprise.

Even if consumers don't demand greater fuel economy in the showroom, citizens and policy makers can take a broader view of the situation (Kempton 1991). As long as the costs of making such an improvement in technical efficiency are lower than the value of the fuel saved, the country would be better off to undertake such change in resource allocation. This would amount to steering in a different direction on the graph of nationwide oil consumption. The curve of Figure 1, which shows light vehicle oil consumption increasing to nearly 9 Mbd by 2010, could be pulled down, perhaps so as to show no net increase over the current level. For the sake of argument, we will use a target of cutting 2-3 Mbd from the level light vehicle oil consumption otherwise projected for 2010. This is of historical note, since a savings target of 2 Mbd was prominent in the discussions leading to the Energy Policy and Conservation Act (EPCA) of 1975 (Nivola 1986). This was the last major policy decision this country made to substantially control transportation oil consumption. Quantitatively, the combined effects on U.S. oil consumption of AMFA (1988), CAAA (1990), ISTEA (1991), EPACT (1992), the recently enacted gasoline tax, and the VMT reduction incentives of the 1993 Climate Action Plan are much lower than the 2 Mbd savings level discussed here as a "substantial" impact over the next 20 years or so.

Policy Options

The crisis mentality following the 1973 oil embargo provided a sense of urgency for taking substantive action. The 1975 EPCA established Corporate Average Fuel Economy (CAFE) standards, which took effect in 1978 for automobiles and 1979 for light trucks. These standards require manufacturers to sell a mix of vehicles over the course of a model year that averages to a pre-determined level of fuel economy (miles per gallon). Failure to achieve the standard results in a financial penalty. The CAFE standards ramped up to 27.5 mpg in 1985 for cars, with lower standards being administratively set for light trucks. Automobile standards for 1986-89 were rolled back by the Reagan Administration. Attempts to substantially increase the standards in recent years have been unsuccessful. As shown in Figure 1, the fuel economy of new vehicles has not increased since dropping slightly below the 1978-88 peak. There is no indication that current market forces will pull new fleet fuel economy above the present levels, which hover just above the level set by CAFE standards. This prognosis of essentially flat fuel economy is confirmed by the industry's own statements in hearings on fuel economy in recent years.[1] Raising CAFE standards is one option for increasing new vehicle fuel economy which has gotten serious attention in recent years.

Today's cars and light trucks are more fuel efficient than those of the early 1970's, with the average rated fuel economy of new light vehicles being 65% higher in 1990 than it was in 1975 (Murrell et al. 1993). It is challenging to sort out cause and effect among the many dramatic changes in fuel availability, fuel price, outlook, and policy that occurred in response to oil crises of 1973 and 1979. However, the lags in technology change and the persistence of the efficiency improvements achieved indicate that CAFE standards had a binding effect on new fleet fuel economy (Greene 1990). Moreover, most of the efficiency improvement was obtained by improving technology, with little change in vehicle size and a net increase in acceleration performance (DOE 1989; Murrell et al. 1993; Williams and Hu 1991). Nationwide oil savings from the standards now exceed 2.5 Mbd (DeCicco 1992). However, as established in 1975 and subsequently administered, CAFE standards have not been sufficient to check growth in light vehicle fuel use while VMT continues to grow. Contributing factors include the fact that light trucks have been more leniently regulated than automobiles while their market share doubled and the estimated growing "shortfall" between the rated and average on-road fuel economy of vehicles, now estimated to be about 20% (Westbrook and Patterson 1989; Mintz et al. 1993).

The other policy developed to affect motor vehicle fuel economy is the Gas Guzzler Tax. This federal excise tax on certain new cars was enacted in 1978 and first took effect in 1980. The threshold fuel economy, below which cars are subject to the tax, was ramped up to 22.5 mpg by 1986 and has since stayed constant. The tax schedule, which increases linearly with fuel consumption below 22.5 mpg, is given in 1 mpg steps, with the maximum tax on cars rated below 12.5 mpg being $7700

[1]For example, presentations by Chrysler, Ford, and General Motors representatives to the Workshop and Meeting of the Committee on Fuel Economy of Automobiles and Light Trucks, National Research Council, Irvine, CA, July 1991.

(in effect since rates were doubled beginning in January 1991). The Gas Guzzler Tax applies to a relatively small portion of the automobile fleet and not at all to light trucks. No estimate of the fuel savings directly attributable to the Gas Guzzler Tax is available. There is evidence that the tax has had some effect on market choices, pulling up the average fuel economy of the least efficient portion of the new car fleet (Ledbetter and Ross 1991; DeCicco et al. 1993).

More extensive guzzler tax and rebate schemes had been considered. For example, Difiglio (1976) examined a temporary guzzler tax imposed in 1977-81, ramping up to $1000 (1975$, $2300 in 1990$) on automobiles rated below 15 mpg and covering automobiles up to 24.5 mpg (about half the fleet in 1980-81). He projected a 13% reduction in fleetwide fuel use by 1985. Rebates on vehicles more efficient than average were also considered. But rebates were not enacted because of concerns that the program would favor imported models at the expense of domestic models. Interest has revived in using an expanded gas guzzler tax or fee and rebate ("feebate") program as a way to steer the vehicle market to lower fuel consumption. A number of feebate or guzzler tax bills have been introduced in recent years at the federal and state levels; see Davis and Gordon (1992) and DeCicco et al. (1993) for reviews.

Thus, aside from the relatively limited role of the Gas Guzzler Tax, U.S. policy makers have relied on regulation to address light vehicle oil consumption. There is a recognized tension between the market forces that result from low fuel prices and the market constraints imposed by fuel economy regulation. There have been persistent calls to address the problem, perhaps exclusively, through fuel taxation. The politics of this debate have evolved slowly. Nivola (1986) pointed out the strong popular sentiment that views gasoline as a necessity and a gasoline tax as an inequitable burden on consumers who have little ability to respond without disruptive lifestyle sacrifices; this political analysis remains largely true today (AAA 1993). By contrast, a number of studies have suggested superior economic efficiency for fuel taxation compared to vehicle regulation (Leone and Parkinson 1990; CRA 1991; DRI 1991; Miles-McLean et al. 1993). Support has also increased for energy taxation as a means to address environmental externalities, particularly greenhouse gas emissions (Dower and Zimmerman 1992). Externality considerations also provide a rationale for vehicle taxation (Koomey and Rosenfeld 1990). To sort out the likely effectiveness of pricing interventions, we will review the ways in which fuel and vehicle pricing changes might affect the average fuel economy realized in the marketplace.

MECHANISMS OF MARKET CHANGE

The major difficulty in sifting through the evidence amassed to date regarding the effects of pricing policies is understanding the mechanisms of change in the complex of interacting markets which determines transportation energy consumption. Many factors have been at work over the years which shape both technology and behavior. Understanding the mechanisms is crucial for guiding policy development.

Consider the recent debate on the effects of a broad-based energy (or Btu) tax. The range of opinions expressed was quite wide. Some opinions appeared to be based on a view that energy use was essentially inelastic. The tax would then be a direct drag on consumers and businesses, and very damaging to those for whom energy costs are a large share of their total expenditures and who have no ability to pass the costs on. Others expressed the opinion that there was some ability to respond by improving the efficiency of energy use, or, more generally, substituting other factors for energy.

Some noted, however, that there are market barriers to efficiency improvement, so that the burden of the tax could be alleviated only if other steps were taken to overcome these barriers. This alludes to important questions: how and to what extent there are market barriers which inhibit the ability to respond to pricing changes. Figure 3 illustrates the relatively small role of fuel cost in the economics of vehicle ownership and use in the United States. That even this small share of fuel costs is remote at time of vehicle purchase an example of an added informational context barrier which can inhibit the ability of the market to respond to fuel price changes, particularly gradual changes as would likely be enacted by policy makers (versus oil supply disruptions).

Time Scales

A key issue is how long it takes for the effects of policy changes to be reflected in market outcomes. Some divergence in opinions about policy mechanisms can be traced to different assumptions about the relevant time frame. There are not generally accepted definitions of how many years constitutes the "long-run" as opposed to "short-run." Mechanisms of short-run response may be considered as part of the long-run response. To set a context for discussion, it will be useful to come up with working definitions of the time frames, shown here in Table 1. There are some underlying cycles of physical stocks that can be used to guide these definitions.

Table 1. Time Scales for Effects of Transportation Energy Policies

Term	Years	Rationale
Short	1-2	Immediate changes, largely behavioral
Medium	15-20	Light vehicle stock turnover
Long	30+	Infrastructure and land-use transformation

It makes sense to define short-run as essentially immediate, one year or so. In the context of the light vehicle market, a short-run effect is one which is observable in the year following a change in the factor causing the effect. New vehicle regulatory policies have a clear short-run effect. For example, the new federal Tier I tailpipe emissions standards take effect in 1994. By the end of 1994, all model year 1994 vehicles will have been put into use, and there will be a definable impact related to the expected usage of those vehicles. Light vehicles up to a year old account for about 10% of vehicle miles driven (Davis and Strang 1993), so the short run effect of a policy will amount to about 10% of the change in characteristics relative to the overall vehicle stock.

Pricing policies will also have a short-run effect, on both vehicles and behavior. For consistency when talking about time frames, we term a short-run behavioral response as one observable within a one year from the change. For example, it is clear that the Oil Embargo of 1973, which constrained our fuel supply, precipitated a short-run response. (I'm not saying that U.S. market conditions should be dictated by someone like OPEC ministers, but here is a clear case of a "policy" change which had a short-run effect on the U.S. light vehicle market.) VMT dropped in 1974 after increasing by nearly 5% annually for the previous two decades (FHWA 1991).

Rather than just distinguish long-run from short-run, it makes sense to define an intermediate, medium-run time scale. A physical basis for this is the turnover of the vehicle stock. There may be regional differences in vehicle lifetime, of course, and lifetimes have increased over the past decade, but these appear to be second-order effects from an energy use perspective (though not when criteria emissions are concerned). Based on statistics from Davis and Strang (1993), the average automobile lifetime is about 12.5 years. Vehicles more than 12 years old account for less than 5% of VMT and those more than 15 years old account for less than 2%. If we also factor in an average design lead-time of 4-5 years and recall the fact that not all models are changed every year, the result is a roughly 15-20 year horizon over which the physical characteristics of the vehicle fleet can essentially be transformed.

Finally, the lifetimes of transportation infrastructure and land-use patterns provide a basis for long-run response. These are on the order of human generations, 30-40 year time scales. Settlement patterns, relating the location of residences and jobs, production sites and markets, do continuously evolve. However, at any given time, new development makes only marginal changes in the overall pattern. If, for example, we were to change pricing and other policies to favor a less automobile-development land-use, new locational decisions would be made, affecting new development. One might even affect choice of residence and location of business. But so many such locations are like sunk costs, especially if one dismisses rapid, draconian changes in the relevant policies, which are politically unrealistic. Thus, the transformations that might have an significant impact on transportation patterns and the resulting aggregate energy consumption can be expected to take a generation or so. Of course, this limitation is less applicable in any circumscribed geographic region, particularly regions that are growing. For example, changes in transportation-related land-use policy, and changes in fuel prices sufficient to affect land use decisions, could have an impact in shaping new growth, say in the Bay area, over even the next decade. The odds of consistent changes happening contemporaneously throughout all major growth areas of the country is quite small, however. Therefore, a 30-40 year time frame seems realistic for observing such long-run effects on oil consumption and CO_2 emissions.

These divisions into short, medium, and long time frames are somewhat arbitrary, of course, since the factors that influence response largely operate on a continuous basis. The time frames are clearly hierarchical, in that the long-run response is inclusive of the effects that happen over shorter time frames. They are useful, however, when it comes to discussing particular policy goals, such as target years for reductions in oil use or greenhouse gas emissions. The intermediate time frame is of particular interest for greenhouse gas emissions goals that might be set for 2000, prior to when a full medium-term response can be reached, and 2010, by when vehicle stock can be essentially replaced.

