FEEBATES FOR FUEL ECONOMY: Market Incentives for Encouraging Production and Sales of Efficient Vehicles

John M. DeCicco, Howard S. Geller, and John H. Morrill

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

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SUMMARY

This report discusses purchase price incentives for making fuel-efficient vehicles more attractive in the automotive marketplace. ***Feebate*** is a contraction of the words "fee" and "rebate." Applied to motor vehicle fuel efficiency, a feebate is a tax/subsidy system which specifies fees for "guzzlers" (vehicles of relatively lower efficiency) and rebates for "sippers" (vehicles of relatively higher efficiency). In the United States, a federal feebate program can be thought of as an extension of the existing gas guzzler tax. State feebate programs could involve tax surcharges ("fees") and tax credits ("rebates") developed as a modification of existing sales tax or licensing programs. Feebates can be designed to be either revenue neutral or revenue generating.

General principles for formulating feebates are described and a brief review is given of programs which have been recently proposed or enacted. Issues that need to be addressed in developing a workable feebate program are discussed, particularly treatment of light trucks and differential impacts on domestic and foreign manufacturers. Other issues identified include: appropriate magnitudes for fees and rebates; coordination with fuel economy standards; likely impacts on consumer and automaker decision making; potential energy savings; understandability to consumers; revenue impacts; tax equity considerations; coverage of alternatively fueled vehicles; and special considerations for state-level feebate programs.

Incorporating vehicle size into the calculation of feebates is a promising approach in our view. Size-adjusted feebates can avoid specifically favoring manufacturers whose model lines are concentrated on smaller vehicles at the expense of those whose model lines include larger vehicles. Efficient vehicles of any size can qualify for a rebate; likewise, fees are levied on the less efficient vehicles of any size. Detailed analysis is provided for feebates based on fuel consumption (or CO_2 emissions) adjusted by vehicle footprint (wheelbase times track width) or interior volume. We show that, by separating cars from light trucks and chosing an appropriate size-adjusted approach, it is possible to develop a feebate system which would not disadvantage U.S. automakers on the basis of the 1990 fleet mix. Because they are effective in addressing the manufacturer equity issue, we recommend the size-based feebate concepts presented here as a foundation for developing federal and state incentive programs.

Further analysis and implementation experience are needed before the effectiveness of feebates can be fully assessed. However, a strong feebate program would shift consumers' new vehicle purchase decisions toward more efficient vehicles. It would also affect manufacturers' product planning, providing an incentive for efficiency-oriented innovation. This technology forcing role (which is shared by ongoing strengthening of fuel economy standards) is likely to have a greater effect on fleetwide efficiency improvement than shifts in consumer choices alone. Feebates are therefore a promising way to reach long-term national objectives of reducing transportation oil use and its attendant adverse economic and environmental impacts. This report provides a concrete basis for developing specific proposals by presenting a detailed analysis of potential feebate programs and identifying the various issues which need to be addressed.

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INTRODUCTION

The benefits of improving light vehicle fuel economy are very weakly reflected in the automobile marketplace when gasoline prices are low and there is little active concern about a petroleum supply disruption. When shopping for a vehicle, new car buyers value many different features--styling, comfort, size, utility, reliability, luxury, performance, accessories, and safety--besides fuel economy. While an automobile is often the second largest consumer expense (after housing), the fuel-related cost is only about 12% of the total cost of owning and operating a vehicle (Ledbetter and Ross 1991). This fraction decreases as fuel economy increases, as long as oil prices and fuel taxes remain low. Thus, the direct costs of inefficiency are not felt except as a minor, out-of-pocket expense. For many Americans (particularly new car buyers, whose incomes are above average), motor fuel costs are only a very small part of their overall cost of living. The benefits of higher fuel economy, which accrue over the lifetime of a vehicle (to owners of both new and used cars), are remote at the time of new car purchase. Future rises in fuel prices are uncertain, serving to further discount their importance at time of vehicle purchase. This uncertainty and the poor sensitivity to life-cycle costs are well-known market barriers against energy-efficient technologies (Hirst and Brown 1990). There are economic losses associated with inefficient fuel use and the chronic trade deficit due to oil imports. Moreover, gasoline prices do not reflect other costs (externalities) associated with petroleum fuel use, such as energy security costs, air pollution, and the risks of disruptive climate change due to carbon dioxide emissions (Gordon 1991; MacKenzie *et al.* 1992).

Under market conditions of low gasoline prices and little public apprehension about future oil supply, manufacturers at best improve fuel economy only to the extent that it provides a very short term payback, is achieved as part of a package of other benefits, or appeals to the relatively limited number of new light vehicle (car and light truck) buyers who highly value fuel economy. This is apparent in the cessation of improvement in new vehicle fuel economy that has occurred since 1988 (Figure 1). It seems unlikely that there will be further improvements in the average fuel economy of new light vehicles given the market conditions that have prevailed since oil prices fell in 1986. In order to control growth in motor vehicle oil consumption, there is a need for some combination of fuel economy regulation and price incentives along with measures for reducing vehicle travel. However, the United States has highly automobile-dependent settlement patterns and transportation infrastructure, which can only be transformed over generation-length time scales. The potential for reducing nationwide fuel consumption through technology improvement (higher fuel economy) is at least three times as great as that achievable through reductions in vehicle use over the next several decades (DeCicco *et al.* 1993).

Fuel pricing, vehicle pricing, and vehicle regulation all have their pros and cons as approaches to control motor fuel consumption. Fuel pricing is directed mainly toward consumer behavior. Vehicle regulation is directed mainly towards manufacturers. Of course, both of these interventions will at least indirectly involve responses by the other parties in the market. Feebates--intervention in vehicle pricing--directly affect both consumers and manufacturers as well as car dealers. While this report focuses on feebates, it does not mean to imply that a feebate program would eliminate the need to pursue the other options of fuel pricing and vehicle regulation. Ideally, motor vehicle fuel use is best addressed by a complementary set of policies: stronger fuel economy standards, feebates, an increased gasoline tax (which could be carbon based), and various strategies for reducing travel demand.

Existing fuel taxes are based mainly on the need to partially fund transportation infrastructure and have not been rationalized as a way of controlling fuel consumption, although conservation has motived gasoline tax proposals in the past (Nivola 1986). The energy tax proposed by the Clinton Administration in early 1993 was motivated by both conservation and deficit reduction, but its gasoline price effect of approximately 7.5¢/gal will have only a minor impact on fuel consumption. Discussions of fuel taxation as an energy policy measure are given by Chandler and Nicholls (1990), EIA (1991), UCS *et al.* (1991), and Dower and Zimmerman (1992), among others. Further analysis is needed regarding the potential for fuel taxation to control the level of fuel consumption in the United States. In contrast to fuel taxation, regulation of all light duty vehicles and taxation of inefficient cars (gas guzzlers) are established parts of U.S. energy policy.

Rebate programs have already been successful in the appliance market. Major appliances, like motor vehicles, are durable goods whose energy consumption depends mainly on their technology. Utility-sponsored rebate programs for refrigerators accelerated the development and sale of highly efficient models between 1990, when the first refrigerator standards took effect, and 1993, when the standards increased by 30 percent. Of themselves, these rebates were not technology-forcing, but they did have an observable effect on the refrigerator market (Morrill 1993).

The Need to Complement CAFE Standards

Corporate Average Fuel Economy (CAFE) standards have been the primary policy tool for improving the efficiency of automobiles and light trucks in the United States. Advancing the Corporate Average Fuel Economy (CAFE) standards can provide a significant improvement in the energy efficiency of light vehicles.[1] First legislated in 1975, CAFE standards have been the principal force behind a 75% increase in on-road automobile efficiency since 1973.[2] Although the impetus for CAFE standards was the oil shock of 1973, and the energy crises of 1973 and 1979 did temporarily raise fuel prices, it is CAFE standards which have provided a steady signal to manufacturers, leading to the availability of efficient vehicles in the marketplace. If oil prices remain low, as they may for the foreseeable future, strengthening fuel economy standards is likely to be the single most effective action the federal government can take to reduce transportation energy use and oil dependency.

Standards alone, however, do not fundamentally change the market conditions which necessitate the regulation. The current labeling for fuel economy (EPA mileage ratings) does help make fuel economy more apparent to a car buyer. However, compared to price, information alone has a relatively weak influence on consumer decisions. Moreover, decisions in the automobile market hinge mainly on features other than fuel economy, some of which (e.g., size, luxury, and power) tend to lower fuel economy. Therefore, CAFE standards encounter manufacturers' opposition because they run counter to other selling points.

[1] CAFE standards were established by the Motor Vehicle Information and Cost Savings Act of 1975 and first came into effect in 1978 (a year later for light trucks). The need for fuel economy standards is discussed by Stobaugh and Yergin (1979), Ross and Williams (1981), and Ledbetter and Ross (1991); evaluations of their effect are given by Greene (1990) and DeCicco (1992a).

[2] Based on fuel economy statistics from EPA (1980) and Heavenrich *et al.* (1991). Greene (1990) concluded that CAFE standards had a significantly larger impact than oil price shocks on this historical fuel economy improvement.

The potential benefits of a vehicle tax and rebate approach for improving fuel economy has long been recognized (Difiglio 1976). An up-front pricing advantage could bolster the sales of efficient vehicles, thereby facilitating compliance with strengthened CAFE standards and possibly raising the average fuel economy above what it would be with standards alone. Feebates would reduce the pressure on manufacturers to modify the pricing of their models for the sake of compliance with CAFE standards. A pricing-induced increase in demand would make efficient vehicles more profitable, thereby addressing the objection that inefficient ("large") vehicles are more profitable than efficient ("small") vehicles. Moreover, a market incentive that creates a subsidy proportional to the extent that a vehicle exceeds a standard is likely to motivate manufacturers to make ongoing technological improvements in efficiency. Finally, taxing inefficient vehicles and subsidizing efficient vehicles is one way to incorporate the environmental and security costs associated with gasoline use into market decision making (Koomey and Rosenfeld 1990).

An established mechanism which relates fuel economy to vehicle purchase price is the gas guzzler tax. Except for luxury line manufacturers who can successfully reach the high-end market in spite of the tax, the gas guzzler tax has been successful in pulling up the bottom end of the fleet as far as efficiency is concerned. This is evidenced by the way that the fuel economy of low-mpg cars continued to improve in the mid-1980s while improvements in the rest of the fleet slowed down (Ledbetter and Ross 1991). Figure 2 plots fuel consumption versus vehicle price for 1990 new cars, clearly showing the constraining effect of the gas guzzler tax, even on some of the more expensive models. Because the threshold for the tax, set at 22.5 mpg, was not raised to keep pace with fuel economy improvements, most new cars are presently unaffected by the gas guzzler tax. Furthermore, the guzzler tax does not apply to any vehicles classified as light trucks.

As enacted in 1978, the gas guzzler tax applied only to a relatively small portion of the automobile fleet. 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), and projected a 13% reduction in fleetwide fuel use by 1985.

For the past several years, a political debate has been raging about whether, how much, and by when CAFE standards should be increased. There is concern among some supporters of stronger fuel economy standards that feebates would be construed as a replacement for standards. Because a broad-coverage feebate system is untried in the U.S. market, there is insufficient evidence that incentives alone can reliably provide as much energy savings as would a significant strengthening of CAFE standards. Clearly, the larger the incentive (i.e., the larger the magnitude of the feebates), the larger the response. Feebates will provide a sales price signal that favors fuel economy, thereby making higher CAFE standards easier for manufacturers to achieve. As is the case for fuel economy standards, the justification for feebates rests on a recognition that there is a significant opportunity for cost-effective vehicle efficiency improvement which is not being realized in the marketplace.

Until an automotive feebate program is tried, however, it will not be known whether a politically acceptable feebate level will induce a significant improvement in fleet efficiency beyond the levels mandated by CAFE standards. Moreover, in spite of intense opposition by the auto industry, CAFE standards do have a successful track record. Feebates for fuel economy, on the other hand, are a new idea yet to be proven in practice. Thus, feebates are best thought of as a complementary policy mechanism to be closely coordinated with strengthened new fleet fuel economy standards.

A Review of Feebate Proposals

This section briefly reviews a number of current and proposed feebate schemes. More comprehensive reviews which summarize the characteristics of recent U.S. proposals are provided by Davis and Gordon (1992) and Calwell, DeCicco, and Gordon (1992).