FUEL PRICING EFFECTS

The effect of fuel pricing is captured through the elasticity of fuel consumption with respect to fuel price. For small changes, this is approximately the percent change in fuel consumption associated with a percent change in fuel price. The response to changes in gasoline price involves a number of mechanisms affecting gasoline demand. Reported estimates of the elasticity of vehicle fuel consumption to fuel price vary by a factor of five, from around -0.2 to -1 (Zimmerman and Bohi 1984; Chandler and Nicholls 1990). There is some consensus that the lower end of the range is the short-run response and that the upper end of the range represents the long-run response. There are questions of interpretation, regarding the elements of the response, which have bearing on the likely responses in both the short- and long-run. The total response can be split into two components: the effect on travel demand and the effect on vehicle efficiency. The magnitude of the total response is the sum of the magnitude of these two components.

Effects on Travel Demand

Of recent analyses which separately examined the travel demand and vehicle efficiency components, the estimated or implied elasticities of travel demand (VMT) with respect to gasoline price are in the range of -0.05 to 0.1. Results given in EIA (1991) imply a short-run VMT elasticity of -0.06 for a 10¢/gal price increase to -0.08 for a 50¢/gal price hike, immediately applied rather than phased-in. The VMT response is lower in the long run or for a phased-in price increase because of offsetting increases in vehicle efficiency. The transportation module of EIA (1990) uses a fuel price elasticity of -0.07 to model VMT growth. Theoretical considerations suggest an upper bound of less than -0.1 for the elasticity of travel with respect to fuel price when accounting for likely medium- and long-run responses of vehicle efficiency and land use (Greene 1993a). Under current conditions, the elasticity appears to be about -0.05, but the response is likely to increase as the fuel cost share of total transportation costs increases.

These estimates are also consistent with results from regional transportation modeling studies. A set of model runs, based on transportation models developed for the San Francisco Bay area, was used to simulate gasoline price increases of $0.75 to $1.50 per gallon as part of a broad transportation demand management strategy (UCS et al. 1991). A breakout of the fuel-price only part of the response implied an elasticity of -0.06. This degree of response appears to be a consensus view among urban and regional transportation analysts, who expect that vehicle efficiency improvement would be the larger component of the response to a fuel price increase and who generally turn to other strategies to control travel demand as part of regional transportation plans (Harvey 1993; Williams 1993).

Figure 4 summarizes the likely effects of gasoline price increases on VMT, using projected gasoline price and VMT levels for the year 2010. EIA (1993) projects an average retail gasoline price of about $1.50/gallon in 2010. Assuming such slowly rising gasoline prices and modest economic growth, the average VMT growth rate for 1990-2010 is likely to be about 2.0%/yr (UCS et al. 1991; EIA 1993). This results in a projection of 2.6 trillion (10^{12}) miles of light duty vehicle travel, a 48% increase over the 1990 level, shown as the dot in Figure 4. The response to changes in gasoline price is illustrated using an elasticity range of -0.05 to -0.15. The mid-range effect is that a doubling of gasoline prices (as might be effected by a $1.50/gallon tax increase) would imply a 7% decrease in VMT.

Effect on Vehicle Efficiency

Most studies suggest that the larger part of the response to an increase in fuel prices will be increased vehicle fleet fuel economy. Recent work by the U.S. Department of Energy (DOE), as reflected in the National Energy Strategy and Annual Energy Outlook projections, assumes that imply that fuel economy will rise continuously as gasoline prices rise above current levels. The rise in new car fuel economy projected in EIA (1993), for example, corresponds to an implied elasticity of about 0.8. This effect is based on a technological response to market demand for greater fuel economy, working from a "supply curve" of costs and benefits of various engineering measures for improving fuel economy (similar to the "EEA" curve in Figure 2). The validity of this response model is open to question, however, since the DOE projections of new fleet fuel economy rising for several recent years have not been borne out by the data, which show new vehicle fuel economy as flat or declining since 1988.

A different approach is embodied in the work of Train (1986), which examines car buyer response using a disaggregate model of household vehicle choice (noted further below when we discuss vehicle pricing policies). This work suggests a smaller response of fleet average fuel economy to fuel price, with implied elasticities of the order 0.2 to 0.4. Some recent results of Greene (1993b) also suggest an elasticity of 0.2 to 0.3 for fuel economy with respect to fuel price. These estimates are consistent with a value of about -0.4 for the overall response of fuel consumption to fuel price, including the smaller VMT response component.

Fuel prices in most European countries range from $2.60/gal to over $4.00/gal (EIA 1991). Schipper et al. made comparisons of international data (Western Europe, Japan, and U.S.) for 1973-1988 on vehicle fuel intensity (the inverse of fuel economy) and fuel price. Their results suggest an elasticity range of 0.2 to 0.3 for new vehicle fuel economy with respect to fuel price. These results are thus broadly consistent with the previously cited analyses of the U.S. market alone. Schipper et al. also note that many countries have vehicle taxation policies, some of which place quite substantial taxes of vehicles of different sizes or engine types. Their gasoline price analysis did not factor in possible effects of vehicle taxation. To the extent that non-fuel vehicle taxes are positively correlated with decreasing fuel economy, the sensitivity of fuel economy to fuel price would be tend to be overstated.

Figure 5 shows a plausible range of response for new light vehicle fuel economy to increases in fuel price, for an elasticity range of 0.2 to 0.4. The projections work from recent conditions, with a gasoline price of $1.20/gallon and new light vehicle average fuel economy of 25 mpg (EPA rated). The mid-range curve, with elasticity of 0.3, implies that it would roughly take a tripling of gasoline prices to yield a 40% increase in new vehicle fuel economy (to an average of 35 mpg for new cars and light trucks).

One limitation of this type of analysis is that it does not account for the effect of fuel economy standards. This is also a limitation of many of the aggregate estimates of the response to gasoline price which show even higher degrees of responsiveness than suggested here. Sweeney (1979a,b) pointed out that when fuel economy standards are binding, raising gasoline taxes will have little or no effect on vehicle efficiency. Under such conditions, the market equilibrium fuel economy (what it would be in response to fuel price alone, in the absense of standards) is very difficult to estimate. Sweeney (1979b) analyzed the effect of CAFE standards in terms of an "equivalent tax" on gasoline, i.e., the gasoline tax increase that would be needed to raise fuel economy from its price-only equilibrium value to the level resulting from the regulations. As long as a new gasoline tax is less than the equivalent tax, there will be no improvement in average fuel economy beyond the fleet average standard level. Sweeney derived theoretical estimates of the equivalent tax for a range of discount rates. His conservative (6% discount rate) projection for what it would have taken to induce a fleet average equal to the 27.5 mpg standard set for 1985 was an added tax of $0.79/gal (1979$, $1.39 in 1990$).

The fact that new vehicle fuel economy has been hovering just at or barely above the standards level in recent years suggests that at present, CAFE standards are still binding on most manufacturers. This is corroborated by the rising share of light trucks in the overall light duty market. Figure 6 is a way to illustrate the constraining effect of fuel economy standards. Although we do not know exactly how large the effect is, for illustrative purposes we show a 2 MPG effect. The solid line represents the hypothetical response of new vehicle fuel economy to fuel price in the absence of CAFE standards. Here we assume an elasticity of 0.3, the mid-range value shown in Figure 5. The dashed curve in Figure 6 goes through the current new fleet average of 25 mpg and runs parallel to the solid curve. The dashed curve response is what might be projected without accounting for the effect of CAFE standards, which is what most recent studies of a gasoline tax have done.

With a CAFE constraint, initial increases in gasoline price will have little or no effect on fuel economy. This is the "region of poor and uncertain response" shown in Figure 6, similar in concept to Sweeney's "equivalent tax." Under the stated assumptions, this region extends to an increase of up to 30¢/gallon. If the underlying response is more elastic, the region of poor response is smaller. For example, with an elasticity of 0.4, the full response would start after an increase of about 15¢/gallon. These values are much smaller than those suggested by Sweeney's pre-1980 analyses; however, Sweeney (1979a,b) derived his equivalent tax estimates based only on the consumer (demand) response, without considering the automaker (supply) response of technology improvement. Since we know that the supply response is dominant, an equivalent tax much smaller than Sweeney's early estimates is implied.

Though largely conceptual, these analyses strongly suggest that energy taxes amounting to less than 10¢/gallon, as recently proposed, will have no effect on fleet average fuel economy. While some economists differ with this view, many non-economists are likely to agree with it as a matter of common sense. The effect of small gasoline tax increases is almost surely limited to the smaller travel demand response. A further implication is that raising CAFE standards would further weaken or even neutralize the fuel economy component of the response to fuel price. This conclusion is quite broad, as Sweeney (1979a) noted, "*no* policy option [referring to gasoline taxes, gas guzzler taxes, and efficient vehicle procurement measures] will increase mean efficiency unless that option provides strong enough incentives to increase mean efficiency above the standards even in their absence." On the other hand, the gap between the regulated fuel economy level and that which would be the fuel price-only market outcome can be viewed as a degree of tension imposed by the standards. (Some economists might also ascribe a "deadweight loss," from reductions in consumer and producer surplus, to this gap.) If fuel economy standards are raised, then raising fuel taxes would serve to ease this tension, although the results shown here suggest that fuel price increases would have to be quite high to eliminate it.

Combined Effects

Separate estimates of the travel demand and vehicle efficiency components yield magnitudes of 0.05-0.15 and 0.2-0.4, respectively, for the elasticity with respect to higher gasoline prices. Summing these estimates suggests a combined elasticity magnitude of 0.25-0.55 (mid-range 0.4).

There has been extensive aggregate analysis of the likely overall effects of higher gasoline prices in the United States. Zimmerman and Bohi (1984) reviewed elasticities of demand in all of the major energy using sectors. Their findings for transportation energy indicated a range extending higher than that suggested here. A number of post-1973 econometric studies suggest combined gasoline consumption elasticities with magnitudes in excess of 0.5, with some estimates reaching a unit elasticity response of 1 (i.e., that the sector can respond to fuel price increases alone so as to keep fuel expenditures constant). Chandler and Nicholls (1990) also reviewed the literature on gasoline demand, indicating an elasticity magnitude range of 0.2 (short-run) to 0.7 (long-run).

Much of this work, however, fails to account for factors other than price which influenced the response to the 1973 and 1979 oil crises. These non-price factors include actual fuel shortages, rationing, accompanying fears of ongoing shortages and much higher future prices, the national consensus to address the energy crisis, and resulting public policies such as fuel economy standards. The failure of the aggregate economic analyses to account for the effect of fuel economy standards in raising vehicle efficiency is a particularly serious flaw, since the more detailed work all suggests that vehicle efficiency improvement is the dominant part of the response to higher gasoline prices. Attributing vehicle efficiency improvement to price alone rather than fuel economy standards (or other non-price factors which influence automaker product planning) yields inflated estimates of the elasticity. Greene (1990) showed that when fuel economy standards and price are examined together for their effect on vehicle efficiency over the 1978-89 period, standards are found to be the dominant factor and that the price effect is only marginally significant.

Careful studies, using more disaggregate data, have generally shown combined effects on gasoline consumption within the lower elasticity magnitude range of 0.3-0.5. A high fuel price scenario by Train (1986) yielded an implied elasticity of -0.32. An earlier analysis of Greene (1979), which examined difference in gasoline consumption among U.S. states, obtained a gasoline price elasticity of -0.34. Thus, the earlier stated range of roughly 0.3-0.5 appears to be a reasonable estimate of the expected response to higher gasoline prices. This can be considered a medium-run response, since it will take a vehicle stock turnover cycle to fully realize the fuel economy improvement component of the response. The short-run response would be even smaller, with an elasticity of the order -0.1, based on the travel demand component of the response.

The evidence for a larger long-run response, e.g., from changes in geographic factors of land use and transportation infrastructure, is unclear. Econometric work has generally failed to find such a response. On the other hand, a broader look at the effect of land use on fuel consumption suggest the possibility of substantial changes in per capita gasoline consumption from changes in land use (Newman and Kenworthy 1989). However, even though higher gasoline prices are correlated with lower rates of fuel consumption, it is far from clear that fuel price itself is any more of a factor than is suggested by the low short-run travel demand elasticities noted above. A reason that fuel price alone may be insufficient to induce a larger long-run response is the dominant medium-run response of higher vehicle efficiency will hold down the cost per mile driven in spite of higher fuel prices, thus dampening the incentive for long-run changes in geographic factors. Of course, other policy changes, perhaps in concert with higher fuel prices, could result in substantially different land use and travel demand.

VEHICLE PRICING EFFECTS

Less published analysis is available on the effects of differential vehicle pricing related to fuel economy. The main sources of information are experience with the existing U.S. gas guzzler tax, international experience with price differentials correlated to fuel economy, and econometric studies of vehicle choice. Common sense suggests that a fee and rebate scheme ("feebate") related to fuel economy should shift the decisions of both consumers and automakers, but quantifying this effect is difficult. Among the many factors that go into pricing, manufacturers presumably price cars so as to help meet CAFE targets. This means cutting prices of efficient vehicles, which means low margins on these vehicles. Conversely, standards can increase the per-unit profitability of inefficient cars. The result is a cross-subsidy tending to benefit buyers of the more fuel efficient vehicles within the two regulatory categories of cars and light trucks. Although there has been some partial analysis of this issue (e.g., Greene 1991), the magnitude of CAFE-induced price differentials is not publicly known and may vary among automakers depending on their favored segments and market strategies.

Government intervention in vehicle pricing could mitigate some or all of this pressure to modify the vehicle pricing for the sake of compliance with CAFE standards. Thus, a pricing-induced increase in demand would make efficient vehicles more profitable. In principle, a subsidy proportional to the extent that a vehicle exceeds a standard could motivate ongoing technological improvements in efficiency. On the other hand, if there is a binding regulatory constraint in place, the response to a feebate could be weakened analogously to the weakened response to fuel price increases illustrated in Figure 6. To the extent that CAFE standards involve cross-subsidy of vehicles based on fuel economy, a feebate would only induce a further response if the feebate differentials were greater than the hidden price differentials induced by the regulatory regime. There might be an added non-economic response from associating a sticker price difference to fuel economy information, but such a consumer-only response is likely to be small and possibly transient.

Gas Guzzler Tax

Feebates can be viewed as an extension of the Gas Guzzler Tax. A look at the past record and fuel economy distribution of the automobile fleet provides evidence that the Gas Guzzler Tax does have an effect. Figure 7 shows the gas guzzler tax threshold along with the average fuel economy of low-mpg cars and that of other cars, from 1980-87. Low mpg cars are a group of vehicles rated at less than 21 mpg prior to the onset of the Gas Guzzler Tax. This shows the way the Gas Guzzler Tax has acted to bring up the less efficient part of the fleet, even while improvement of the rest of the fleet slowed down.

Figure 8 is a scatter plot of fuel consumption vs. new car price for the 1990 fleet. There is a definite positive correlation for the bulk of the fleet, but the points level off along the 22.5 mpg line corresponding to the Gas Guzzler Tax threshold. Few models cross that line, putting a turn in what is otherwise a linear trend. Another view of this same phenomenon can be seen in the cumulative distribution of vehicle sales with respect to fuel economy (not shown here; see Table 2 of Heavenrich et al. 1991). There is a kink at 22.5 mpg, above which the sales fraction rises rapidly. Thus, it seems clear that the Gas Guzzler Tax is having an effect on the market, through some combination of decisions by both consumers and manufacturers. Because of the aforementioned effect of CAFE standards (as noted by Sweeney 1979a), however, it is not likely that the Gas Guzzler Tax is resulting in higher fleet average fuel economy. Manufacturers meeting a CAFE standard constraint are probably balancing fewer sales of guzzlers with fewer sales of their most efficient cars.

International Experience

Internationally, vehicle taxes are often related at least indirectly to vehicle fuel consumption rates (Schipper et al. 1992; Dolan et al. 1992). Taxes specifically related to emissions or fuel economy have been enacted in Austria, Denmark, Germany, and Sweden. Austria's new tax program took effect in January 1992; it applies a scale ranging from 0% to 14%, with 0% tax for cars averaging less than 3 liters/100km on European driving tests (a fuel economy better than 80 MPG). In many countries, tax schedules have been traditionally based on weight, engine displacement, or power (IEA 1991). Vehicle tax rates are thereby linked to fuel consumption rate, since these attributes are correlated with fuel consumption. Further analysis of this issue is being reported at this conference by Erikson and Schipper (1993).

In 1989, the Province of Ontario established a gas guzzler tax consisting of a four-tier tax schedule applicable to cars having a *highway* fuel consumption above 9.5 liters/100km, i.e., an adjusted highway fuel economy less than 19 mpg (Millyard 1991). In 1991, the guzzler tax was expanded, increasing the maximum tax level and providing a rebate of $100 for vehicles using less than 6 liters/100km (adjusted highway fuel economy greater than 36 mpg). Termed the "Tax for Fuel Conservation," this program set a precedent for feebates in North America. The Ontario program is designed to generate revenue, estimated at $30-$35 million in 1991, which is dedicated to other environmentally related transportation programs. An expansion of the program to cover all light truck classes and provide rebates up to $250 was proposed in April 1992 but not enacted. An evaluation of the effects of this program on vehicle choice has not yet been reported.

Von Hippel and Levi (1983) developed a graph of vehicle purchase and registration taxes, reduced to equivalent cents per mile, against fuel consumption rate, illustrating the general trend of increasing tax rate with increasing fuel consumption. Taxes rates reported at that time often went up substantially at consumption rates greater than 10 liters/100km (lower than 23.5 mpg). Dolan et al. (1992) tabulate a number of vehicle tax schedules, which might be used to further analyze the correlations shown by Schipper et al. (1992) which relate vehicle fuel consumption to fuel price. Since so little analysis relating these vehicle taxation policies to national fleet average fuel economy has been reported, this remains a promising area for research.

Vehicle Market Analyses

There has been extensive econometric analysis of consumer decision making in the light vehicle market. The most sophisticated analyses reflect the disaggregate nature of consumer decision making which characterizes durable goods markets, such as that for automobiles. Qualitative choice models, which treat choice among exhaustive, finite, and mutually exclusive options, provide a useful way to describe and estimate automobile demand (Train 1986). Such models have been applied to analyze the potential consumer acceptance of alternatively fueled vehicles and the response to changes in fuel taxes and other vehicle-related policies. A DOE-sponsored study (to be discussed below) is using qualitative choice methods to analyze feebates (Davis et al. 1993).

Aggregate analyses have generally concluded that the consumer response to feebates is relatively small, on the order of a 1 mpg response for a vehicle pricing differential of $300/mpg (based on one of the author's analyses of the proposed California DRIVE$^+$ program; Gordon and Levenson 1989). Greene (1991) examined short-term pricing strategies for improving fuel economy. Although feebates were not directly addressed, he concluded that beyond small shifts (less than about 1 mpg), it is difficult to improve fleetwide fuel economy through consumer-side sales shifts alone; manufacturer responses were not analyzed. Response to a feebate would exhibit short- and medium-run characteristics analogous to those described earlier when discussion response to a gasoline tax. The short-run response represents no more than a one-time reordering of consumer choice. A larger response can be expected after manufacturers have time to make product changes in response to fuel-economy related tax differentials.

Unfortunately, manufacturers' responses to feebates is the area about which the least information is publicly known. A strong manufacturer response could yield a large fleetwide fuel economy improvement if automakers add efficient technologies to their new vehicles and downplay technology applications, such as acceleration performance enhancements, which are detrimental to fuel economy. Estimation of manufacture response to feebates can be guided by a technology cost model such as those developed by EEA (1985, and later work, e.g., Greene and Duleep 1992) or ACEEE (DeCicco and Ross 1993). However, as when used to model response to fuel price, this technology-cost framework faces limitations because other factors influencing manufacturer decision making (such as CAFE standards) may not be adequately accounted for. The technology cost rationale assumes that automakers will improve fuel economy up to the point where the marginal cost of improvement matches the feebate rate.

Using an updated technology cost model based on EEA and an updated consumer demand model based on Train (1986), Davis et al. (1993) estimated the overall response for a variety of feebate formulations. The principal case analyzed is a feebate roughly equivalent to a front-loaded $0.50/gal gasoline tax, or $60 per mpg for cars and $110 per mpg for light trucks at current new fleet average fuel economy levels. Preliminary results of Davis et al. indicate improvements of about 11% by 2000 and 14% by 2010 in average new light duty fleet fuel economy relative to their baseline, which itself had new light vehicle fuel economy improving 32% over the 1990 level. They therefore predict a roughly 50% improvement in new light vehicle fuel economy by 2010 with the feebate in place. The Davis et al. model also indicates that the technology improvement component is dominant by far, with the manufacturer response contributing 13% and the consumer response contributing only 1% to the 14% overall response they project for 2010. This is a substantial response for feebates that appear to average 1%-2% of new vehicle price on a fleet average basis. Feebates for some models would be larger; the Davis et al. scenario has maximum rebates of $760 for cars and $920 for trucks, or 5%-6% of the $14,500 average new light vehicle price in 1990.

Feebate Response Possibilities

Thus, while the medium- to long-run fuel economy improvement that might be induced by a feebate could be substantial, it remains quite uncertain. Clearly, the response of both consumers and manufacturers to a feebate will be related to the magnitude of the fees and rebates. As just noted, preliminary modeling results of Davis et al. (1993) suggest that feebate magnitudes averaging 1%-2% of vehicle price could induce a substantial response. A big issue is the effect of unmodeled factors that might weaken the response, such as binding CAFE standards or strong consumer/manufacturer preferences for applying technologies for performance and other vehicle amenities besides fuel economy. Sweeney (1979a) projected that the guzzler tax would have no impact on fleet average fuel economy in the presence of CAFE standards. The feebate scheme analyzed by Davis et al. is much broader in coverage (it includes light trucks and rebates on efficient vehicles) but somewhat weaker in leverage (average feebate as a percentage of price) for the vehicles that the existing guzzler tax does cover. However, Davis et al. did not attempt to simulaneously model feebates with CAFE standards and so, with the information at hand, it is difficult to say what the effect of a feebate system would be in the presence of either current or strengthened CAFE standards.

DeCicco et al. (1993) suggest that feebates averaging 5%-10% of vehicle price might be needed to obtain a substantial fuel economy improvement. Manufacturer sales rebates typically fall in the range of 5%-10% of price, which is coincidentally close to the average feebate magnitude of 8% of vehicle price which would be obtained by extending the current U.S. gas guzzler tax (DeCicco et al. 1993). A feebate or guzzler tax can be linked to a schedule of increasing fuel economy standards, as proposed by ECC (1993) and DeCicco and Geller (1993). This combined approach would provide a greater degree of predictability because manufacturers would be constrained by the standards. It may not initially improve average fuel economy beyond the standards level. However, if standards become fixed at some point in time, feebates might eventually pull the fleet average above the standards level if advances in automotive engineering yield technologies for ongoing efficiency improvements at low cost.

At present, the uncertainty regarding the response to vehicle taxation appears to be greater than that to fuel taxation. However, the influence of feebates on the vehicle market is clearly more direct than that of fuel taxes. According to the technology cost rationale and the preliminary results of Davis et al., feebates might begin to close the efficiency gap noted in the introduction to this paper. The resulting induced fuel economy improvements could be in line with estimated technically feasible levels well above the 1990 new fleet average, depending on what one believes about technology effectiveness and costs. For example, the preliminary Davis et al. (1993) projection of a 2010 new fleet average fuel economy roughly 50% higher than the 1990 level is well into the range of 30%-80% potential improvement identified in Figure 2. Clearly, such improvements could be achieved with greater certainty if feebates are used in combination with strengthened fuel economy standards.

POLICY IMPLICATIONS

Although the responses to fuel taxation and vehicle pricing policies not fully certain, the uncertainty does not appear to be so large as to preclude some policy conclusions. For the sake of argument, we will examine what it would take to hold U.S. light vehicle gasoline consumption to the 1990 level of roughly 6 Mbd, in 2010. As noted earlier, without policy changes, gasoline consumption is likely to increase to 8-9 Mbd by 2010. Policies adequate to achieve consumption reductions of 2-3 Mbd, i.e., savings of 25%-33% relative to expected growth, would therefore be required.