Internationally, vehicle tax incentive programs 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, thereby linking the vehicle tax rate to fuel economy at least indirectly. Schipper *et al.* (1991) provide an international review of taxation policies related to motor vehicle emissions and fuel use.

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.[3] 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,[4] which is dedicated to other environmentally related transportation programs. An expansion of the program was proposed in order to cover all light truck classes and provide rebates up to $250. Even though this expanded proposal had been developed with the support of the Canadian Auto Workers and Ford Canada (Fair Tax Commission 1992), it was defeated in April 1992 after a campaign mounted against it by General Motors (Peapples 1992).

In April 1992, the State of Maryland enacted a comprehensive tax bill which included the first U.S. feebate program for motor vehicles.[5] To date, Maryland has levied a flat 5% tax, based on the purchase price (or book value for used vehicles), paid once by vehicle owners when they apply for a vehicle title. The Maryland feebate program divides vehicles into three groups: "gas guzzlers," with fuel economies lower than a specified guzzler level, "gas sippers," with fuel economies above a specified sipper level, and other vehicles, with fuel economies between the guzzler and sipper levels. The 5% tax remains as a base to which a fee (tax surcharge) is added for guzzlers and from which a rebate (tax credit) is subtracted for sippers. Vehicles other than guzzlers or sippers simply pay the existing 5% tax. The Maryland program was designed to generate revenues of at least $15 million annually. Further information on the structure and likely impacts of the program are described in DeCicco (1992c). At time of this writing, implementation of the Maryland feebate has been blocked by a U.S. Department of Transportation opinion stating that state fuel economy incentive programs are federally preempted; further discussion of this issue is given later in this report under "State Feebate Programs."

[3] See Millyard (1991). Adjusted mpg ratings are the same as those given on a vehicle's sticker and as defined in the Gas Mileage Guide (EPA 1990).

[4] Range of preliminary estimates for 1991, net of approximately $2 million in rebates; revenues are sales-linked and 1991 was a low sales year; the overall Provincial budget is about $50 billion ($Canadian; pers. comm. from various Ontario officials).

[5] Contained in Section 13-818 of the Transportation Article of Maryland's 1992 tax legislation, based on a bill introduced by Delegates Chris Van Hollen and Brian Frosh of the Maryland Legislature.

The DRIVE+ program proposed in California is an example of a feebate based on emissions of various air pollutants, including carbon dioxide (CO_2).[6] It would establish a sliding-scale sales tax or credit linked to tailpipe emissions of reactive hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), and CO_2. Since tailpipe CO_2 emissions are in direct inverse relation to fuel economy, DRIVE+ provides a market incentive for purchasing vehicles that are more efficient as well as less polluting than average. The California legislature passed a feebate program called DRIVE+ in 1990 but it was vetoed by then-governor Deukmejian. A re-introduced version is now pending in the California legislature. Feebate or gas guzzler tax proposals have also been considered in a number of other states, including Arizona, Connecticut, Maine, Massachusetts, New York, and Wisconsin.

A federal feebate (fuel economy "credit") was proposed in the 1970s when CAFE standards were being considered. However, concerns about the way such a program would favor import vehicles at the expense of domestic vehicles led to its rejection, so that only CAFE standards were enacted. CAFE standards were formulated to apply separately to domestic and import fleets in hope of curbing any potential advantage to foreign automakers. Subsequently, in 1978, the gas guzzler tax was enacted, but it has no rebate component, which was also avoided because it would have largely favored imported cars (Bleviss 1988, p. 167). This "domestic vs. import" problem is a major issue for feebates, as it is for CAFE regulation. It results from the potential fuel economy advantage of some foreign (mainly Asian) automakers whose historical focus has been on the economy classes of the market.

In recent years, a number of feebate proposals have been introduced at the federal level in the United States. None of them have yet gained a status of active legislative consideration. During the 102nd Congress (1991-1992), a Senate bill proposed increased gas guzzler rates plus a consumer tax credit for vehicles 15% more efficient than average for their size class (Gore, S. 201, 1991). Two feebate proposals based on CO_2 emissions and vehicle size (as measured by interior volume) were introduced in the House. The Scheuer (H.R. 1583, 1991) proposal specifies a schedule of CO_2 emissions in grams/mile by size class (subcompact, compact, etc.) and establishes a feebate proportional to the difference between a model's CO_2 emissions (to be rated by the EPA) and an emission standard for the model's size class. The Synar (H.R. 2960) proposal uses a continuous size measure and is also an example of a "dynamic" feebate (discussed below) in that the fee vs. rebate threshold tightens each year to a lower level of CO_2 emissions per unit vehicle size.

A general liability of size-based feebate schemes is that they create an incentive for manufacturers to upsize their vehicles instead of upping fuel economy. This problem can be worse for a size-class based proposal, since a small size increase might enable some vehicles to move into the next larger class, resulting in a more favorable feebate level. The form of size adjustment for light trucks was left unspecified in these proposals, since it is difficult to apply the size measure chosen for cars (interior volume) to the variety of vehicles in the light truck classes. One motivation for a size-based feebate is to mitigate the domestic vs. import problem; we will examine this more thoroughly later in the report.

Another federal feebate proposal is the safety-linked program introduced by Wirth (S. 741, 1991). This proposal, also called "DRIVE-SAFE," bases part of the feebate on the results of crash tests and part on fuel use. It uses a single crashworthiness index based on a weighted average of injury likelihood measures (Gillis 1992). This index is calculated from the injury criteria determined

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[6] DRIVE+ stands for "Demand-based Reductions In Vehicle Emissions Plus improvements in fuel economy" and is analyzed in Gordon and Levenson (1989). See also Davis and Gordon (1992), Appendix B.

by crash tests as specified by the National Highway Traffic Safety Administration (NHTSA). By providing an incentive to make cars both more efficient and more crashworthy, this program addresses the objections of some opponents of fuel economy improvement, who claim that raising fuel economy involves sacrificing safety.[7] Some concerns about such a program are that it involves monetizing vehicle safety without there being a firm basis for assigning a dollar value to levels of crashworthiness; the imperfection of crash test statistics, which reflect but one aspect of vehicle safety; and the possibility of "gaming" crash test results, through design changes that improve performance on the formal tests but have little impact on actual safety in use.

[7] This argument is made by U.S. automakers, those opposed to regulations in general, such as the Competitive Enterprise Institute, and some economists, such as Crandall *et al.* (1988).

HOW FEEBATES WORK

The most straightforward automotive feebate program is one based strictly on fuel consumption. Each vehicle would have a fee or rebate proportional to how much its fuel consumption is above or below some reference fuel consumption. In general terms, a feebate is defined as the product of a *feebate rate* and the difference between a vehicle's *energy factor* and some *reference level* relative to which all vehicles are judged:

$$\text{Feebate} = -(\text{feebate rate}) \times [(\text{energy factor}) - (\text{reference level})] \qquad (1)$$

The convention used here is for fees to be negative and rebates to be positive, with the energy factor being a measure of a vehicle's energy consumption.

The energy factor for a consumption-based feebate would simply be a vehicle's rate of fuel use, e.g., gallons per mile (gal/mi) or liters per 100 km. The reference level is some standard or average value of the energy factor. For example, the reference level could be the fleet average fuel consumption rate, which is the reciprocal of the fleet average fuel economy (mpg).

The feebate rate represents the monetary value assigned to each unit difference in the energy factor above or below the reference level. The feebate rate could be expressed, for example, in dollars per gal/mi. The rate could be based on the incentive needed to change market decisions or on the economic value assigned to avoided fuel consumption. More generally, a feebate could take into account other vehicle attributes (size, emissions, domestic content, crashworthiness) by incorporating them into the definition of the energy factor and feebate rate. Feebates can also be defined using multiple reference levels or feebate rates; for example, there could be separate schemes for cars and light trucks.

The strength of the incentive to improve fleet fuel economy depends mainly on the feebate rate--the larger the rate, the stronger the incentive. Generally, the incentive does not depend on the reference level. A vehicle having a consumption rate higher than the reference level will incur a lower fee if its fuel economy is improved, even if its consumption rate remains above the reference level. Similarly, relatively efficient vehicles can receive a larger rebate if their fuel economy is improved even further. Assuming a uniform feebate rate, the strength of the incentive is the same in both cases. However, there could be a symbolic value associated with being a "gas guzzler" or "gas sipper" which might influence consumer decisions in addition to the monetary incentive of the fees or rebates.

The revenue impact of a feebate depends on both the feebate rate and the reference level. A feebate system using a single feebate rate will be revenue neutral if the reference level exactly matches the sales-weighted energy factor of the fleet, as determined with the feebate in effect. Maintenance of a feebate's revenue targets (including neutrality) therefore involves projecting the market response and, since projections are never perfect, a procedure to adjust the program in light of actual market response.

Feebates Based Only on Fuel Consumption or CO_2 Emissions

It is useful to examine a straightforward, consumption-based feebate because it provides a simple example of the concept. It will also reveal issues which complicate the formulation of feebates and which need to be addressed in developing a workable proposal. We focus only on feebates for new vehicles, since (as discussed later), a most important part of the response to feebates is their likely influence on manufacturer product planning. Little additional gain in stock average fuel economy is likely to be obtained from incentives on used vehicles.

For illustrative purposes, we use light vehicle fuel economy and sales data for the 1990 model year, the most recent year for which sufficient information is publicly available. Table 1 lists the 1990 Corporate Average Fuel Economy (CAFE) levels by manufacturer for cars, light trucks, and combined light duty fleets. Unless otherwise specified, the fuel economy values used in this report are unadjusted EPA fuel economy ratings, defined as the average of a vehicle's city and highway test ratings weighted for 55% city cycle driving and 45% highway cycle driving, as used for federal CAFE compliance purposes. Fleets separately classified as domestic or imported for regulatory purposes are averaged together in this table to show a single line for each manufacturer.[8] The feebates analysis is done at the nameplate level rather than at the manufacturer level. A nameplate refers to a particular, named model (such as a Chevrolet "S-10"). Nameplate-level statistics are sales-weighted averages of all configurations of the nameplate (4- vs. 6-cylinder engine, manual vs. automatic transmission, 2- vs. 4-wheel drive, etc.).

Because we assume a fixed sales mix, that of 1990, the net effects of the feebates analyzed here correspond to manufacturers' 1990 CAFE values. In reality, manufacturers would change their production and sales strategies in response to a feebate and consumers would change their purchase decisions. These responses are being investigated by a study still in progress (Train 1991). It is beyond the scope of this analysis to estimate such changes or other changes due to evolving market conditions (for example, some automakers listed in the fixed 1990 fleet analysis have subsequently withdrawn from the U.S. market). Therefore, our feebate outcome estimates should not be interpreted as projections of what would actually happen if a feebate is established. Our results are provided only to make the concept of a feebate more concrete and to help identify the issues that need to be addressed.

A consumption-based feebate can be constructed by extending the existing U.S. federal gas guzzler tax. Table 2 lists the current gas guzzler tax schedule. The highest tax, $7700, is on vehicles with a fuel economy of 12.5 mpg or less. The gas guzzler tax, which is plotted as the step function in Figure 3, can be extended to a feebate by fitting the tax to fuel consumption rate. If plotted with a horizontal axis of fuel consumption rather than fuel economy, the tax fits a straight line with slope $749 per liter/100 km and intercept 9.56 liters/100 km (24.6 mpg). This feebate rate corresponds to $1.17 per gallon of excess gasoline consumption over vehicle lifetime travel of 120,000 miles.[9] The result is the consumption-based feebate curve in the Figure 3, which matches the gas guzzler tax quite well. A fuel consumption-based feebate is equivalent to a CO_2 emission-based feebate for gasoline vehicles (see Appendix).

[8] A vehicle is classified domestic if it has at least 75% domestic content; otherwise, it is classified imported.

[9] Assuming 20% shortfall in actual on-road fuel economy compared to rated fuel economy and with "excess" referring to the difference between a vehicle's fuel consumption and the feebate reference level fuel consumption.

A feebate of this magnitude, matching the gas guzzler tax within its existing range, is most likely to be appropriate for implementation at the federal level. Feebate rates for a state level program are likely to be smaller, comparable to existing state sales taxes or vehicle registration fees. However, the relative impacts on different models and manufacturers would be the same as those discussed here.