A range of estimates for the required increase in fuel price can be obtained by examining cases of low-growth (25% cut needed), high-elasticity (-0.55) and high-growth (33% cut needed), low-elasticity (-0.25). The resulting requisite price increase is by factors of 1.7 to 5. The mid-range estimate is that fuel prices would have to rise by a factor of 2.4, to about $3.00/gallon (1990$), in order to obtain a 30% cut in light vehicle fuel consumption. This estimate does not fully account for stock turnover time, for a likely phase-in of the tax increase, or for the region of poor price response due to the CAFE constraint. Thus, an even higher tax level would probably be needed to return fuel consumption to the 1990 level by 2010.

Compared to fuel prices, vehicle taxation will more directly affect fuel economy, which, as noted earlier, is the principle component of response. With unadjusted projections of VMT growth, achieving 25%-33% cuts in gasoline use 2010 implies a need for 30%-50% increases in stock fuel economy by that time. This is within the range noted earlier as potentially achievable assuming a technology-cost model for the manufacturer response to feebates of adequate magnitude. Davis et al. (1993) suggest that vehicle tax differentials averaging only 2% of new vehicle price could achieve a substantial degree of fuel economy improvement. DeCicco et al. suggest that higher feebates, averaging 5% or more of new vehicle price, might be needed. In any case, this range of vehicle pricing changes is certainly much smaller than the range of fuel pricing changes needed to achieve similar effects.

If gasoline prices are stable or rise only slowly (without major fuel tax increases), and if a feebate causes fuel economy tp rise more than fuel price, then the cost per mile of driving will fall. The resulting "rebound" effect of increased VMT will follow curves like those shown earlier in Figure 4. This suggests that vehicle-oriented fuel economy policies, such as feebates or stronger CAFE standards, might usefully be complemented with fuel tax increases sufficient to keep the cost of driving from falling. To do this, a gasoline tax increase could be phased-in at a rate chosen to match to rate of stock (all vehicles, new and used) fuel economy improvement. For example, offsetting a 40% improvement in stock average fuel economy achieved over 20 years would involve a fuel tax increase of 2%/yr (about 2.5¢/yr) in real terms and will not increase the average gasoline tax burden. From a fiscal policy perspective (federal and state), such tax increases would be needed to avoid erosion of this revenue source due to the increased fuel economy. Of course, other policies to hold down VMT, such as transportation demand management, greater provision of alternative modes, and pay-as-you-drive insurance, would also counteract a fuel economy rebound effect.

The combined impact of fuel price and vehicle fuel economy policies can be calculated from their estimated effects on VMT and stock average fuel economy. Figure 9 is a contour plot of projected 2010 light vehicle gasoline consumption, providing a way to view the separate effects of stock fuel economy and fuel price. It is a projection of a gasoline consumption "surface," which slopes downward for both increasing gasoline price and increasing fuel economy. Superimposed is an estimated locus of the medium-term response of fuel economy to fuel price (assuming a fuel economy vs. gasoline price elasticity of 0.3, the mid-range value of Figure 5). The intersection of the dotted lines represents forecast gasoline consumption in absence of policy change, with gasoline price at $1.50/gal and stock fuel economy rising only marginally, to about 26 mpg. The resulting consumption level is 8.4 Mbd (between the plotted "level curves" for 8 Mbd and 9 Mbd).

Following the fuel economy response locus up to the 6 Mbd level curve indicates what is required to achieve this degree of oil consumption control with fuel taxation; the implied fuel price is about $3.50/gallon. (This accounts for stock turnover, but not tax phase-in or likely non-equilibrium of the current fuel economy market.) The region above the fuel economy vs. fuel price locus represents possibilities obtainable with vehicle taxation policies inducing a greater degree of fuel economy improvement. For example, if fuel taxes are not increased and the 2010 fuel price is $1.50/gal, extending the vertical dotted line up to the 6 Mbd contour gives the requisite 2010 stock fuel economy, roughly 37 mpg (average of both cars and light trucks, new and used; this does account for the rebound effect). One can interpolate results of stock model analyses to find the new vehicle fuel economy trajectory needed to achieve a given degree of stock improvement. For example, scenarios of continuous improvement from 1994 to 2010 suggest new fleet CAFE improvements of 30% by 2001 and 60% by 2010 would yield a stock average of approximately 37 mpg by 2010 (DeCicco 1992), provided there are proportional improvements in light trucks and the light truck market share stabilizes at 33%.

Within the plausible range of elasticity estimates, it appears that increasing U.S. fuel taxes to levels comparable to those in Europe might be sufficient to substantially curtail growth. After adjusting for the medium-run response, this represents an increase in taxation of roughly $140 billion. U.S. Federal individual income tax receipts are now approximately $400 billion annually. Therefore, effectively controlling light vehicle fuel consumption (and CO_2 emissions) through fuel taxation will entail not only a major energy policy challenge, but a profound transformation of the U.S. taxation system.

Compared to gasoline tax increases amounting to a 100%-200% change in fuel price, vehicle tax differentials averaging 5%-10% of new vehicle price would appear to be less politically intimidating. Since a feebate can be revenue-neutral, such a policy can also be implemented without the need for major tax reform. Politics and practicality are surely not wholly ignorant of economics and economics can be informed by both. Nevertheless, the obvious practical contrast between these two policy approaches was apparently lost on the authors of one recent study sponsored by EPA (DRI 1991), which found raising the gasoline tax to be the superior option in terms of "economic efficiency."

It goes without saying that the "error bars" on an analysis such as that presented here are quite large, since it involves extrapolations well beyond the observed ranges of response for MPG and VMT. The synthesis shown in Figure 9 is clearly illustrative rather than definitive. Other analysts could develop other scenarios based on different assumptions for the key parameters. However, the policy implications would not differ greatly for other reasonable values of the elasticities as reviewed here. It appears that a combination of policies would be most effective to achieve the degree of control over U.S. gasoline consumption examined here. Vehicle-directed policies, such as feebates or CAFE standards, appear to be essential. A fuller accounting of the costs of such actions is beyond the scope of this work, as is a further revisiting of the arguments why such a degree of control would be desirable. There will be a need to develop a greater understanding of the mechanisms and effectiveness of vehicle pricing policies if they are to complement or replace the regulatory approach. Nevertheless, the need for a vehicle-directed approach means that policy makers should not delay actions to fill the current void in U.S. energy policy that leaves rising light vehicle oil use unaddressed.

There is a crucial role for the automotive industry in the policy development effort needed to formulate workable vehicle taxation policies. All indications are that the greatest response to any policy change will be the effects on manufacturer product planning. Government and independent analysts can only hope to approximately estimate the industry's response when attempting to formulate rational policies. Vehicle pricing interventions must also address the difficult area of inter-manufacturer equity, which again can only be treated with the industry's help. One response by the industry might be to deny that there are serious problems associated with the rising light vehicle fuel consumption. Another response might be to parry responsibility by stating that the only appropriate intervention is through fuel tax increases. These responses will insure ongoing political battles resulting in policies that satisfy neither side and only set the stage for future controversies. There may be progress, but it will be intermittent and painful.

We envision different type of response, however. To start, there would have to be a process of building consensus about common goals and setting the framework for vehicle taxation based policies. But if this process succeeds, the industry and government can together change the rules of the marketplace so that fuel economy improvement becomes part of the game. Progress is a key to survival--ongoing improvements in cars and light trucks are part of a competitive business strategy.

Today, raising fuel economy is not part of that improvement strategy. Establishing a meaningful price advantage for more efficient vehicles would change the rules so that fuel economy gets the ongoing attention of the substantial design and engineering talents that the industry can marshall. Developing a policy structure that is equitable, effective, and allows adequate time for improvements is a challenge that cannot be met without good-faith participation by the industry. If this challenge is met, we can look ahead to a time when car and trucks will be continually improved in many ways, including fuel economy. The United States will have then succeeded in steering itself down a road of decreasing transportation oil consumption.

CONCLUSION

Raising the average fuel economy of light vehicles is a most important aspect of controlling transportation oil use and its associated economic and environmental problems for the United States. Market conditions in recent years and as expected over the next decade or so entail relatively low oil prices, rising slowly in real terms and possibly punctuated by transient disruptions related to political instabilities in supply regions. Little if any improvement in fuel economy is expected in the absence of policy change. From an engineering perspective, however, fuel economy could be improved 30% to 70% through technology changes costing less than the value of fuel saved even at low oil prices. This potential to improve fuel economy implies an efficiency gap, representing a foregone opportunity to improve economic efficiency by improving the technical efficiency of the transportation system. If realized, this level of fuel economy improvement would be adequate to avoid net growth in U.S. light vehicle gasoline consumption by 2010 relative to the 1990 level, yielding environmental as well as economic benefits. What one believes regarding the extent of such an efficiency gap partly determines the degree of policy intervention justified to improve automotive fuel economy.

Past U.S. policy has relied on fuel economy regulation--CAFE standards--as the primary means to control light vehicle fuel consumption. Tension between regulatory requirements and market forces is inevitable. But if it becomes too extreme and is in disagreement with political thinking, such tension is destabilizing from a public policy perspective, leading to unsteady and inadequate policy guidance. This is manifest in the CAFE standard rollbacks of 1986-89 and the political hurdles faced by attempts to renew and strengthen fuel economy regulation. Market-based policies offer hope of addressing the issue in a way that results in less tension while achieving comparable goals. Fuel taxation and efficiency-related vehicle taxation are two market-based policy options which have been proposed as a way to replace or complement fuel economy regulation. This paper explored the potential for and limitations of such pricing policies for reducing light duty vehicle fuel consumption.

Existing information on the response of the vehicle and travel demand markets indicates that dramatic increases in fuel price would be needed to stabilize light vehicle fuel consumption in the United States. While there is uncertainty in the response, even the most optimistic suggest at least a doubling of fuel prices would be needed. On one hand, price levels in excess of $3.00/gal would be on a par with those of most OECD countries, and therefore need not be considered unreasonable if phased in. On the other hand, achieving such price levels would entail a truly radical change in U.S. taxation policy, amounting to a transfer equivalent to about one-third of present personal income tax revenues. Much smaller tax increases, of the order $0.10/gal or less as recently discussed, fall inside an area of great uncertainty of response; although there might be some tiny (probably unobservable) effect on travel demand, it is most likely that the effect of such a small tax increase on fuel economy will be nil.

Less information is available about the response to efficiency-based vehicle pricing policies, such as an expanded gas guzzler tax or feebates. There is clear evidence that the existing U.S. gas guzzler tax, even though it touches a relatively small fraction of the fleet, is bolstering the fuel economy the least efficient automobile classes. The more extensive experience with similar vehicle taxes in OECD countries has yet to be analyzed in a way that permits quantitative extrapolation to the U.S. market. Vehicle choice modeling does offer some guidance, suggesting that vehicle pricing approaches could induce fuel economy improvement approximately equal to the technical potential for improvement, which, as noted earlier, is likely to be sufficient to stabilize light vehicle oil consumption. Studies also indicate that the dominant part of the response is through manufacturer product improvements, with a much smaller response through changes in consumer product choices. Although the magnitude of the required tax differentials is uncertain, modeling results and other evidence (existing gas guzzler tax and manufacturer sales rebates) suggest that average tax differentials amounting to 5%-10% of vehicle price could accomplish a substantial fuel economy improvement.

Compared to a fuel pricing approach, adequate control of rising light vehicle gasoline consumption through vehicle taxation would require a much less radical change in existing fiscal and economic policies. Fuel economy regulation will increase the certainty with which a given (standards) level of fuel economy improvement would be obtained. However, the existence of a binding regulatory constraint weakens the fuel economy response to either feebates or fuel taxes. In particular, given the low elasticity of fuel economy to fuel price, it is possible that fuel taxation will never be an effective way to raise fuel economy in the U.S. context as long as reasonably strong vehicle-directed policies (either regulation or feebates) are in place. Nevertheless, increased fuel taxes will be a valuable complement to fuel economy policies at least because higher taxes can offset a "rebound" effect by keeping the cost per mile of driving from falling. Other policies to control travel demand can also address the rebound effect; there may also be other good reasons to raise the gasoline tax.

In short, if the U.S. hopes to steer light vehicle fuel consumption through pricing interventions, policy makers should focus on vehicle stickers rather than gasoline pumps. Given goals based on either stabilizing light vehicle oil consumption or closing the apparent efficiency gap, fuel taxation may be helpful but is far from sufficient. While vehicle taxation shows great promise, a much greater understanding is needed of the industry's response and the conditions for effectiveness of such an approach. It would therefore be imprudent to abandon the trying but tried and true regulatory approach for the current round of policy making. However, adding a feebate or expanded gas guzzler tax to strengthened standards would provide an opportunity to develop and refine this type of market approach. Vehicle pricing policies are likely to be the key to a long-term strategy for obtaining substantial ongoing improvements in fuel economy, perhaps without the need to periodically agonize over strengthening the regulatory standards. A concerted effort, in which industry must play a crucial role, is needed if the country is to avail itself of this promising new approach to addressing the problems associated with rising transportation energy consumption.

REFERENCES

AAA. Press release on results of a public option poll regarding proposed increases in energy and gasoline taxes. American Automobile Association, Washington, DC, February 1993.

Chandler, W.U., and A.K. Nicholls. Assessing carbon emissions control strategies: a carbon tax or a gasoline tax? Policy Paper No. 3, American Council for an Energy-Efficient Economy, February 1990.

CRA (Charles River Associates). Policy alternatives for reducing petroleum use and greenhouse gas emissions. Report prepared for the Motor Vehicle Manufacturers Association by Charles River Associates, Boston, MA, September 1991.

Davis, S.C., and S.G. Strang. Transportation Energy Data Book: Edition 13. Report ORNL-6743, Oak Ridge National Laboratory, March 1993.

Davis, W.B., and D. Gordon. Using Feebates to improve the average fuel efficiency of the U.S. vehicle fleet. Report LBL-31910, Energy Analysis Program, Lawrence Berkeley Laboratory, Berkeley, CA, January 1992.

Davis, W.B., M.D. Levine, K. Train, and K.G. Duleep. Feebates: Estimated Impacts on Vehicle Fuel Economy, Fuel Consumption, CO_2 Emissions, and Consumer Surplus. Preliminary results of a study forthcoming from the Energy Analysis Program, Lawrence Berkeley Laboratory, presented at the Asilomar Conference on Transportation and Energy, August 1993.

DeCicco, J.M. Savings from CAFE: projections of the future oil savings from light vehicle fuel economy standards. American Council for an Energy-Efficient Economy, Washington, DC, May 1992.

DeCicco, J.M., and H.S. Geller. A size-based feebates approach for increasing light vehicle fuel economy. American Council for an Energy-Efficient Economy, Washington, DC, January 1993.

DeCicco, J.M., and M. Ross. An updated assessment of the near-term potential for improving automotive fuel economy. American Council for an Energy-Efficient Economy, Washington, DC, November 1993.

DeCicco, J.M., H.S. Geller, and J.H. Morrill. Feebates for fuel economy: market incentives for encouraging production and sales of efficient vehicles. American Council for an Energy-Efficient Economy, Washington, DC, May 1993.

Difiglio, C. Analysis of fuel economy excise taxes and rebates. Special Report 169, pp. 40-46, Transportation Research Board, National Research Council, Washington, DC, 1976.

DOE. Energy conservation trends: Understanding the factors that affect conservation gains in the U.S. economy. Report DOE/PE-0092, U.S. Department of Energy, Washington, DC, September 1989.

Dower, R.C., and M.B. Zimmerman. The right climate for carbon taxes: creating economic incentives to protect the atmosphere. World Resources Institute, Washington, DC, August 1992.

Dolan, K., B. Anderson, H. Nishimaki, L. Schipper, R. Steiner, and W. Tax. Policies affecting automobile attributes in Western Europe and Japan. Draft manuscript, International Energy Studies Program, Lawrence Berkeley Laboratory, Berkeley, CA, January 1992.

DRI (DRI/McGraw-Hill, Inc.). An Analysis of Public Policy Measures to Reduce Carbon Dioxide Emissions from the U.S. Transportation Sector, prepared for the U.S. Environmental Protection Agency, Office of Policy, Planning, and Evaluation, January 1991.

ECC. Combining consumer and manufacturer incentives with stronger fuel economy standards. Energy Conservation Coalition, Takoma Park, MD, April 1993.

EEA. Documentation of the characteristics of technological improvements utilized in the Technology Cost Segment Model (TCSM), Report prepared for the U.S. Department of Energy, Energy and Environmental Analysis, Inc., Arlington, VA, June 1985.

EIA. Transportation Energy Demand module for the PC-AEO spreadsheet model, Energy Information Administration, Washington, DC, 1990.

EIA. Studies of Energy Taxes. Service Report SR/EMEU/91-02, U.S. Department of Energy, Energy Information Administration, Washington, DC, 1991.

EIA. Annual Energy Outlook 1993. U.S. Department of Energy, Energy Information Administration, Washington, DC, Januaryn 1993.

Erikson, G., and L. Schipper. Taxation of personal vehicles and fuel in OECD countries: truth and consequences. Presentation to the Transportation and Energy Conference, Asilomar, California, August 1993.

FHWA. Highway statistics 1990. Report FHWA-PL-91-003, Federal Highway Administration, Washington, DC, 1991.

Geller, H., J. DeCicco, and S. Laitner. Energy efficiency and job creation: the employment and income benefits from investing in energy conserving technologies. Report, American Council for an Energy-Efficient Economy, Washington, DC, October 1992.

Gordon, D. Steering a new course: transportation, energy, and the environment. Union of Concerned Scientists, Cambridge, MA, 1991.

Gordon, D., and L. Levenson. DRIVE+: a proposal for California to use consumer fees and rebates to reduce new motor vehicle emissions and fuel consumption. Lawrence Berkeley Laboratory, Berkeley, CA, July 1989.

Greene, D.L. State differences in the demand for gasoline: an econometric analysis. Energy Systems and Policy 3(2):191-212, 1979.

Greene, D.L. CAFE or Price? An analysis of the effects of federal fuel economy regulations and gasoline price on new car MPG, 1978-1989. The Energy Journal 11(3), September, 1990.

Greene, D.L. Short-run pricing strategies to increase corporate average fuel economy. Economic Inquiry 29(1), January 1991.

Greene, D.L. (Oak Ridge National Laboratory). Personal communication, February 1993.

Greene, D.L. Effect of a gasoline tax on fuel economy and gasoline consumption. Presentation to the SAE Government/Industry Meeting, Washington, DC, May, 7, 1993.

Greene, D.L., and K.G. Duleep. Costs and benefits of automotive fuel economy improvement: a partial analysis. Report ORNL-6704, Center for Transportation Analysis, Oak Ridge National Laboratory, TN, March 1992.

Harvey, G. (DHS Associates, Berkeley, CA). Personal communication, January 1993.

Heavenrich, R.M., J.D. Murrell, and K.H. Hellman. Light-duty automotive technology and fuel economy trends through 1991. Report EPA/AA/CTAB/91-02, U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, MI, May 1991.

IEA. Fuel efficiency of passenger cars. International Energy Agency, Organization for Economic Cooperation and Development (OECD), Paris, 1991.

Koomey, J., and A.H. Rosenfeld. Revenue-neutral incentives for efficiency and environmental quality. Contemporary Policy Issues, VIII:142-156, July 1990.

Ledbetter, M., and M. Ross. Light vehicles: policies for reducing their energy use and environmental impacts, in Byrne, J. (ed.) Energy and Environment: The Policy Challenge. Energy Policy Studies, Volume VI, University of Delaware, Transaction Books, 1992.

Leone, R.A., and Parkinson, T. Conserving energy--Is there are better way? A study of Corporate Average Fuel Economy regulation. Prepared for the Association of International Automobile Manufacturers (AIAM), Washington, DC, May 1990.

MacKenzie, J.J., R.C. Dower, and D.D.T. Chen. The going rate: what it really costs to drive. World Resources Institute, Washington, DC, June 1992.

Miles-McLean, R., S.M. Haltmaier, and M.G. Shelby. Designing incentive-based approaches to limit carbon dioxide emissions from the light duty vehicle fleet. Chapter 4 in D.L. Greene and D.J. Santini (eds.), Transportation and Global Climate Change, American Council for an Energy-Efficient Economy, Washington, DC, 1993.

Millyard, K. Brief on the Ontario Tax for Fuel Conservation. Friends of the Earth, Ottawa, 1991.

Mintz, M.M., A.R.D. Vyas, and L.A. Conley. Differences between EPA-test and in-use fuel economy: are the correction factors correct? Paper No. 931104, Transportation Research Board, Washington, DC, January 1993.

Murrell, J.D., R.M. Heavenrich, and K.H. Hellman. Light-duty automotive technology and fuel economy trends through 1993. Report EPA/AA/CTAB/93-01, U.S. Environmental Protection Agency, Office of Mobile Sources, Ann Arbor, MI, May 1993.

MVMA. MVMA motor vehicle facts and figures '92. Motor Vehicle Manufacturers Association, Detroit, Michigan, 1992.

Newman, P.W.G., and J.R. Kenworthy. Cities and automobile dependence: a sourcebook. Gower Technical, Aldershot, England, 1989.

Schipper, L., S. Meyers, R.B. Howarth, and R. Steiner. Energy Efficiency and Human Activity: Past Trends, Future Prospects. Cambridge University Press, 1992.

Stobaugh, R., and D. Yergin (eds.). Energy future: report of the Energy Project at the Harvard Business School. Random House, New York, 1979.

Sweeney, J.L. Effects of federal policies on gasoline consumption. Resources and Energy 2:3-26, 1979(a).

Sweeney, J.L. New car efficiency standards and the demand for gasoline. Advances in the Economics of Energy and Resources 1:105-133, 1979(b).

Train, K. Qualitative choice analysis. MIT Press, Cambridge, MA, 1986.

Train, K. Methodology for estimating the impacts of feebates for new vehicles. Department of Economics, University of California, Berkeley, CA, December 1991.

Train, K. Feebates design: impacts on vehicle technology, consumer choice, fuel consumption, and consumer surplus. Presentation to the Transportation and Energy Conference, Asilomar, California, August 1993.

UCS et al. (Alliance to Save Energy, American Council for an Energy-Efficient Economy, Natural Resources Defense Council, and Union of Concerned Scientists). America's Energy Choices: investing in a strong economy and a clean environment. Union of Concerned Scientists, Cambridge, MA, December 1991.

von Hippel, F., and B. Levi. Automobile fuel efficiency: the opportunity and the weakness of existing market incentives. Resources and Conservation 10: 103-124, 1983.

Westbrook, F., and P. Patterson. Changing driving patterns and their effect on fuel economy. Presented at the 1989 SAE Government/Industry Meeting, Washington, DC, May 1989.

Williams, J. (Metropolitan Council of Governments, Washington, DC). Personal communication, January 1993.

Williams, L.S., and P.S. Hu. Highway vehicle MPG and market shares report: model year 1990. Report ORNL-6672, Oak Ridge National Laboratory, Oak Ridge, TN, April 1991.

Zimmerman, M.B., and D. Bohi. Review of energy demand elasticities. Annual Review of Energy, 1984.