Table 3 lists the top-selling nameplates in 1990 along with their average fuel economy ratings[10] and hypothetical consumption (or CO_2) based feebates. The 35 vehicles listed in Table 3 accounted for just over 50% of light duty vehicle sales in 1990 and have an average fuel economy of 24.7 mpg, quite close to the 24.8 mpg average of new light vehicles in 1990. Except for the Cadillac Fleetwood/Deville, all of the top selling models are currently untouched by the existing gas guzzler tax, which does not apply to light trucks. Under this feebate system, 21 of the 35 vehicles have rebates and 14 have fees, on a nameplate average basis.

The last column of the table gives the feebate as a percentage of vehicle sales price, which suggests the likely sales impact of the feebate. Lacking sales-weighted transaction price data, vehicle price was 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. Price estimates for the top 35 light vehicles are listed in Table A1. For these top-selling models, the range is from fees of 28% (for the Ford Econoline van) to a rebate as high as 23% (for the Ford Escort) as a percentage of price. Two-thirds of the feebates fall within ±10% of the vehicle price.

The top selling light vehicle in 1990 was the Honda Accord.[11] According to this hypothetical feebate scheme, it has an average rebate of $1155, or 8% of the vehicle's sales price. The top-selling domestic automobile was the Ford Taurus; its average fuel economy of 25.9 mpg was just above the reference level, for an average rebate of $305. The domestic vehicles with the second and third highest sales are the Ford and Chevy pickup trucks. With sales-rated average fuel economies just under 18 mpg, these vehicles have average fees of about $2800, 22% of their nameplate average sales price. The Chrysler minivans had fuel economies near the light duty fleet average, so that on a nameplate average basis, they have essentially no net fee or rebate. Not shown in this table is the fact that different configurations of a nameplate can have significantly different fuel economies. For example, different configurations of the 1990 Taurus were rated from 24 mpg to 27 mpg, implying feebates ranging from -$230 (fee) to $580 (rebate) under this hypothetical consumption-based system.

The sales-weighted mean absolute value of the feebates in this example is $1153, which is 8.0% of the average new light vehicle price of $14,500. We term this the *leverage* of the feebate, since it represents the average influence (positive or negative) on vehicle purchase price exerted by the feebate.[12] If all feebate schemes were identically formulated, then the feebate rate (as in Equation 1)

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[10] Our analysis is based on statistics from Williams and Hu (1991). The resulting fleet average fuel economy estimates are lower than those given by NHTSA (1991) because the latter includes test procedure adjustments, a different model year definition, and sales estimates made at a different point in time. Final model year sales statistics as officially used by NHTSA for CAFE compliance determination are not generally available until some months after the end of a model year. The Williams and Hu statistics are used here because they are reported in much more detail.

[11] Vehicle sales are often reported separately when there are "domestic" and "import" versions of given nameplate; this is the case for the Accord, for example. In this analysis, the domestic and import versions of a nameplate are combined into a single entry, since they have essentially the same values of fuel economy and other attributes.

[12] The simple mean of a revenue-neutral feebate is zero, of course, since the sum of the fees cancels the sum of the rebates. By averaging the absolute values (i.e., treating both fees and rebates as positive numbers), one can get a measure of the average magnitude of the fees and rebates. Mean absolute value is preferred to the root mean square value (or standard deviation) because of its lower sensitivity to extreme values. Also, note that sales-weighted statistics are always used for an analysis such as this.

would suffice as an indicator of the strength of the feebate as a market incentive to improve fuel economy. However, since we wish to examine a variety of feebate formulations, it is useful to have a dimensionless indicator that can be used to make comparisons. As defined here, leverage can be used to compare various feebate schemes according to the strength of their influence on decision making. One can also examine the relative impact on different manufacturers of various feebate formulations defined so as to have a specified leverage. We do this below to compare the relative manufacturer impacts of a size-normalized feebate with those of a straight consumption-based feebate.

Table 3 reveals the first challenge for developing a workable feebate scheme, namely, the low fuel economy of light trucks. The 1990 light truck CAFE standard was 20.0 mpg--lower than the guzzler tax threshold of 22.5 mpg. The light truck standard has changed little since it first reached 20 mpg in 1984 and the 1992 standard is only 20.2 mpg. In short, most light trucks are gas guzzlers relative to cars, as shown in Tables 1 and 3. Eighty percent of light truck usage is strictly for personal transportation according to a recent survey (Bureau of the Census 1990). The market share of light truck class vehicles increased from 19% in 1975 to 33% in 1991 (Heavenrich *et al.* 1991). Thus, it is critical to provide a strong incentive to improve light truck fuel economy if light vehicle fuel consumption is to be fully addressed. However, a transition period might be needed, over which trucks are initially rated separately from cars or have their feebates phased-in. Complementing standards or feebates with substantially higher fuel taxes would help provide an incentive to improve light truck fuel economy.

Table 4 summarizes the impact of the consumption-based feebate by manufacturer. As expected, the relative outcome of a fuel consumption-based feebate system corresponds to the manufacturers' respective CAFE levels (Table 1). The U.S. "big three" (Chrysler, Ford, and General Motors) accounted for 69% of all light duty vehicle sales in 1990. We refer to these automakers as the "D3" group. The automakers with the next highest sales are five Japanese firms (Toyota, Honda, Nissan, Mazda, and Mitsubishi). We refer to these as the "J5" group; they accounted for 25% of 1990 sales. The D3 and J5 together comprised 94% of the 1990 light duty vehicle market. In a feebate system based only on fuel consumption, the D3 all pay net fees, amounting to $3.1 billion in aggregate for the 1990 model year sales mix used in this example. The J5 receive net rebates, amounting to $2.7 billion in aggregate. This highlights the second major issue for a straightforward fuel consumption feebate scheme: the "domestic vs. import" problem of net fees for the "big three" and net rebates for most Asian manufacturers. Such was the case when a gas sipper credit program was proposed in the 1970s. The evolution of fleets since that time has not fully removed the disparity. As we will see upon examination of alternatively formulated feebates, this issue is generally pervasive, even after accounting for vehicle size or other attributes. The domestic vs. import problem is linked to the light truck problem, since light trucks are an important part of D3 market share (see Table 1).

It is also possible to construct feebates based on fuel economy rather than fuel consumption. Such feebates could follow the "mpg based feebate" dashed line in Figure 3. The ranking of vehicles is identical to that in Table 3, but the guzzlers would get smaller fees and the sippers would get larger rebates. Appendix A discusses the technical relations between various types of feebates; mpg-based feebates for the top-selling vehicles are shown in Table A1. While a consumption-based feebate is more technically correct from the fuel savings perspective, giving large rebates for the most efficient cars may provide an extra stimulus for technical innovation leading towards ultra-efficient vehicles. However, there are other approaches to encouraging major innovation, such as supporting research and development or sponsoring a competition for advanced vehicles (Ledbetter and Ross 1991; DeCicco 1992d).

Issues for a Workable Program

The preceding example reveals a number of issues that must be addressed in developing a workable feebate program: (1) how to deal with light trucks; (2) the domestic vs. import problem; (3) more generally, how to treat manufacturers equitably, ensuring that all have an incentive to improve their fleets without creating an unfair competitive advantage because of particular fleet characteristics. Some additional issues also come to mind: (4) what are the administrative costs, revenue, and tax equity impacts of a feebate program; (5) how can feebates address alternatively fueled vehicles; (6) how to make the program understandable to consumers; (7) how large feebates should be in order to affect decision making; and (8) how to structure a feebate program so that higher fuel economy targets can be reached. Here we briefly discuss issues (4-6). The next section of the report introduces size-based feebates as a way to address issues (1-3). The remaining issues are discussed in later sections of the report.

Regarding revenue impacts, the hypothetical example given above is "revenue neutral" based on *past* sales, since the reference level was set to the sales-weighted average fuel economy of the fleet. The actual revenue impact will, of course, depend on *future* sales. If a feebate has the desired effect of shifting decision-making towards more efficient vehicles, less fees will be collected and more rebates will be paid out. Some prediction of the response to a feebate program is therefore needed to insure a predictable revenue balance. A feebate program must generate at least enough revenue to cover administrative costs. A program may also be designed to generate additional revenue for other purposes, which can raise questions regarding complementary and appropriate use of the funds. Further discussion of revenue aspects is taken up in the section on "Revenue Stability and Dynamic Feebate Schedules."

Promotion of alternatively fueled vehicles will involve incentives,[13] since early versions of vehicles (with limited production volumes) are likely to cost more than comparable gasoline-powered vehicles and since gasoline-powered vehicles are so well established, e.g., with familiarity and the ready availability of services stations for fuel and repairs. In the long run there will be a need to rationally address vehicles of different types. Feebates could be based on tailpipe emissions, primary energy consumption, or full fuel cycle carbon dioxide (CO_2) emissions. A long-run view favors choice of CO_2 emissions, which are the principal contributor to global warming. A greenhouse gas emissions factor can be defined for any fuel (it could be zero for a renewable fuel). The emissions factor should account for all greenhouse gas emissions associated with use of the fuel, including those involved in production and distribution of the fuel. Because conventional vehicle CO_2 emissions are proportional to fuel consumption, use of CO_2 emissions as the basis for a feebate (as in the feebate examples presented here) does not affect the relative impacts on different manufacturers, as long as gasoline is the dominant fuel.

Addressing issue 6, a feebate based on fuel economy or fuel consumption would be easily understood by consumers. Fuel economy is already a widely recognized vehicle attribute, particularly since there are labeling requirements for prominent display of fuel economy information on new vehicle sales stickers. However, when other factors--such as CO_2 emissions, vehicle size, vehicle class, or other attributes--are incorporated into a feebate, its interpretation becomes more complex

[13] The Energy Policy Act of 1992 provides a 15% income tax credit for electric vehicles and a tax deduction of up to $2000 for other alternatively fueled vehicles. These federal subsidies would be available in addition to state and local subsidies such as those offered by California's air quality management districts.

and the issue of making it understandable to consumers would be of greater concern. A feebate program will therefore need a well thought-out labeling provision to explain to consumers the reason why a particular vehicle has a given fee or rebate. The feebate information could replace much of the present fuel economy labeling information, since the feebate will be largely based on a vehicle's rated fuel economy. The range of feebate values for similar models could also be provided to facilitate comparisons. "Fine print" could explain the program in more detail. Implementation of a feebate would generate news coverage which could be supplemented with fact sheets distributed through car dealerships, additional material in the Gas Mileage Guide, or other information programs.

SIZE-BASED FEEBATES

Some of the drawbacks of a feebate program based on fuel economy alone may be addressed by incorporating other vehicle characteristics into the calculation of the incentive. Vehicle size, pollutant emissions, and crashworthiness have all been used for formulating feebate proposals. Other attributes which could be considered are payload weight, power or power/weight ratio, alternative fuel use, and domestic content. Here we focus on size-based incentives.

There are precedents for considering size when evaluating energy efficiency in other products. For example, the national appliance efficiency standards and electric utility incentive programs for refrigerators and freezers use an "energy factor" rating based on annual electricity consumption and the volume of a given unit (see Wilson and Morrill 1991). Similarly, size is taken into account for energy-efficiency standards and incentive programs for buildings, e.g., with larger buildings being allowed higher energy consumption than smaller buildings.

The variation in average size or other vehicle attributes among different manufacturers has also motivated alternative forms of CAFE standards. Specifying a fuel economy standard relative to one or more vehicle attributes is generically termed a "vehicle-based" approach to standards. For example, proposed "Volume Average Fuel Economy" (VAFE) standards account for vehicle size in setting efficiency standards.[14] A VAFE standard is based on the product of interior volume times fuel economy (ft^3mpg). This corresponds to size (volume) divided by energy consumption, since fuel economy (mpg) is the reciprocal of fuel consumption (gallons per mile). A general concern for size-based standards is their inability to insure that the fleet reaches a given fuel economy target.[15] This may be of lesser concern for size-based feebates, provided that the feebates are coordinated with stronger fuel economy standards expressed strictly in terms of fleet average fuel economy.