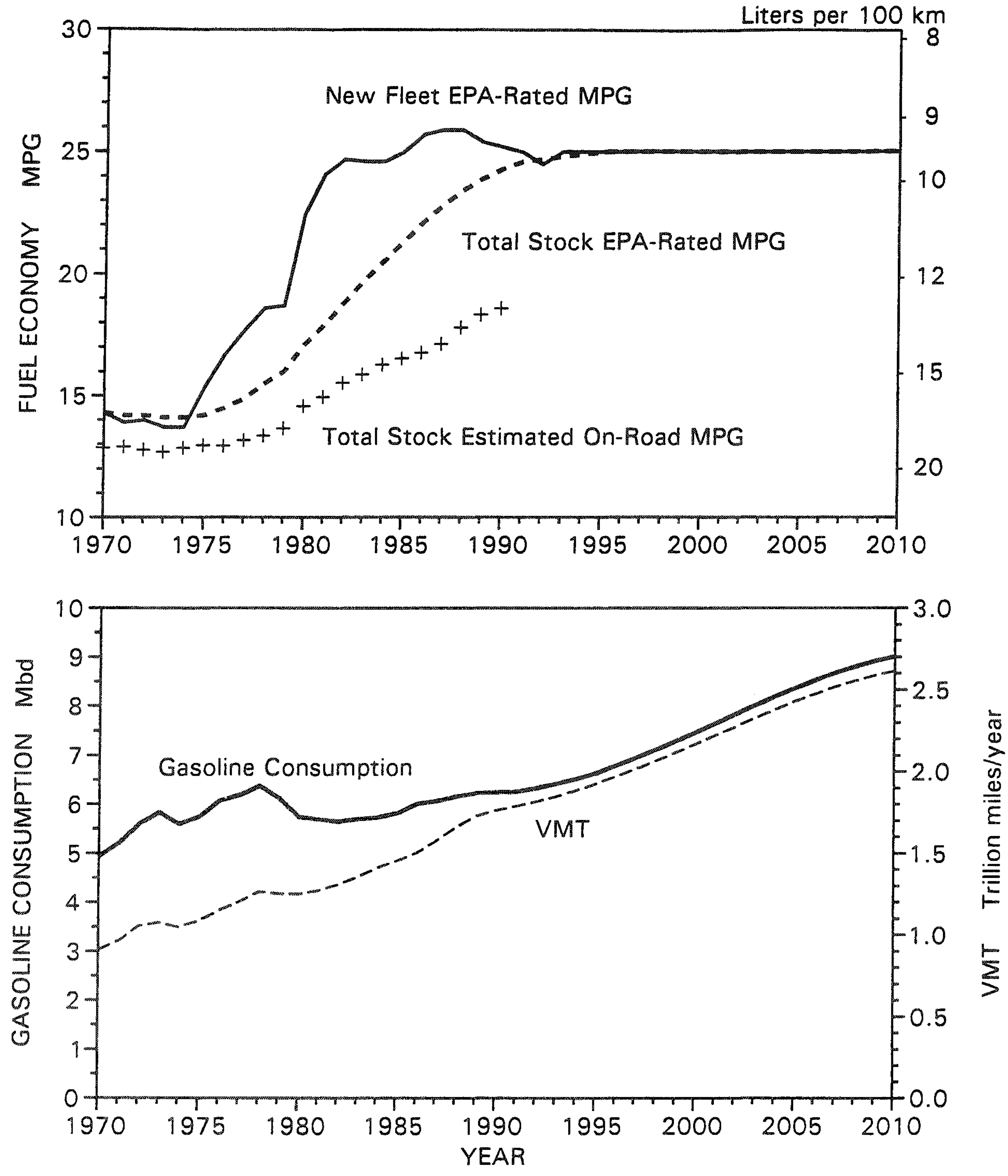

Figure 1. Light vehicle fuel economy, VMT, and fuel consumption: historical statistics 1970-93 and current policy projections through 2010.

EPA-rated average fuel economy of cars and light trucks through 1993 is from Murrell *et al.* (1993) for new fleet and from the ACEEE stock model for total light vehicle stock. Stock on-road MPG estimates, VMT, and gasoline consumption (million barrels per day, Mbd) through 1990 are based on Davis and Strang (1993). Projections are based on VMT growth averaging 2%/yr through 2010 and an assumption of frozen rated new vehicle fuel economy.

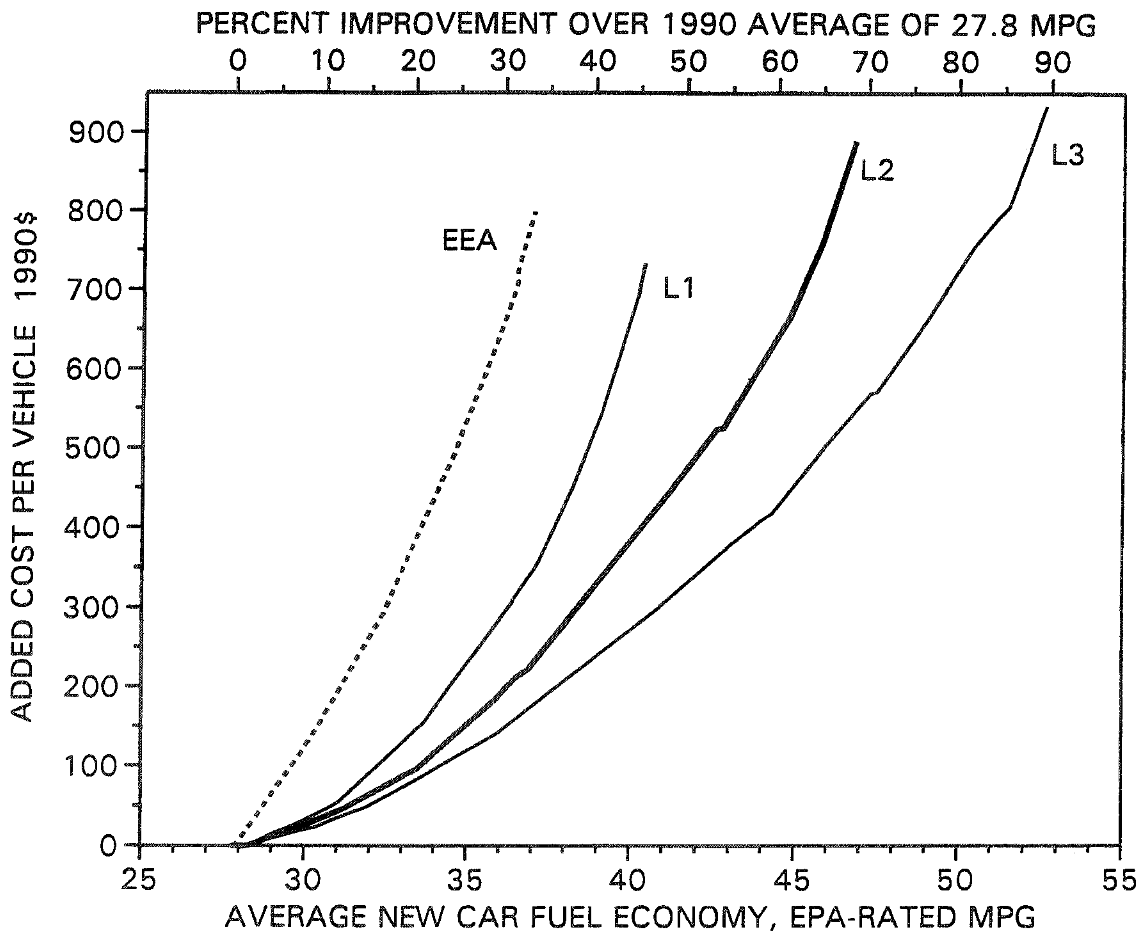

Figure 2. **Estimated cost of automobile fuel economy improvement for varying assumptions regarding technology availability and effectiveness.**

Curves L1-L3 represent increasing levels of optimism regarding the availability and feasibility of improved technologies, as estimated by DeCicco and Ross (1993); the EEA curve is based on Greene and Duleep (1992) and is similar to other recent DOE estimates.

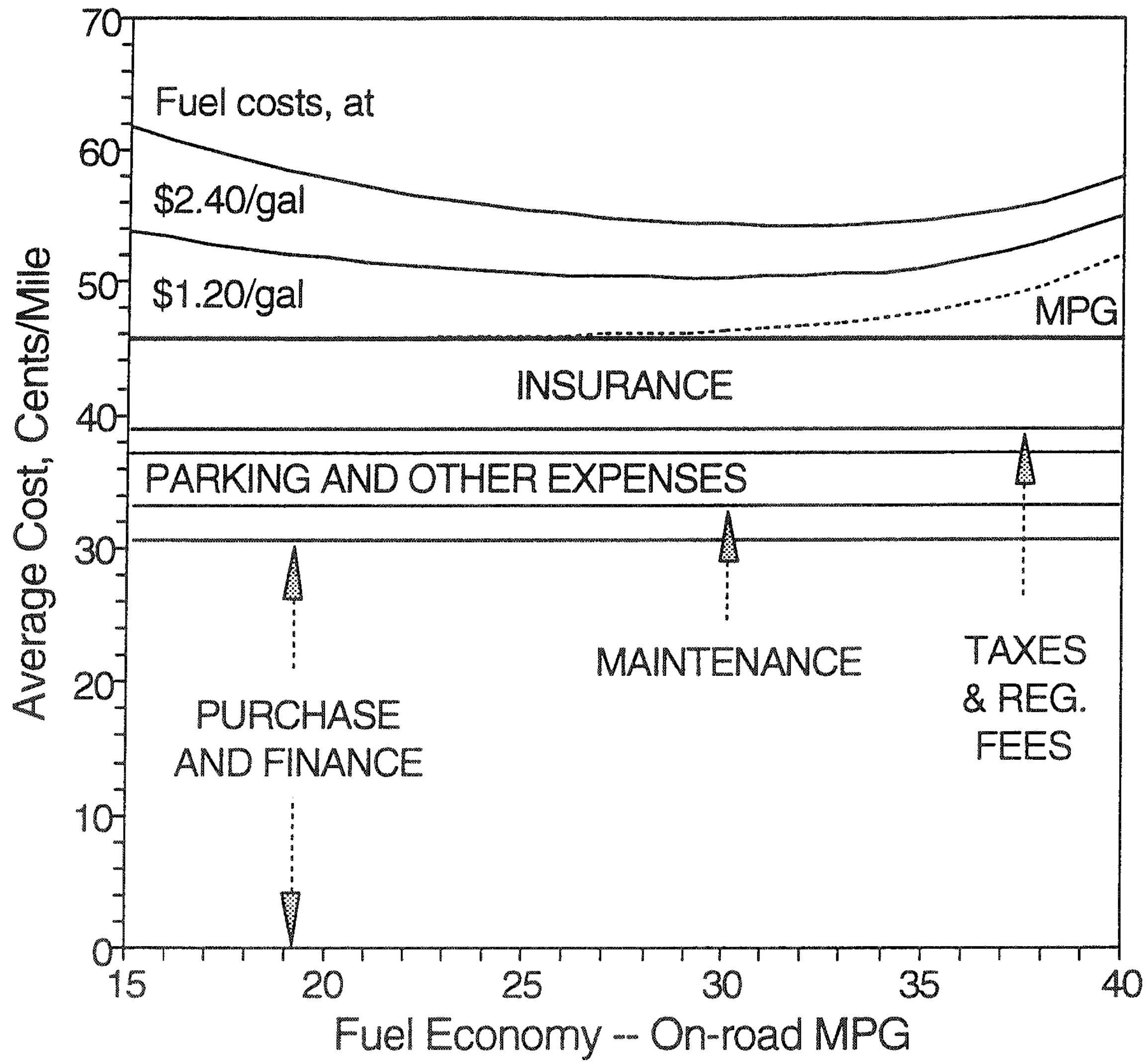

Figure 3. Costs of fuel and fuel economy improvement in the context of the total costs of owning and operating a car.

Automobile expense statistics are from MVMA (1992); fuel economy improvement ("MPG") cost estimates are from DeCicco and Ross (forthcoming 1993).