Selecting a Vehicle Size Measure

Size is an indicator of service level. A larger car can carry more passengers or cargo, a capability highly valued by some consumers, such as large families. Simultaneously achieving a roomy and efficient car is often a reflection of good overall design, since size relates to other desirable attributes including comfort, stability, and transport utility. What constitutes good design varies, of course,

[14] First analyzed by McNutt and Patterson (1986) and Duleep and Vanderveen (1986); see also OTA (1991), pp. 73-78.

[15] The potential merits and drawbacks of such approaches have been discussed in technical sessions of SAE meetings and are reviewed in OTA (1991) and DeCicco (1992b).

depending on the type of vehicle. Little premium is attached to size-related amenities for many sports cars, for example, while high performance is greatly valued. On average, size has been a very stable vehicle attribute, in spite of CAFE standards and changes in fuel prices. Figure 4 shows trends in key vehicle attributes over the past 15 years relative to their values in 1976. The two size measures, interior volume and wheelbase, have changed the least. Size is physically related to fuel economy at a given technology level. Consumers preferences for vehicle size are stable, at least when there is not a crisis level of concern about fuel price or availability. For example, although the 1973 and 1979 oil crises and the resulting fuel price increases, along with expectations of higher prices and CAFE standards, did result in some downsizing of new cars, the effect has been small (Figure 4). Thus, market forces are likely to sustain average vehicle size as far as consumer utility is concerned.

Interior volume is one measure of the utility of a vehicle and forms the basis of the size classifications used by EPA to group vehicles as reported in the Gas Mileage Guides. As shown in Figure 4, the average interior volume of new cars is little different now than it was 15 years ago. However, it is difficult to compare interior volume among different passenger vehicle types (e.g., cars, station wagons, vans) and it is even less valuable for measuring light trucks (pickups, sport utilities, cargo vans). Payload weight might be considered for light truck classes, but is not currently defined for regulatory purposes. Comparisons of vehicle classes by volume and payload weight are presented in Heavenrich *et al.* (1991). A payload weight measure is not currently defined for use in fuel economy or emissions testing and it appears that defining payload weight in a consistent and reliable way across vehicle classes would be difficult.

Exterior dimensions provide a more universal measure of vehicle size. For example, one could use vehicle "shadow," the product of overall length times overall width. Although information on these exterior dimensions is commonly reported, a comprehensive data base on exterior dimension trends is not available. The main difficulty with exterior dimensions is that they can be easily affected by cosmetic changes to vehicles, and so we make no attempt to examine them here.

Wheelbase (the distance between the front and rear axles) is a universal measure of vehicle size for which trend data are available, as shown in Figure 4. Average automobile wheelbase has dropped only about 7% since 1976. Recent trends towards "cab-forward" design, and generally increasing size, may yield an upward trend in wheelbase. For example, Figure 5 illustrates one automaker's view of the evolution of car size, based on maintaining interior volume. This also allows a vehicle with "large car" interior space to be designed with smaller exterior dimensions. This trend is facilitated by the advances in engine specific power output, allowing high performance with small engines. The performance benefits are compounded by weight savings from the more efficient packaging and the rounded, low-drag shape. The progression is demonstrated in General Motors' Ultralite prototype, which has a profile quite like that shown for the year 2000 in Figure 5. If wheelbase grows, its growth is nevertheless likely to be limited given the apparent stability of interior volume.

Tread, or track width, is the distance between the right and left tire centerlines. Track width often differs slightly between the front and rear pairs of wheels, but the two measures can be readily averaged. Vehicle ***footprint*** is the product of wheelbase and average track width and has units of area, m^2 or ft^2. Wheelbase and track width are related to the underlying structural design of a vehicle, and for a given model, they are not changed except during major redesigns. Wheelbase and track width are widely reported vehicle specifications. Neither is presently considered for purposes of fuel economy or emissions regulations. However, in contrast to payload weight or interior volume, these measures are well-defined for all major classes of light duty vehicle (except motorcycles or three-wheeled vehicles, which we do not consider here). Figure 6(a) is a scatter plot of fuel consumption versus footprint and Figure 6(b) shows the distribution of footprint, for all light duty vehicles in model year 1990. The 1990 sales-weighted average values are 3.86 m^2 (41.6 ft^2) for automobiles, 4.45 m^2 for light trucks, and 4.05 m^2 for the overall light-duty fleet.

For the light truck classes, there is less certainty about the likely design response to incentives based on footprint. Light trucks have a wide variety of characteristics and this market segment has evolved rapidly over the years. Note that the outlying points and greatest scatter in Figure 6(a) are for light trucks. Track width varies little among the configurations of a given model (although some heavy duty pickups have twin rear wheels, resulting in a wider rear track). However, pickups and vans often have a range of wheelbases. For example, the Ford F-Series pickups have wheelbases ranging from 117-208 inches; the Chevrolet standard pickups have wheelbases ranging from 118-169 inches. This is one area of concern for footprint-based incentives, since it would be relatively easy to shift sales to larger wheelbase versions. Light truck buyers' load carrying needs are unlikely to radically change. However, it is unclear whether there would be a strong incentive for manufacturers to upsize footprint in response to such a size-based incentive. Significant increases in average tread or wheelbase are likely to incur a weight penalty, which will lower fuel economy. The relative manufacturing cost trade-offs among these attributes will merit further investigation if a footprint-based incentive (or standard) is pursued.

For the 1990 model year, average light truck footprint is 15% higher than average car footprint, while average light truck fuel consumption is 35% higher than that of cars. Going back in time, however, average light truck fuel consumption was only 15% higher than that of cars in 1975; light truck footprint statistics are not readily available for 1975.[16] On average, therefore, uniform footprint-based feebates would presently still favor cars over trucks, but the disparity would not be as much as for feebates based on fuel consumption alone.

Feebates Based on Footprint and CO_2 Emissions

To develop a model feebate scheme, we define an energy factor based on size-normalized energy consumption. Size normalization refers to a procedure for adjusting a vehicle's fuel-use rating to account for size. One approach would be to take a ratio of an energy measure to a size measure. Another approach would be to find a statistical relation between size and fuel consumption, e.g., through regression analysis, and then use the resulting parameters to develop a size-normalized energy factor. We use a ratio approach, with an energy factor proportional to fuel consumption divided by footprint. For convenience and ease of extension to alternatively fueled vehicles, we express the energy factor in terms of footprint-normalized CO_2 emissions.

Formally, the energy factor is defined as CO_2 emissions per distance of travel divided by area (footprint), assuming full fuel cycle CO_2 emissions of 12 kgCO_2/gallon (DeLuchi 1992) and a fuel economy shortfall of 20%. For example, a vehicle rated at 30 mpg with a 4 m^2 footprint would have

[16] Average new vehicle fuel economy was 13.7 mpg for light trucks and 15.8 mpg for cars in 1975 (Heavenrich *et al.* 1991). Average wheelbase and track width statistics for that model year are not readily available for comparison purposes. Since the mid-1970s, much growth in the light truck classes have been from minivans and small (sport) utility vehicles, both of which trends are more likely to have pushed average light truck footprint down rather than up.

an energy factor of 78 $gCO_2/(km\ m^2)$.[17] In general, the energy factor is computed by multiplying a vehicle's compliance fuel economy by its footprint and then dividing the product into the conversion constant 9320.57 (mpg g/km). In terms of understandability to consumers, size-normalized CO_2 emission ratings may be too complex to put on a vehicle label as such. Rather, the rating could be given as simply the "energy factor," with an explanation that it represents energy consumption or CO_2 emissions relative to vehicle size. For the rest of our discussion, we drop the units and refer simply to the "energy factor." The 1990 model year average energy factors are 87 for cars, 102 for light trucks, and 92 for the overall light duty fleet.

The variation of a size-normalized energy factor among vehicles is inherently less than the variation of fuel economy or CO_2 emissions. For example, while the average fuel consumption of 1990 light trucks is 35% higher than that of 1990 cars, their footprint-normalized fuel consumption is only 17% higher. Indeed, such equalization is partly the purpose of size normalization. However, the lower variation of size-normalized ratings implies that the leverage with respect to fuel economy improvement will be lower than that of a consumption-based feebate derived from a similar monetary value per unit difference in fuel consumption. That is to say, the "pull" of a size-normalized feebate is partly deflected away from increasing fuel economy toward increasing size. This is a fundamental aspect of size normalization; to compensate for it, the feebate can be scaled up to achieve the leverage (average feebate-to-vehicle price ratio) needed to influence the market.

Table 5 shows footprint-based energy factors for the 35 top-selling nameplates in 1990 along with feebates based on deviations from the fleet average energy factor of 92. The feebate rate was chosen to provide the same leverage (8%) as the consumption-based feebates in Table 3, which were derived from the fit to the gas guzzler tax. The results include some major changes from the non-size-adjusted feebates of Table 3. Rebates generally drop for the subcompacts; for example, the Toyota Corolla and Geo Prizm rebates fall from 13%-15% down to 7%-8% of their sales prices. The rebate for the Ford Escort, however, increases slightly, from 23% to 25% of its price. The Chevy S-10 switches from a 3% rebate to a 5% fee. The Chrysler minivans (Caravan and Voyager) now have 8%-9% rebates rather than the essentially neutral outcome shown in Table 3. The Ford Econoline, which had a consumption-based fee of 28%, has a size-adjusted fee of only 3% of its price. The fees on the Ford and Chevy full-size pickup trucks drop from an average of 22% down to about 14% of their price. Thus, the fee burden in this system shifts away from vehicles that are simply the largest toward vehicles which have relatively poor efficiency for their size. In particular, the largest fees would fall on sport utilities such as the Chevy Blazer and Jeep Cherokee, for which the size-adjusted fees are 18%-20% of vehicle price. Two cars whose 1990 model year technology levels were rather old, the Ford Mustang and Tempo, also get larger fees under a size-adjusted system.

The feebates for all 224 nameplates analyzed are plotted in Figure 7 by vehicle class. Without size normalization, all vehicles would fall on a curve, similar to that shown in Figure 3. Size normalization rearranges the position of vehicles, resulting in scatter related to the variation in fuel consumption *not* explained by variation in size. Thus, at a given fuel economy, there is now a range of fees and rebates above and below the curve. For example, the figure shows a number of vans which have larger than average footprints in the 15 mpg to 20 mpg fuel economy range, so that they have smaller fees, or even rebates, compared to some other vehicles of similar fuel economy.

[17] Corresponds to 11.6 $g/(mi\ ft^2)$ using U.S. customary distance units, or footprint-normalized unadjusted fuel economy of 1292 ft^2mpg.

Conversely, as noted above, utility vehicles have low fuel economy for their size, resulting in larger fees. The variation in feebates at a given fuel economy is as much as ±\$3600, or ±25% of average vehicle price, but is smaller at higher fuel economy levels; this corresponds to the larger scatter against footprint in the high fuel consumption range as shown in Figure 6(a).

The relative effects on manufacturers of the hypothetical footprint-normalized feebate program are shown in Table 6. This feebate program involves comparisons among similarly sized vehicles, so that small vehicles are not systematically rewarded relative to large ones. Based on the 1990 data, the D3 all still have net fees, but the aggregate fee is reduced to \$1.4 billion for size-adjusted feebates compared to \$3.1 billion for the fuel consumption case (Table 4). The J5 aggregate rebate falls from \$2.7 billion to \$1.9 billion. Thus, the domestic vs. import transfer problem is lessened but not eliminated, at least based on the fixed 1990 model year market shares. Honda is the automaker that fares best in either system, since it sold only cars in 1990 and its main models (the subcompact Civic and compact Accord) were among the most efficient for their size.

Separate Treatment of Cars and Trucks

A footprint-based feebate system does not adjust away the large fuel economy gap between cars and light trucks, which accounts for much of the feebate gap between the D3 and J5 fleets. One way to remove the effect of the car vs. truck efficiency gap is to treat the two fleets separately, so that there is no net fee transfer from trucks to cars. Tables 7 and 8 show the top-selling vehicles' feebates and the outcome by manufacturer, respectively, for footprint-normalized feebates using separate reference levels of 87 for cars and 102 for light trucks. The feebate rate is kept the same for both fleets, representing a common incentive level per unit of size-normalized fuel consumption. The resulting feebates for all nameplates are plotted in Figure 8.

Rebates on subcompacts are reduced. Some cars, which received rebates when compared to the overall light vehicle average, now get fees, since their adjusted fuel consumption is above average for cars. The largest fees among the top-selling 1990 car nameplates fall on the Ford Mustang and Tempo. Light trucks in general and vans in particular fare much better under this system. Rebates for the Chrysler minivans rise to 16%-17% of their price and even the Ford Econoline now shifts to a rebate. This is illustrated in Figure 8, which shows van rebates well above the curve, even more so than in Figure 7. There are still large fees on the sport utilities, but the fees are much reduced compared to Table 5. For example, nameplate average fees drop to 10%-11% of price for the Chevy Blazer and Jeep Cherokee. Separating the car and light truck fleets thus results in a marked difference in the treatment of some vehicles. For example, the "m" outlier below the curve at 21 mpg is the Porsche 911, a high-powered luxury sportscar classified as a minicompact. It's fee is over \$6000 since it is so inefficient for its size relative to other passenger cars. In contrast, some minivans (plotted by small "v") of similar fuel economy would earn rebates over \$1000, because their footprints are much larger and they are compared to the class of all light trucks.

Table 8 shows the manufacturer outcomes for a system using separate car/truck reference levels. The D3 fees for cars become smaller on average and are partly offset by Chrysler's and Ford's net rebates for light trucks, so that the aggregate D3 fee falls to \$0.6 billion. The J5 aggregate rebate drops to \$1.1 billion, the bulk of which is still rebates for Honda cars. Thus, on a footprint-normalized scale, separate treatment of cars and trucks is not quite sufficient to eliminate an effective D3 to J5 transfer problem, at least on the basis of the fixed 1990 fleet mix. However, the magnitude of the net transfer is greatly reduced from that of the original non-size-adjusted feebates of Table 4.

Another way to improve the outcome for U.S. domestic manufacturers is with a hybrid system, using volume-normalized feebates for cars with footprint-normalized feebates for the light truck classes. Interior volume data (passenger volume only, not counting cargo volume) were taken from the 1990 EPA Gas Mileage Guide. For cars, a volume-normalized energy factor was computed by multiplying fuel economy and passenger volume and dividing this product into the on-road CO_2 emissions conversion constant (as done above for the footprint-based feebates). For convenience, the volume-adjusted energy factors were scaled to the same numerical magnitude as the footprint-adjusted energy factors, permitting the use of the same feebate rate for all vehicle classes.[18] Truck feebates were kept the same as in the preceding example (Table 8b), as were the feebates for two-seater cars, for which an EPA interior volume measurement is not defined.

Table 9 shows the outcome by manufacturer for car feebates based on passenger interior volume and scaled to have the same feebate rate as the feebates based on footprint. For the car fleet only, GM displaces Honda as the recipient of the largest net rebates. Volume normalization results in net rebates for Ford but net fees for Chrysler. Mazda, Nissan, and Toyota also have net fees. Table 10 shows the resulting feebates for the top-selling light vehicles that were listed in Tables 3 and 5. Compared to a footprint-based scheme, there are notable rebate drops for the Honda Accord, Toyota Camry and Corolla. Rebates rise for the Nissan Sentra, Ford Tempo, GM's LeSabre, Corsica, and Grand Am, among others, and the Cadillac Fleetwood gets a smaller fee.

Figure 8 plots the hybrid feebates for all 224 nameplates. The range of size-normalized feebates for vehicles having the same fuel economy is now quite large, as much as $\pm$\$7,000, as illustrated by a \$14,000 difference between a minivan and a relatively inefficient sports/luxury minicompact. Manufacturer outcome in this hybrid system is summarized in Table 11. This scheme results in aggregate net rebates of \$0.8 billion for the D3, mainly due to GM's positive outcome of \$0.6 billion for volume normalized car fuel economy, and gives all of the domestics a net positive outcome. The J5 end up slightly negative, with aggregate net fees of \$0.2 billion.

These results show that, by separating cars from light trucks and chosing an appropriate size-normalization approach, it is possible to develop a feebate system which would not disadvantage U.S. automakers on the basis of the recent fleet mix. In other words, incorporation of vehicle size into the feebate definition can reorder vehicles so that domestic manufacturers begin with small net rebates. Clearly, a feebate program's relative impact on domestic vs. import automakers is an important consideration politically. However, the hybrid system presented here may appear to be *ad hoc* and there are reasons why other approaches may be desirable.

First, while our results are based on the 1990 fleet makeup, the product offerings of various manufacturers could substantially change in the future. The Japanese automakers have been expanding into larger and more luxurious lines; a feebate system that appears to benefit them based on their past market emphasis on economy models is likely to constrain them as they move into higher performance

[18] Specifically, we divided the ft³mpg product into 9320.57 (mpg g/km), and then scaled the result by the ratio of average car passenger volume to average car footprint (92.2 $ft^3 \div 3.86\ m^2$). The reference level is the car fleet average energy factor of 88.10 g/(km m^2) [scaled], which corresponds to a "VAFE" of 2527 ft^3mpg.

and luxury segments. Thus, the more self-consistent, footprint-only system presented in Tables 7 and 8 should not be ruled out. While it does not completely eliminate the domestic vs. import problem based on a fixed 1990 fleet mix, it does greatly mitigate it compared to a system based only on fuel consumption.

Second, the past decade's growth in leniently regulated light trucks has been very detrimental to fleetwide efficiency. While beneficial to U.S. domestic manufacturers, a two-tier system for cars and light trucks would preserve what is arguably a market distortion due to the unevenness of past regulation. The situation could be rectified with an incentive system that places emphasis on improving light truck fuel economy. This would be accomplished by either combining cars and light trucks together within a single feebate framework or by combining them for the purposes of a fuel economy standard complementing the feebates. There will be further discussion of these issues in the "Design Considerations" part of the report, below.

Configuration choice

Nameplate-level results are presented here because they are easier to analyze, involving a much smaller and more readily available data base.[19] However, a nameplate-level analysis masks one important aspect of a feebate, namely, the way it can influence consumer choice among different configurations of the same make and model. Configuration refers to the exact specification of a vehicle regarding attributes that affect emissions and fuel economy. Engine displacement, transmission type, air conditioning, payload rating, wheelbase, and tire options are among the attributes that can be specified as options on different configuration of the same model. Table 12 shows fuel economy and hybrid feebate values for various configurations of several top-selling 1990 nameplates. For each nameplate, the most efficient configuration is 10%-40% more fuel efficient than the least efficient configuration. A nameplate-level fuel economy value, computed as the sales-weighted average of all of a nameplate's various configurations, hides this variation.

The subcompact Geo Prizm, for example, was available in configurations ranging from 31 mpg to 35 mpg in 1990. Its nameplate average fuel economy was 31.4 mpg, implying a nameplate average rebate of $332, or 3% of its average sales price (Table 10). However, the Prizm's most efficient configuration, rated at 35 mpg, would earn a substantially larger rebate of $1421. There is a similarly large variability among different configurations of nearly every model. The range of rebates for the Ford Escort is from $448 to $3192, depending on configuration. Various configurations of the Ford Taurus, for which the nameplate average is near the reference level for cars, range from a fee of $578 to a rebate of $700. Even the Jeep Cherokee qualifies for a $948 rebate in its most efficient configuration, while its least efficient gets a $1852 fee. Since we lack detailed size (volume or footprint) information by configuration, we used nameplate average sizes for all of these estimates. Therefore, the range of feebates among configurations of a given nameplate is due entirely to the range of fuel economies available for the nameplate. Particularly for light trucks, the range may not be quite as large as suggested here if, for example, more fuel efficient configurations have a wheelbase smaller than the nameplate average.

[19] Our nameplate-level data base includes 224 models of 1990 cars and light trucks; the EPA Gas Mileage Guide lists 1056 configurations; sales and footprint data are not readily available at the EPA configuration level.

The Ford pickup trucks are an important example of the way a feebate would influence configuration choice. The Ford F150 series full-size pickup trucks were the top selling domestic light vehicle in 1990. These Ford pickups outsold the Ford Taurus by 2% and were topped only by the combined domestic plus import sales of the Honda Accord. The nameplate average fuel economy of the F150's was 17.7 mpg (well below the 22.5 mpg threshold for the gas guzzler tax, which does not apply to light trucks). The fuel economy of various F150 configurations ranges from 15 mpg to 21 mpg. Under our hybrid scheme, with its separate footprint-normalized scale for light trucks, some of the F150's get rebates, as shown in Table 12. Thus, the customer might decide to opt for a smaller displacement engine for his chosen make and model. For many customers, 4-wheel drive and a large engine might be superfluous (but marketable) niceties, not really warranted by their actual use of the truck. (Recall the Bureau of the Census 1990 statistics that 80% of light trucks are used strictly for personal transportation.) A feebate would make it much more likely that buyers forego unnecessary options that are detrimental to fuel economy. In aggregate, many such decisions could yield a large positive response to a feebate program, which would not be fully captured in a nameplate-only analysis.

FEEBATE DESIGN CONSIDERATIONS

This section addresses a number of the other issues to be considered for developing feebate programs, covering in turn: setting the magnitude of feebates, maintaining stable revenue targets or neutrality, linking feebates to standards, treating different vehicle classes, estimating energy savings, and special issues for state-level programs.

Magnitude of Fees and Rebates

A crucial question is: how large must feebates be in order to induce significant fleetwide efficiency improvement? Our examples were hypothetical federal feebate programs having fees comparable in size to the existing gas guzzler tax. There is no guarantee, however, that a feebate so derived would be practical and effective. Are the resulting feebates too large to be acceptable, e.g., too large a percentage of vehicle price? Or are they too small to make a difference in decision-making by consumers and automakers? Technically, specifying the magnitude of fees and rebates is a question of how to set the feebate rate. There are four approaches that can be used for guidance:

(1) Extension of existing taxes. For a federal program, this would be an extension of the gas guzzler tax. For a state program, feebates can be derived from an existing sales tax, e.g., converting a flat 5% tax to a sliding scale between zero and 10% tax.

(2) Size of manufacturer's sales rebates. Manufacturer's rebates range from $500-$2000 and average 7% of sales price.

(3) Economic value of avoided fuel consumption. This might include the direct fuel costs to consumers as well as externality costs.

(4) Cost of technology improvement. This would consider the estimated cost to manufacturers of achieving efficiency improvement by adding new and improved technologies.

We elaborate on these rationales in the discussion that follows; a summary of the implied feebate leverage values is given in Table 15.

Closely related to the question of how strong to make the vehicle price incentive is the inverse question: what is the expected energy-saving and economic impact of a given feebate program? Little experience is available to answer this important question. Modeling analysis of vehicle choice factors can also be used to guide the setting of feebate rates. For example, an econometric model would partially incorporate items (3) and (4) along with past market data and economic theory in order to analyze the response to a feebate program. The vehicle choice modeling approach is an active area of research that can provide some general answers about both the setting of a feebate rate and expected program impacts; we discuss it below under "Energy Saving Impact."

As was shown in Figure 3, the federal gas-guzzler tax provides one basis for setting a feebate rate. Fitting a consumption-based feebate curve to the gas guzzler tax yields a feebate rate equivalent to $1.17 per gallon over 120,000 miles of vehicle usage (undiscounted). The corresponding fuel economy-based rate is $291/mpg. Although the rates for size-based feebates are given in terms of a size-adjusted energy factor, there is always a corresponding $/mpg value which may be defined at a feebate's reference level. We refer to this common $/mpg rate for convenience of exposition. Earlier we defined the term ***leverage*** to be the average feebate expressed as a percentage of vehicle price. Given the average 1990 new light vehicle price of $14,500, a consumption-based feebate derived from the gas guzzler tax would have a leverage of 8%.

A similar leverage can be inferred by examining manufacturer sales rebates. Table 13 shows a sampling of rebates used by manufacturers for promoting sales of particular models. Values are rarely less than $500 and range up to $2000. The size of a rebate generally depends on the base price of the vehicle, with more expensive vehicles having larger incentives. Incentives range from 4% to 12% of manufacturer's suggested retail price (MSRP) and the median is 7.2% of MSRP--closely matching the leverage derived by extending the current gas guzzler tax. Manufacturer incentives can be assumed to represent a degree of price flexibility in new vehicle sales strategies and to be large enough to get a buyer's attention. Feebates comparable in magnitude to existing manufacturer incentives should therefore be effective in influencing market outcome. Further evidence of response to incentives in this range comes from a $1000 incentive offered in January 1992 by Monsanto, Co., to its employees for buying a North American made car. There was a strong response to the program, which was reported to generate $53 million in new car sales (Auerbach 1992).