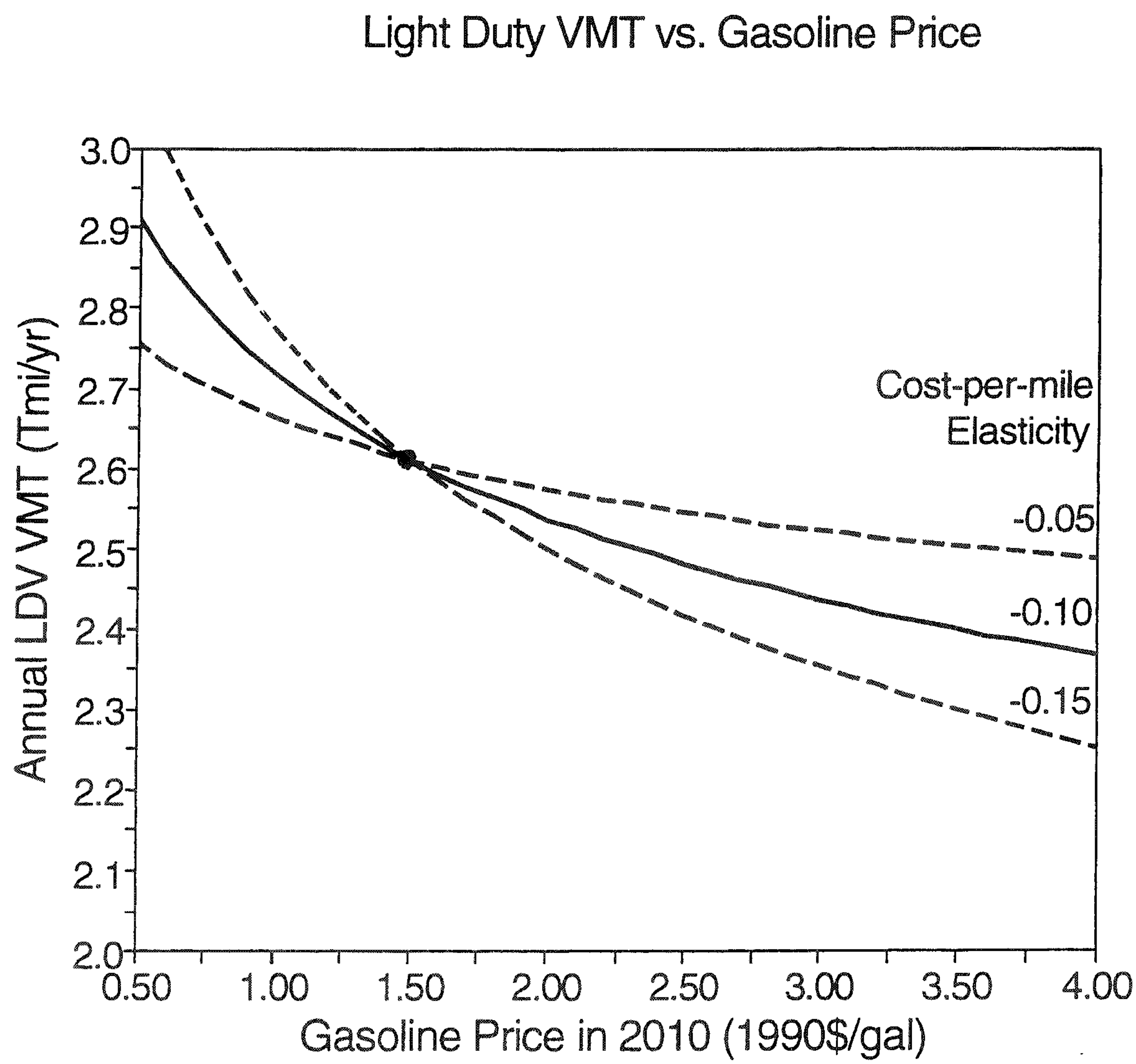

Figure 4. **Projected light duty vehicle miles of travel (VMT) in 2010 as a function of gasoline price, for varying values of price elasticity.**

Based on a nominal projection of 2.610 x 10^{12} miles per year (Tmi/yr) at a gasoline price of $1.50/gallon (1990$).

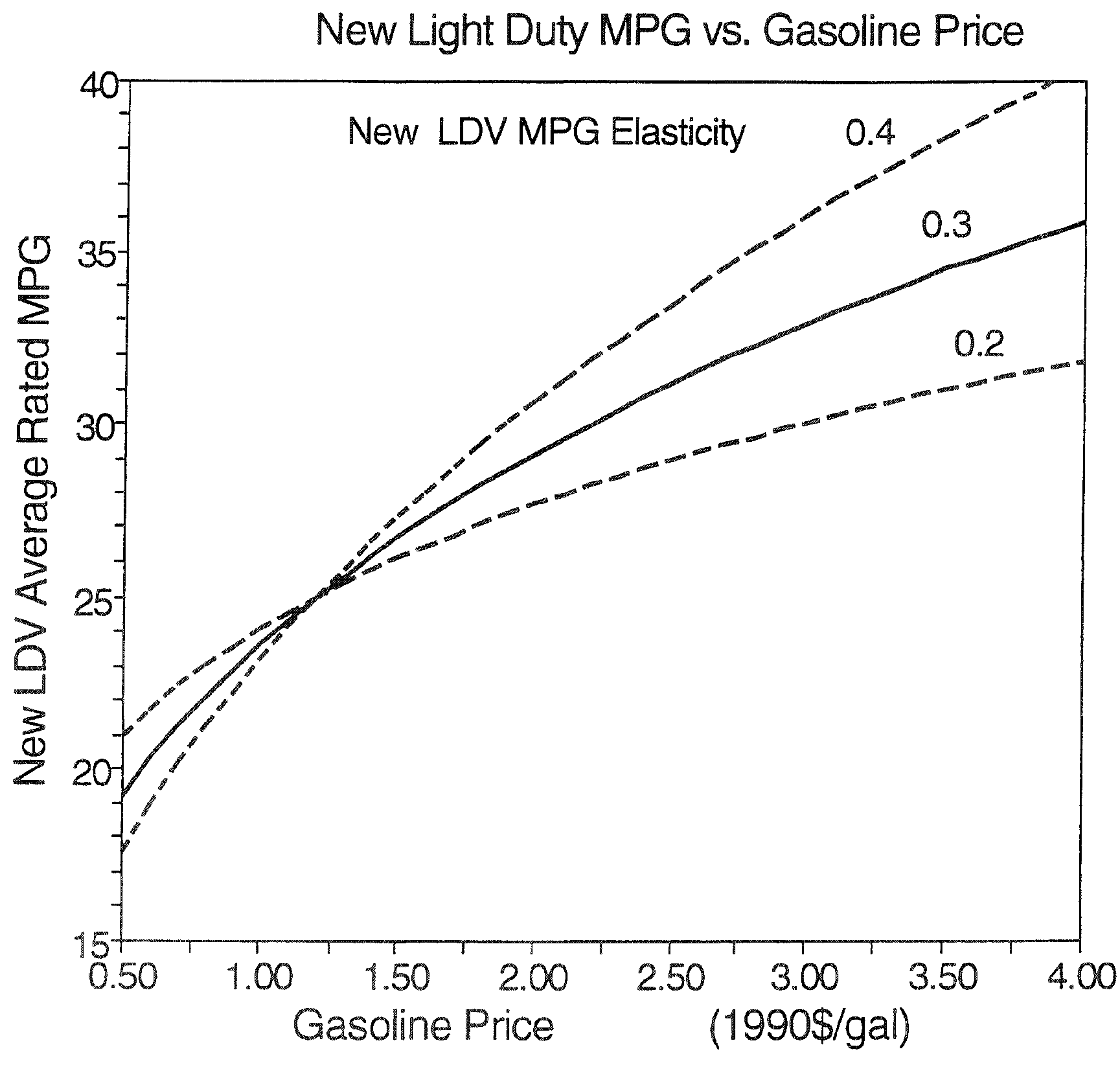

Figure 5. **Estimated new light vehicle fuel economy as a function of gasoline price, for varying values of price elasticity.**

Based on a nominal estimate of 25 mpg (EPA-rated city/highway mpg, average of cars and light trucks) at a gasoline price of $1.20/gallon (1990$). Assumes adequate lead time for changes in manufacturer product planning in response to changes in fuel price.

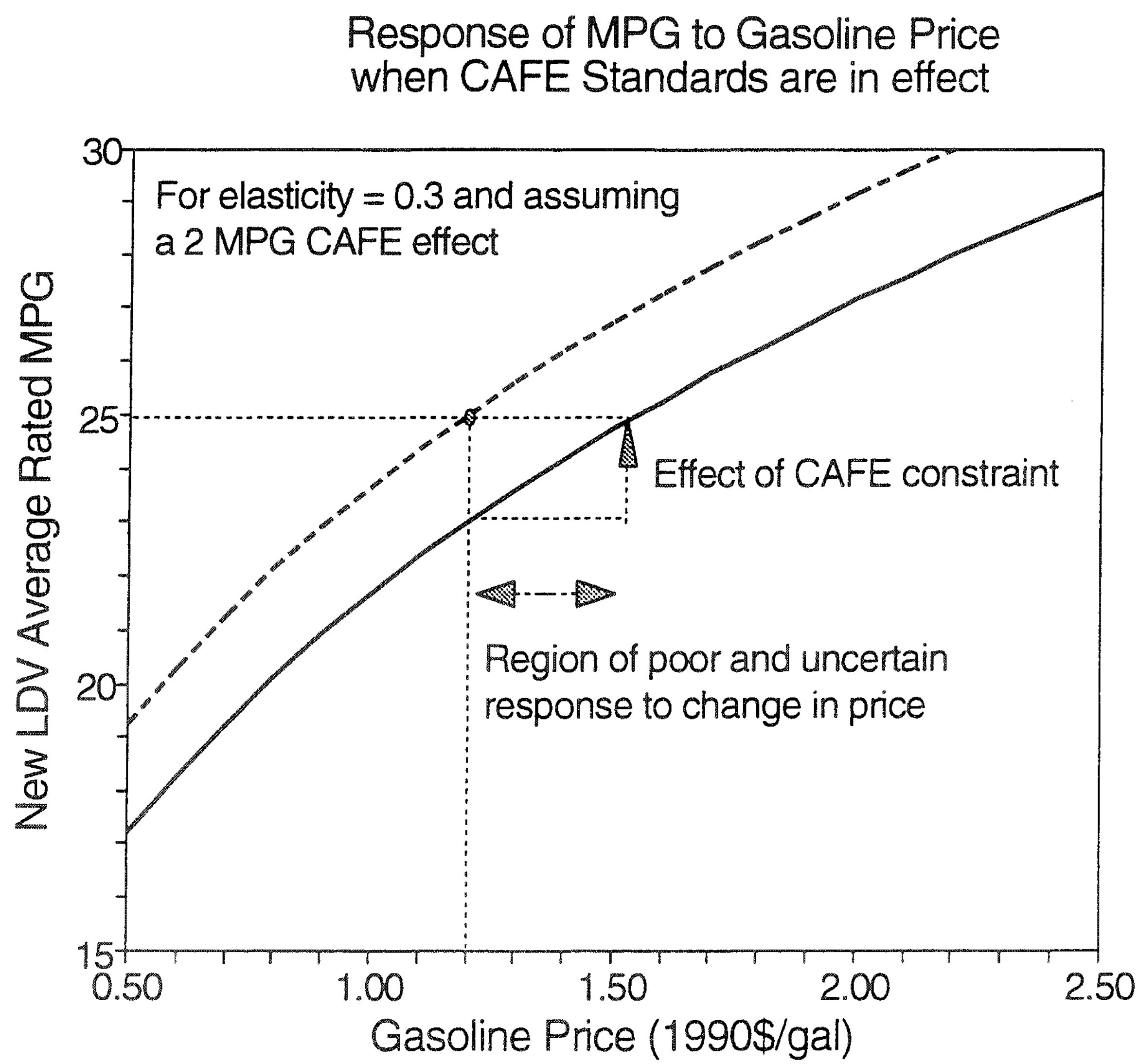

Figure 6. Possible effect of fuel economy standards in holding new light vehicle fuel economy above the level induced by gasoline price alone.