As noted in the introduction, rebate programs have been used by electric utility companies to encourage consumers to purchase more efficient appliances. In incentive programs for efficient refrigerators, rebates typically range from $50 to $100, or 8% to 15% of new product price. These rebates have been successful in influencing manufacturer product planning and dealer marketing strategies as well as consumer purchasing decisions (Quigley and Jacobson 1990). Similar results can be expected in the automobile market. Incentives would naturally affect both manufacturers and car dealers, who would change their sales strategies accordingly. Under a feebate system, manufacturers and dealers are likely to have lower profit margins on guzzlers, but they would obtain higher margins on sippers.[20] Feebates with a leverage of 7%-8% or more are likely to affect manufacturers' design decisions, thereby playing a technology-forcing role as well. Again, experience with incentives for energy-efficient appliances provides a precedent. The Super Efficient Refrigerator Program (SERP, or "Golden Carrot" for refrigerators) was created--with manufacturer cooperation--to

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[20] Because sales of small/economy vehicles tend to be more elastic than those of large/luxury vehicles, it is quite possible that, on average, the increased profits on sippers will be larger than the reduced profits on guzzlers.

develop refrigerators incorporating technological advances which provide a large improvement in energy efficiency (L'Ecuyer *et al.* 1992). In this case, utility companies are pooling rebate payments which will be provided directly to the manufacturer with the most efficient models, once the qualifying models are produced and sold.

Should feebates be capped? A feebate system with a leverage of 7%-8% results in large rebates on some economy cars. For example, Table 12 shows that the most efficient configuration of the Ford Escort would get a rebate of nearly $3200, or 38% of the model's average price. Because the fuel efficient vehicles are often inexpensive vehicles (see Figure 2), their rebates can be a large fraction of their sales price. There is an economy niche of the market, where buyers favor both low first cost and low operating cost. Policy makers may wish to consider a percentage capping fees and rebates at a percentage of a vehicle's base sales price (MSRP). Manufacturers or dealers might then raise the base price on efficient models, capturing a larger profit since rebates can then rise proportionately. However, this does not present a problem regarding program objectives--it simply transforms part of the incentive to buy efficient vehicles into a greater incentive to sell them, enhancing efficient vehicle sales in either case.[21]

High dollar values of feebates also occur at the guzzler end of the market. Particularly for cars, however, the less efficient models are typically the more expensive models. Even for pickup trucks, which are inexpensive relative to most cars, the fees as percentage of price are not extreme. The highest fee in Table 12 is on the least efficient models of the Ford F150: $2764 is 22% of the estimated nameplate average sales price of $12,700. The actual percentage of price is likely to be lower because the least efficient models, with 4-wheel drive and other options, are likely to be more expensive than the nameplate average. Furthermore, the existing gas guzzler tax, which ranges up to $7700, sets a precedent for a very steep tax on the least efficient vehicles, which are presently expensive sports and luxury cars.

Large rebates for efficient economy cars might actually expand the overall market for new vehicles. If the cost of a new economy car is cut by, say one-third or more, some consumers who would otherwise buy a used car might opt for a new, efficient car. At the pricier end of the market, a high guzzler fee might affect a buyer's choice of models, but it is very unlikely to dissuade a higher-income buyer from purchasing at all.[22] The result could be an overall increase in sales and an acceleration of fleet turnover, with a pronounced emphasis on replacement by vehicles in the most efficient classes. Furthermore, very high rebates on the most efficient cars would create an incentive for manufacturers to take larger leaps forward toward offering ultra-efficient vehicles. Rebates on the most efficient cars amounting to a substantial fraction of price would greatly decrease manufacturer's perceived risk of moving innovative technologies more quickly into production.

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[21] Economists will recognize this as an issue of tax incidence. Also, sellers' raising of the base price to capture larger profits is self-limiting, since sales will drop as sellers raise the price, as long as the rebate cap is less than 100% of price.

[22] Studies do indicate that sales of economy cars are more price elastic than sales of large and luxury cars (Boyd and Mellman 1980).

On balance, we see no reason to severely limit the size of feebates. If other considerations dictate a cap, it would be far preferable to impose a percentage cap (say, 33% of price) than to lower the overall leverage of the program. It is important to have high leverage in the middle of the distribution, where most sales occur. Thus, another possibility is to reduce the feebate rate for the least efficient and most efficient vehicles, maintaining a rate of at least 7%-8% for vehicles in the middle of the fleet. A feebate that is steeper near the reference level than at the tails is termed a "nonlinear" feebate and discussed further by Davis and Gordon (1992).

Economic rationales. Feebates can be viewed as a way to front-load part of fuel consumption costs that occur over the life of a vehicle. There are various rationales for front-loading a fuel tax, based on different aspects of the market failure with respect to motor vehicle energy use. One is to correct for the poor sensitivity of consumers to lifetime operating costs. Another is to correct for externalities, which are economic costs not reflected in the market price of gasoline. A third rationale is to provide a price signal related to the cost of technologies than can be used to increase vehicle efficiency, which manufacturers are otherwise unlikely to make (or apply for efficiency improvement) because of the relatively weak consumer interest in fuel economy.

New car buyers do not fully account for future fuel costs when making their purchase decisions. Economic theory suggests that rational consumers should be willing to pay a certain amount more for a car that is more efficient, other factors being equal, because of future fuel savings. Econometric studies indicate that there is some willingness to pay for higher fuel economy, but the apparent value consumers place on fuel economy is quite uncertain and the future savings can be highly discounted (Greene 1983). This market imperfection can be addressed by using the value of fuel consumption over the life of a vehicle as the basis of a feebate (see Appendix). This is not the same as actually front-loading all of the fuel costs, which would be like double-charging the consumer for the fuel (once at time of vehicle purchase, but then again every time fuel is purchased). That would only be the case if the feebate reference level were set at the zero consumption level (i.e., no rebates).

According to the second rationale, external costs, expressed per unit of fuel consumption, can form the basis of the feebate (Koomey and Rosenfeld 1990). For example, assuming an undiscounted externalities cost of $0.50/gallon over a vehicle lifetime yields a feebate rate of $120/mpg (a leverage of about 3%). Generally, as shown in Table 15, each $1.00/gallon of external costs implies a feebate leverage of 6.8%.

The Appendix describes how a feebate rate can be set on the basis of CO_2 emissions. For example, an undiscounted, front-loaded tax of $25/ton on vehicle lifetime CO_2 emissions would correspond to a gasoline tax of $0.33/gallon and yield a feebate rate of $5.32 per (g/km).[23] The California DRIVE+ proposal, which considers emissions of other air pollutants as well as CO_2, is determined as the sum of front-loaded emissions "taxes" for the various pollutants considered. The CO_2 portion of DRIVE+ was based on a rate of $9.50/ton, or about $2.00 per (g/km) (Gordon and Levenson 1989), for a leverage of just under 1%. Clearly, the implied feebate rate will vary widely depending on the choice of parameters used for a lifecycle or externality cost analysis. Estimating

[23] Based on an full fuel cycle emissions factor of 12 $kgCO_2$/gallon (DeLuchi 1992) and expressed on a CO_2 rather than carbon mass basis ($25/ton$CO_2$ corresponds to $92/tonC).

the external costs of fuel use is an area of uncertainty, complexity, and potential controversy--and beyond the scope of this paper. See Ottinger *et al.* (1990), UCS *et al.* (1991); Moffet (1991), CRS (1992); Greene and Duleep (1992); MacKenzie *et al.* (1992); among others.

Generally smaller feebate rates would be inferred from the estimated cost of technology improvement. The estimated average cost of past improvements already achieved in the fleet is $30 to $60 per mpg (Geller 1991; Greene and Liu 1988). The estimated average cost of future improvements of 30%-40% in new car fuel economy is $40 per mpg (Ross *et al.* 1991) to $110 per mpg (Greene and Duleep 1992). These estimates suggest that a feebate rate one-fourth as large as our examples might provide an incentive for manufacturers to add technologies for improving fuel economy. Automakers and some other parties argue that the cost of improving fuel economy is higher, as much as $300 per mpg as reported in NRC (1992) and industry-sponsored studies such as SRI (1991). Thus, one might expect manufacturers' support for higher feebate rates, such as those used in the hypothetical feebates analyzed here. Note that these technology cost estimates are based on a fixed set of options for efficiency improvement. The result is a supply curve of automobile efficiency (see Ross *et al.* 1991) in which some measures have very low cost but the marginal cost of improvement rises with increasing mpg. The estimates here are also averages over some range of fuel economy improvement. Ongoing technical innovation will tend to result in lower average costs over any fixed range of fuel economy improvement.

Rates likely to be effective. Given the large uncertainties and imperfections in the automobile market, it would be imprudent to set a feebate rate solely on the basis of economic analysis (e.g., externalities or technology costing). As Koomey and Rosenfeld (1990) point out, "given the wide range of [external cost] estimates, one should set incentives at a level within the range that will promote vigorous consumer response." Therefore, given a goal for higher average fuel economy, the choice of a feebate rate should be strongly guided by what it takes to change the behavior of the decision-makers, namely, both consumers and automakers, sufficiently to reach the goal. It is the automakers who know the most about vehicle pricing and its influence on consumer decisions. Thus, important guidance is provided by the 7% average magnitude of the rebates which automakers themselves use as sales incentives.

The need for relatively high rates to shift consumers toward greater fuel economy, given a fixed set of technological offerings, can also be inferred from analysis such as that of Greene (1991). On the other hand, large fuel economy improvements can be made at low cost if manufacturers incorporate efficiency improvement into their product planning. Technological advances rather then changes in consumer buying patterns were responsible for a major portion of past improvements in fuel economy (Greene 1987). With only a vehicle purchase price incentive mechanism in place (that is, no ongoing strengthening regulatory standards), manufacturers and consumers will have to be sufficiently swayed by the feebates so as to create a minimal market risk for models incorporating technology-based advances in efficiency. This clearly argues for setting the feebate rate higher than a level which might be inferred from technology costs alone. A complementary regulatory regime will also reduce manufacturers' risks in planning more efficient models, since they will know that their competitors are similarly bound.

Finally, average fees and rebates at 7%-8% of price sound reasonable from a common business sense point of view. No matter what you're selling, a 1%-2% discount won't mean much to people. Buyers will take notice at 5%-10% discounts, and 20%-30% off is a big sale. Because feebates are determined on a sliding scale, average rates at 5%-10% of price will imply that some vehicles would get much higher fees or rebates as a fraction of price. A cap or decreasing proportional ("nonlinear") rate around the 30% level is not likely to detract from overall program effectiveness.

Consumer Equity

Feebates are progressive from a tax equity perspective, at least on average. Figure 2 shows the positive correlation between car price and fuel consumption and it is safe to presume that what buyers pay for a car is related to their income. In other words, upper income households would be more likely to pay fees and lower or moderate income households more likely to receive rebates. As discussed here, feebates apply only to the new car market, where average car buyer income is 60% higher than the overall U.S. average (MVMA 1992).

Since fees fall on only a portion of the new vehicles, and are most likely to fall on more expensive vehicles, a relatively small portion of the public whose incomes are above average will bear the burden of the fees. Rebates would benefit another set of new car buyers but their incomes are very likely to be lower on average than those of guzzler buyers. For example, analysis of the Maryland feebate program indicates that the average price of 1990 cars eligible for rebates is $7800, clearly in the modest-income, economy-car segment of the market (DeCicco 1992c). The net transfer effect of a feebate program would therefore be progressive. Analysis using market data with both buyer incomes and vehicle prices could be done to examine this issue further if warranted.

Relating Feebates to CAFE and Revenue Targets

A feebate program would be managed with objectives regarding both fleet average fuel economy and revenue impacts. The feebate programs analyzed above were "static" in the sense that we presented only a fixed reference level (neutral point) of fleet average fuel economy, or fixed set of reference levels for a class-based system. If a feebate program is to induce fuel economy improvement, then there will be a need to adjust the program in line with the evolving fleet composition. Adjustments can be made by changing the program parameters: reference levels, feebate rates, or both. The types of adjustments made will depend on the particular management objectives of a feebate program.

The dynamics of a feebate program can be analyzed in terms of the revenue balance between fees and rebates. Adjustment procedures can be thought of as a way to maintain revenue stability. The revenue impact of a feebate program over a model year is

$$\text{(Excess Revenue)} = \text{(Total Fees)} - \text{(Total Rebates)} - \text{(Program Budget)} \quad (2)$$

At minimum, the program budget will include administrative overhead. If a feebate program is intended to generate revenue for other purposes, then the budget includes the revenue goal plus overhead. In any case, a "neutral" outcome of zero excess revenue is the program management objective. In practice, sales uncertainties will make it unlikely that zero excess revenue is achieved in any given year. The administering agency will therefore need some flexibility to adjust the parameters of a feebate program and probably develop a buffer fund to protect itself against unexpected shortfalls (e.g., by allowing higher overhead in the first few years of a program).

There are two approaches to managing a feebate program for expected increases in fuel economy over an extended time period. In a "dynamic" or "active" approach, reference levels are pre-set according to targeted levels of fleetwide fuel economy and the feebate rate is adjusted to maintain zero excess revenue. This is the recommended approach for a national-scale feebate program designed to achieve some specified overall efficiency improvement target. In a "passive" approach, parameters are adjusted as needed to maintain zero excess revenue regardless of market outcome. Although program reference levels would change, and would generally be expected to rise, the feebate rate would remain fixed no matter what the market outcome. A passive program is the recommended approach for a state-scale feebate, which is less likely to have sufficient leverage to improve the overall vehicle fleet (see further discussion under "State Feebate Programs" below).

A dynamic ("active" management) feebate program with a schedule of reference levels pegged to the future fuel economy targets is especially attractive for a federal program. The feebates could then work as a market-based complement to a CAFE standards program. If the market outcome results in a low average fuel economy, such that the average energy factors are lower than the reference levels, the total fees collected under the program will exceed the total rebates paid out. The excess fees could then be used to increase the rebates in the following year by setting a higher rebate rate,[24] thereby providing a stronger incentive for purchasing more efficient vehicles. Conversely, if a high fleet average fuel economy results in average energy factors exceeding the reference levels, the rebate rate can be lowered as needed to maintain the desired revenue balance. The result is a dynamic feedback system, with rebates being adjusted to keep fleet fuel economy "on track" in terms of meeting the goals of the fuel economy standard. If the feebates rates and adjustment procedure are strong enough, a dynamic feebate could potentially replace a fuel economy standard as a way to meet specified fuel economy targets.

By way of example, consider a federal feebate program with a goal of achieving a 60% improvement in overall light vehicle fuel economy over 15 years. Assume a baseline (initial) fleet average of 25 mpg, the new light vehicle average for 1991 (Heavenrich *et al.* 1991). Five years into the program the reference levels would be set for a 20% increase, for an overall target of 30 mpg. For purposes of this discussion, we treat this as the program's reference level (in reality, different size-based reference levels would be derived from this target depending on energy factors by vehicle class). If the fleet is falling behind target, total fees will exceed total rebates by an excess of, say, 10%. The administering agency would then specify that all rebates be increased by 10% for the following model year. This would be done by increasing the rebate rate while keeping the fee rate the same. For example, if an initial feebate rate of \$300/mpg is insufficient to reach the target, the rebate rate would increase to, say, \$330/mpg above the reference levels, while the fee rate would remain at \$300/mpg. If the fleet remains behind target in the following year, the rebate rate would be increased further.

[24] *Rebate rate* refers to the feebate rate used for calculating rebates as differentiated from fees, the latter being calculated using a *fee rate*. These distinctions are made whenever different rates are used for vehicles above and below the reference levels, as for the adjustment mechanism described here.

Such an adjustment procedure is a way to "fine tune" a feebate program, given that whatever feebate rate is initially chosen, it will be an educated guess regarding the strength of the incentive needed to move the fleet. If the initial incentive level is nearly correct, then the adjustment procedure will start to close the gap between the targeted and achieved fuel economy averages. A shrinking gap with incrementally higher rebate rates would indicate that the shortfall is likely to be eliminated within a year or two.

It is the vehicle manufacturers who ultimately have the greatest leverage over fuel economy improvement. Because of the lead time for product planning, decisions manufacturers make today determine the characteristics of the models to be sold 4-5 years from now. Consumer choice among a set of models having given technology-based efficiency characteristics will have a smaller effect on average fuel economy than the technology changes that manufacturers can make given adequate lead time. Thus, it is important that the incentive program either be strong enough to influence manufacturer product planning or be coupled to a fuel economy standard which gives manufacturers a separate compliance incentive to improve the technical efficiency of their products.

If a feebate program falls chronically behind target, a backstop or drastic adjustment procedure would be needed. Such a procedure might involve increasing (say, doubling) the fee rates applied to vehicles below the reference levels, but assessing the increased portion of the fees only on the manufacturers, so that the consumer feebate rate remains unchanged. Another way of making a drastic adjustment for an off-target program would be a very large across-the-board increase in the feebate rates, for example, doubled fees and rebates for all vehicles. Alternatively, a parallel strengthening of CAFE standards could provide the backstop for feebates. The ongoing increases in regulatory incentives would then pressure manufacturers to remain on-target. Given the importance of manufacturer product planning in determining ultimate program outcome, it is reasonable to impose on manufacturers the major responsibility for reaching program goals and therefore the greater penalty for being greatly off-target.

Domestics vs. Imports, Cars vs. Trucks

Except for the hybrid size-normalized system using passenger volume for cars and footprint for light trucks, the outcome by manufacturer for the feebate schemes analyzed here results in net aggregate fees for U.S. domestic manufacturers and net aggregate rebates for Asian import manufacturers (dominated by the "J5"), assuming the fixed 1990 sales mix. Clearly, in a feebate scheme based only on fuel economy or CO_2 emissions, larger rebates generally go to smaller vehicles since it is easier to achieve fuel economy with a smaller vehicle, other things being equal. Manufacturers of full-line fleets would find themselves disadvantaged relative to manufacturers who emphasize smaller models. Although the size disparities between the major domestic and import fleets are not now as great as they were in the 1970's, Asian imports are still smaller on average than domestic models. Thus, absent significant product mix changes, a straightforward consumption-based feebate would imply an increase in imports at the expense of sales by U.S. domestic manufacturers.

Such a sales shift would not exactly correspond to, say, the potential increase in the automotive portion of the U.S. trade deficit. All of the U.S. automakers have models produced outside of the

U.S. and some of the Japanese models are manufactured in the United States.[25] Moreover, a feebate system could be implemented with several years of lead-time or a phase-in period. A domestic automaker might improve its fleet efficiency in anticipation of the feebate, so that it would have net rebates rather than fees by the time the system was in place. To switch to net rebates, however, U.S. automakers would have to increase the average fuel economy of their vehicles by a greater amount than would their major Asian competitors. In any case, a system that results in a large apparent transfer from U.S. domestic automakers to Asian automakers can expect to encounter strong political opposition.

Including other vehicle attributes along with fuel economy does generally serve to mitigate the domestic to import transfer problem. This is clear from the analysis of the size based programs presented above. Simulation results for the California DRIVE+ proposal are shown in Table 14.[26] DRIVE+ would yield net rebates for Chrysler, but not for GM and Ford, and the net D3 vs. J5 outcome is still unfavorable to the domestics. Table 14 shows results for a DRIVE+ program that covers only cars; if trucks were included, the D3 vs. J5 outcome might be worse. The safety and fuel economy related (DRIVE-SAFE) proposal mentioned earlier also mitigates the domestic vs. import issue, in that Ford collects net rebates while Toyota pays net fees.[27] Overall, however, the D3 are still likely to pay net fees since light trucks were not included in the DRIVE-SAFE analysis.

Treatment of light trucks. The domestic vs. import transfer issue is strongly influenced by the manner in which light trucks are treated in the feebate system. The U.S. domestic manufacturers dominate the light truck market, particularly for full-size models. The federal standards governing fuel economy, safety, and emissions for light trucks have been more lenient than those for passenger cars. Therefore, including any of these factors in a feebate scheme based on deviations from overall average light vehicle values of the attributes will not eliminate the transfer problem. The only feebate programs that appear to avoid the problem are those which divide light vehicles into more than one class. Such is the case for two systems presented here, the footprint-normalized system of Tables 7-8 and the hybrid system of Tables 10-11.

Recall that the economic incentive to improve fuel economy depends only on the "slope" (feebate rate), not on the reference level. This is particularly true for the manufacturer response. On the consumer side, the reference level could have significance due to the symbolic value of not having a fee or having a rebate. Generally, however, separate reference levels for cars and light trucks should not weaken the overall potency of the feebate.

The disadvantage of separate reference levels is the liability of reclassification ("gaming"), by moving a model from one class to another. A model could then obtain a better feebate (lower fee or higher rebate) without any technical improvement in efficiency. Separate feebate treatment for domestic and import fleets would also be liable to reclassification problems. More broadly, the risk is that manufacturers might re-orient production and sales strategies to emphasize less efficient market

[25] The automobile industry is becoming increasingly global and interconnected. The national origin of a company need not match the origin of the vehicles it sells or builds. All major automakers have arrangements among themselves ranging from components supply to partial ownership or shared assembly (Wards 1992). Therefore, while the labels "domestic" and "imported" may still be politically potent, their relationship to actual U.S. employment is complex.

[26] Based on an analysis of an early version of the proposal using 1988 vehicle data, from Gordon and Levenson (1989).

[27] D. Gordon (Union of Concerned Scientists), pers. comm. 1991.

segments for the sake of better feebate treatment. Such a distortion would ultimately be self-limiting: in the extreme, all light vehicles end up classified in the least efficient class, but then have to improve from there. There would nevertheless be a loss of fleetwide efficiency improvement potential because of reclassification toward the "least common denominator." One way to counteract gaming tendencies is by offsetting the reference levels so as to advantage the more efficient classes.

Phase-in. Both of these key issues--domestics vs. imports, cars vs. light trucks--suggest that a feebate phase-in period might be desirable. This would give manufacturers an opportunity to revise their product plans in light of the stronger market incentive for fuel economy. The feebate could be phased-in, for example, by starting with a low feebate rate in the early years of the program and successively increasing the rate over a period of, say, five years, until a full value is reached. Another type of phase-in could be used to address the large fuel economy gap between cars and light trucks. Initially there would be separate reference levels for cars and light trucks, as in the hybrid program illustrated in Table 10. The light truck reference level could be raised each year while the car reference level remains fixed. When the light truck reference level reaches the car level, the system will have converged on a single reference level for all light vehicles. Subsequent increases in the level would then apply to the light duty fleet as a whole.[28]

Direct approaches to the issue. In principle, one could also address the domestic vs. import problem head-on by adjusting or managing the feebates according to vehicle origin. DeCicco (1991) identifies three possibilities: (1) prorate or otherwise adjust the rebates according to domestic content, with fees based only on efficiency; (2) provide the rebates as an investment tax credit, thereby benefiting only manufacturers who are making investments in the U.S.; (3) provide the rebates as an employment tax credit, e.g., by linking them to some measure of a manufacturer's employment of U.S. workers. These approaches are liable to criticism as violating the General Agreements on Tariffs and Trade (GATT) or other so-called "free trade" principles, which are politically controversial issues. An "internationally revenue neutral" approach has also been proposed, which might sidestep GATT concerns; in this type of system, the feebates would be separately managed for domestic and import fleets.[29]

The feebate concept is inherently very flexible in that a schedule of reference levels and feebate rates could be developed so as to obtain almost any outcome desired for a given sales mix. For example, the recently proposed expansion of the Ontario feebate system set different schedules for different vehicle classes. Because it included rebates for some models made in Ontario, the program expansion was supported by the Canadian Auto Workers Union and Ford Canada, although it was opposed and subsequently defeated by General Motors. While the transfer problem is a serious concern, we do not believe that it should override the basic motive of providing a strong incentive which can operate effectively to improve fuel economy no matter what the sales mix is, especially since the mix could change in the future and an objective of the program is in fact to influence the vehicle sales mix.