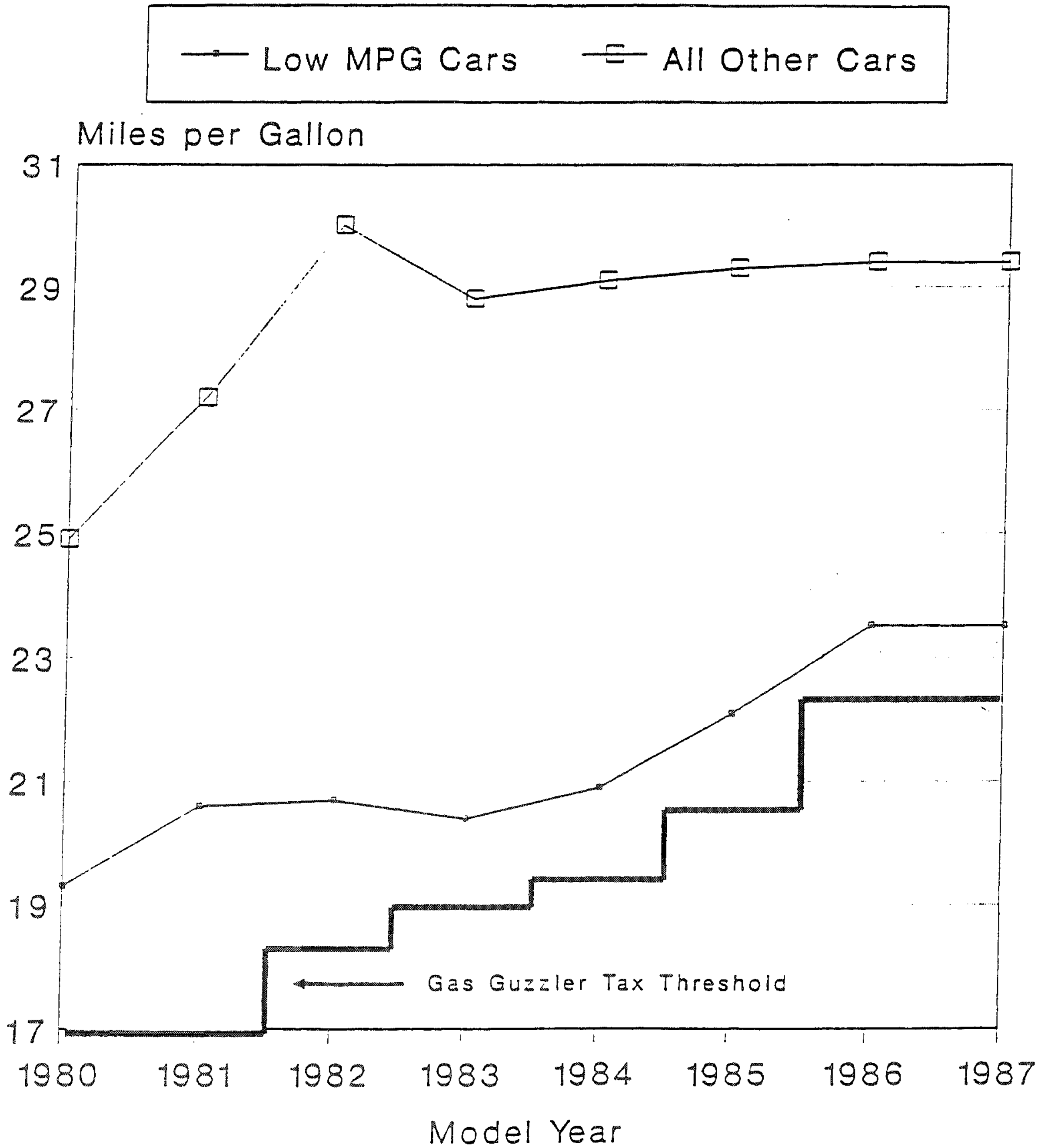

Figure 7. Gas guzzler tax thresholds and the average fuel economies of new low-MPG cars vs. other cars, 1980-1987; from Ross *et al.* (1991).

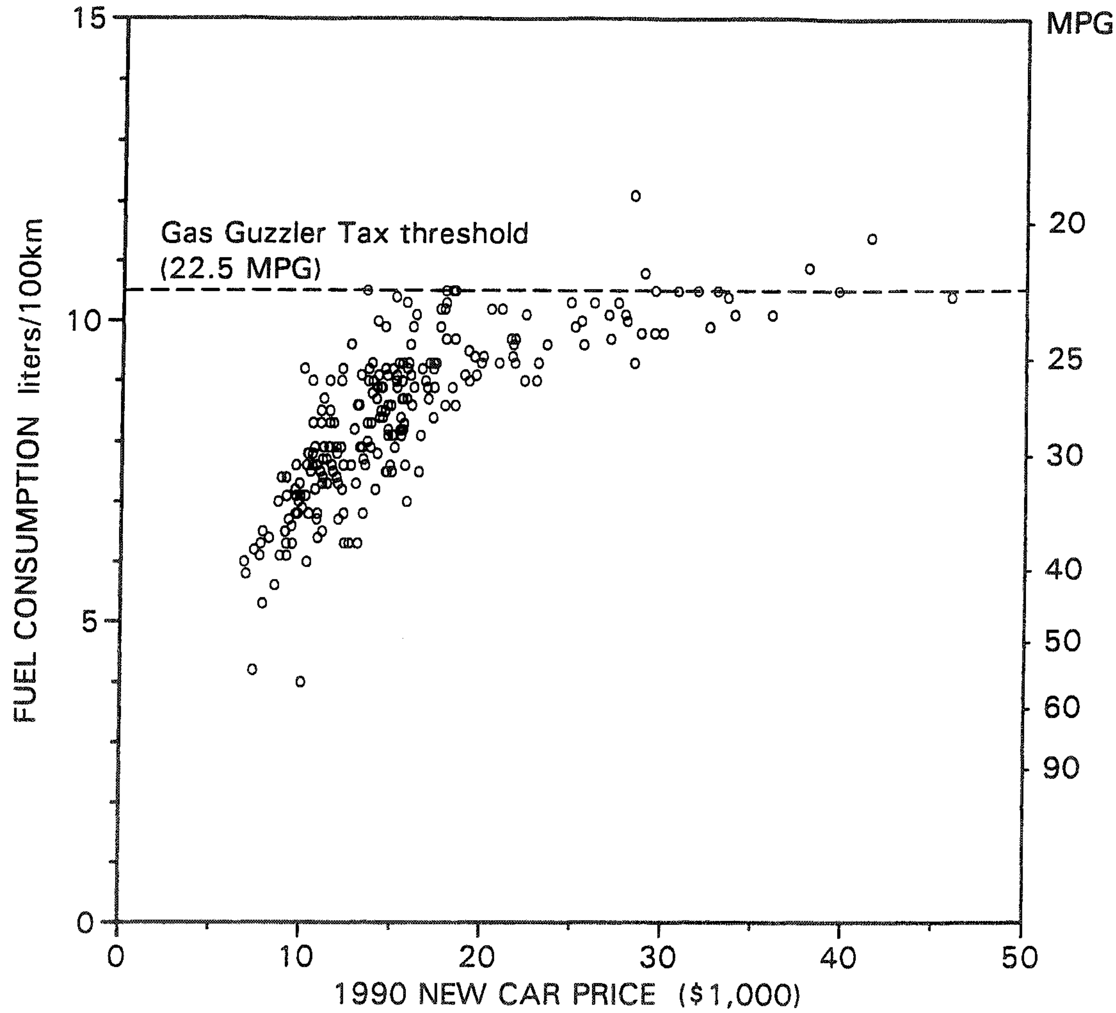

Figure 8. Fuel consumption versus vehicle price for 1990 new cars.

Based on nameplate average fuel economy from Williams and Hu (1991); prices estimated as the median of the base Manufacturer's Suggested Retail Price (MSRP) listings for each nameplate, rounded to the nearest $100, from the Automotive News 1990 Market Data Book.

For the vehicles in our data base, the estimated 1990 average new car price was $15,100, slightly lower than the $16,000 average 1990 new car transaction price reported by MVMA (1992). The estimated average price of 1990 new light trucks was $13,200 and the overall 1990 light duty vehicle average was $14,500.

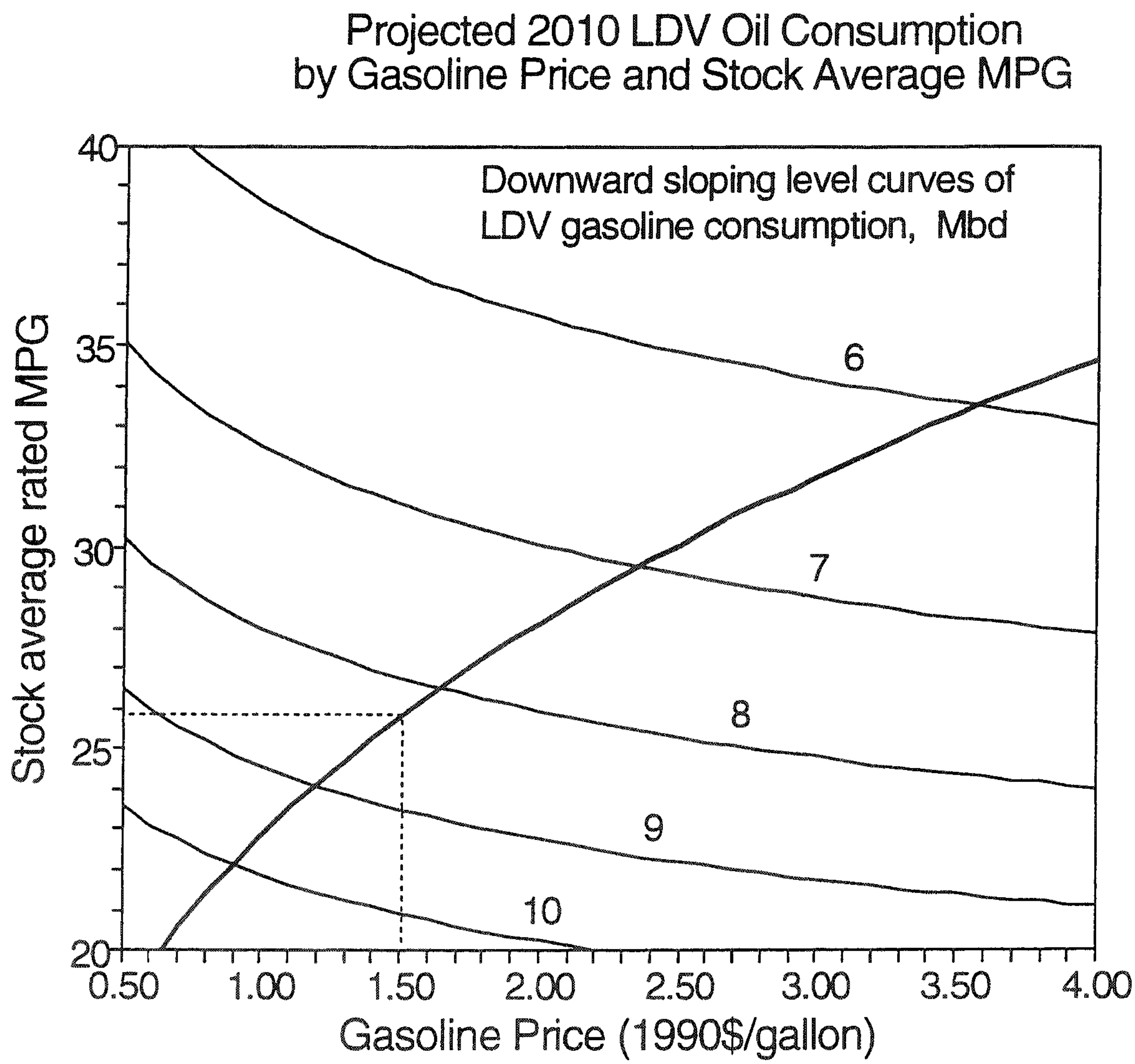

Figure 9. **Projected light vehicle gasoline consumption in 2010 as a function of gasoline price and stock average fuel economy.**

Assumes nominal projections of 2.61 x 10^{12} miles/year VMT and $1.50/gal gasoline, fuel price elasticities of -0.10 for VMT and 0.30 for MPG, and 20% shortfall between rated on on-road fuel economy. Level curves (contours) of projected gasoline consumption are shown in millions of barrels per day (Mbd).