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[28] A similar effect could be obtained by computing the feebate as a sum of two components: a class-specific component based on separate reference levels for cars and trucks plus a general component based on a single overall light duty vehicle reference level (Davis and Gordon 1992). Convergence could be obtained by successively change weights on the separate and overall components until the separate fleet component is eliminated.

[29] C. Mendler (Energy Conservation Coalition, Takoma Park, MD), pers. comm. 1992.

Risk of Upsizing

Our analysis has focussed on size-based feebates because of their ability to address manufacturer equity issues. Nevertheless, there is a danger that the incorporation of a size measure (e.g., footprint, interior volume) into a regulatory or incentive system will induce increases in average vehicle size. If the cost of a percent increase in size is less than the cost of a percent increase in fuel economy, for example, it makes sense for an automaker to increase size to gain a larger rebate (or smaller fee). This is provided, of course, that the changes in attributes are sufficiently marketable. In other words, the degree and form of upsizing induced by a size-based feebate would depend on the relative values in the marketplace of size and fuel economy, which would in turn depend on their respective marginal production costs, marginal consumer preferences (utility), as well as the feebate rate. Data with which to examine the full market response (supply and demand side) are not known to be readily available. Rough estimates could be made by comparing prices among existing vehicle offerings.[30]

If a size-based feebate system is implemented along with a standard, and the standard is either based solely on fuel economy (i.e., CAFE) or is size-based with locked-in fuel economy targets (DeCicco 1992b), then the standard would provide a check on market distortions which might result in increasing size at the expense of fuel economy. Alternatively, the feebate reference levels for a given manufacturer could be raised if a manufacturer upsizes their fleet beyond a certain point, say, 5% more than the average vehicle size in some base year. In any case, a feebate system can be designed to discourage substantial upsizing just to achieve lower fees or higher rebates.

Energy Savings

A most important question is, how much oil can feebates save? A related question is, how dependent are energy savings on the feebate magnitude? Answering such questions involves quantifying the sales shifts and vehicle technology changes expected in response to a feebate program. We expect that significant sales shifts would be induced by feebates as large as those based on levels derived from the existing gas guzzler tax or manufacturer sales rebates. But, specific estimates for the likely sales shifts are unavailable at this point, so the only honest answer regarding the impact of feebates is that we really don't know. This is an active issue for research. However, given the lack of directly related empirical information, there will be significant uncertainty in any predictions of the response to a feebate program.

There is no prior experience with feebates in the U.S. automobile market. There is, however, strong evidence for the effects of the gas guzzler tax, which applies to automobiles rated at less than 22.5 MPG and ranging up to $7700 for cars rated at less than 12.5 MPG (Table 2, Figure 3). U.S. domestic automakers seem to avoid significant gas guzzler penalties by keeping their mass-market cars just above the guzzler tax threshold of 22.5 MPG (Ross *et al.* 1991). The constraint of the gas guzzler tax threshold is clearly visible in the plot of fuel consumption vs. vehicle price (Figure 2). Part of this could be a "stigma" effect in which automakers avoid having cars labeled as gas guzzlers even in cases when the tax is a fairly small percentage of vehicle price. In spite of its apparent

[30] For example, trucks and vans come in a variety of wheelbase options. The price differentials among different wheelbases, holding other attributes fixed, would indicate the relative cost of increasing the energy factor by raising the wheelbase as compared to adding technologies for efficiency. A similar approach is used to estimate the costs of fuel economy technologies.

effectiveness, the gas guzzler tax applies to less than 10% of the new car market and it seems to operate at least as much as a constraint as a price incentive. Therefore, it provides little guidance regarding the quantitative effects of a broad-based feebate.

An evaluation is yet to be made of the modest feebate program that was established in Ontario in 1991. Automakers routinely use market incentives (rebates) as part of their sales strategy, but analyses of such programs are not known to be readily available in the public domain. An obvious difficulty is that many other complex and interacting factors, starting with overall economic conditions, affect both the overall level and composition of vehicle sales. A review of international policies (Europe and Japan) for automobile fuel use and pollution has examined fuel taxation and vehicle taxation, relating these factors to aggregate statistics on ownership rates, travel, and fuel use (Schipper *et al.* 1993). However, there have not been a disaggregate analysis of the international data that breaks vehicle populations into classes by type, fuel consumption rate, price, etc., as needed to make inferences about the effects of feebate programs. Research is also underway to use a consumer-choice model developed for household motor vehicle purchases in conjunction with a technology cost model of the manufacturer response in order to estimate the impact of feebate programs (Train 1991; Davis and Gordon 1992 provide related background). Sponsored by the U.S. Department of Energy (DOE), this research effort will provide estimates of the impact of U.S. federal feebate programs.

Although he did not directly address feebates, Greene (1991) concluded that, beyond small shifts (less than 1 mpg), it is difficult to improve fleetwide fuel economy through consumer-side sales shifts alone; manufacturer responses were not analyzed. DRI (1991) compared the impacts of feebates, an increased gasoline tax, and an oil import fee. Although the results showed that a feebate could be effective in reducing oil consumption, the study concluded that a gasoline tax would be the more "economically efficient" option; however, such a conclusion was largely predetermined because of the methodology, prior assumptions, and parameters chosen for the study. Gordon and Levenson (1989) analyzed possible sales shifts for the California DRIVE+ proposal using size class based price elasticities and accounting for the consumer (demand side) response for cars only.[31] While they reported expected sales impacts by manufacturer (Table 14), they did not attempt to estimate a resulting change in the California-fleetwide fuel economy. DRIVE+ has tailpipe emissions factors included as well as fuel economy, so the effects would not be the same as those for feebates based on fuel economy or size.

Subsequently, estimates were made using the DRIVE+ data base, again, looking only at the consumer response to the fuel economy portion of a DRIVE+-like feebate. Roughly, a feebate rate of $300/mpg could shift consumers' purchase decisions enough to achieve a 1 mpg improvement in the automobile fleet average fuel economy.[32] A 1 mpg improvement represents roughly a 3.5% increase in the current new fleet average. On a nationwide basis, a one-time 3.5% fuel economy improvement would bring oil savings of 0.1 Mbd (million barrels per day) within 2-3 years, rising to 0.3 Mbd within 10-12 years as the improved vehicles come to dominate the on-road vehicle stock. If a feebate program induced an ongoing improvement in the fleet, e.g., by inducing automakers to

[31] The price elasticities used by Gordon and Levenson (1989) were derived from selected car model estimates of Boyd and Mellman (1980). Gordon and Levenson applied them according to automobile size class; the average was -3.2. This is likely to overstate the consumer-only response, as more recent analysis indicates new car price elasticities in the range of -1 to -2 (pers. comm., Bart Davis, Lawrence Berkeley Laboratory, Berkeley, CA 1992).

[32] Based on estimates provided by D. Gordon (Union of Concerned Scientists, Berkeley, CA), personal communication, 1991.

plan more efficient product offerings, the savings would be much greater. For example, a steady 1%/yr improvement in new light vehicle fuel economy starting in 1996 would yield savings of 0.2 Mbd by 2001 and 0.9 Mbd by 2010. Maintaining an average 3.5%/yr improvement rate would yield savings approaching 3 Mbd by 2010.[33] This latter case would entail a doubling of average new car fuel economy by 2010, to 56 mpg, which is in the mid-range of the technically feasible levels identified by EEA (1991).

A feebate response estimate based on a simple price-elasticity analysis is uncertain and incomplete for several reasons. First, it may not fully reflect choices among different configurations of a given model. Second, it is static, representing a one-time response rather than the effect of a program over a number of years. Third, it is based on a highly simplified model of the market. The choice of when and what kind of car to buy depends on many more factors, and more sophisticated modeling is needed to capture these effects.[34] Finally and most importantly, however, an elasticity-based estimate of the impact of a feebate program reflects only the consumer portion of the response, for a fixed set of models offered by manufacturers. As such, it represents no more than a one-time reordering of consumer choice. It reflects the fact that the overall impact on fleet fuel economy will be quite small unless manufacturers modify their products in response to the feebate system.

Thus, what appears to be the most important aspect of feebates, namely, manufacturers' responses, is the area about which the least information is known. Further efforts to characterize manufacturer response are part of the ongoing DOE study (Train 1991). Preliminary results from this study do suggest that the manufacturer response is substantially larger than the consumer response.[35] A strong manufacturer response could yield a large fleetwide fuel economy improvement if automakers add efficient technologies to their new vehicles and downplay features, such as high power performance, which are detrimental to fuel economy. Therefore, it is desirable to provide manufacturers with a consistent, long-term feebate program, so that they can predict the feebate values for future vehicles from the start of product planning.

The importance of manufacturer planning suggests that the technology-cost rationale is an important guide for setting feebate rates. Given sufficient lead time, automakers are likely to improve fuel economy up to the point where the marginal cost of improvement matches the feebate rate. However, as noted earlier, estimates of technology costs vary widely. Also, because supply curves climb steeply beyond a certain point, marginal costs grow rapidly for higher levels of fuel economy improvement. This is only a technologically static view, of course. Under a strong incentive for fuel economy improvement, manufacturers would be motivated to innovate for further efficiency improvement. Thus, there is a potential technology-forcing effect, which makes feebates a promising way to reach long-term goals such as achieving substantial, absolute cuts in nationwide oil consumption and CO_2 emissions.

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[33] Savings relative to frozen new vehicle fuel economy, based on method described in DeCicco (1992a).

[34] There is a literature on methods for analyzing the car market for response to energy policy initiatives dating from the 1970s. Train (1986) provides a review of methods and findings and presents a model of automobile choice, which is the basis of the current study of Train (1991) as part of the DOE-sponsored feebates analysis effort.

[35] W.B. Davis (Lawrence Berkeley Laboratory, Berkeley, CA), pers. comm., March 1993.

STATE FEEBATE PROGRAMS

The analysis presented here focussed mainly on model feebate programs at the federal level. The one existing program in North America is that of the Province of Ontario. The State of Maryland has enacted a feebate program, but its implementation remains pending. As noted in the introduction, many other states have expressed an interest in feebate or gas guzzler tax programs. There are several issues particular to developing state programs, the first of which is federal preemption.

Federal Preemption

An issue that may constrain state feebate programs is the current U.S. federal law which preempts states from setting their own fuel economy standards. The federal law says that states may not make any "law or regulation relating to fuel economy standards."[36] There is also a federal preemption of state fuel economy labeling requirements. The Maryland feebate program, as enacted in 1992, is based on federally determined fuel economy ratings and has a labeling provision requiring that dealers display on a vehicle a notice stating the average fuel economy rating and the amount of tax surcharge or credit applied to the vehicle. In an letter regarding the Maryland feebate, the U.S. Department of Transportation asserted that federal law does preempt state feebates (Rice 1992). This conclusion has been partly contested by Maryland Attorney General, who issued an opinion affirming the state's right to enact the feebate but conceding that the associated labeling requirement does violate that aspect of federal preemption.

The labeling issue does not appear to be a fundamental obstacle, since it can probably be overcome by careful specification of the state requirements and coordination with federal agencies. The broader issue of whether or not states can enact incentives associated with fuel economy is still subject to legal investigation. In the view of the Maryland Attorney General, a tax or feebate scheme is not a standard binding on manufacturers; moreover, there is a constitutional prerogative for states to enact taxes not explicitly proscribed by the federal government. As of this writing, a request for resolution of the Maryland feebate preemption issue is pending with the Clinton Administration.

It would be helpful to have federal legislation clarifying that "feebates are not standards" and upholding the principles of federalism by amending the federal preemption clauses so as to explicitly allow states to enact feebate programs for vehicle fuel economy (Caldwell *et al.* 1992; Curran 1992). In the meantime, one way to avoid a preemption challenge would be to base a state feebate program on some vehicle attribute physically related to but legally distinct from fuel economy (see "Surrogates for Fuel Economy," below). For example, existing state fees based on weight or horsepower have not been challenged for violation of federal preemption.

Even if a nationwide feebate program is put in place, state programs would serve to reinforce the federal incentives. The auto industry might raise an argument about "regulatory chaos" from multiple programs. Feebates are fundamentally a type of tax/subsidy system, not a regulation. Manufacturers themselves regularly modify their own pricing schemes in ways that are likely to be much less predictable to their competitors than any set of government programs, which would be announced well in advance. In the past, the industry has operated successfully while facing a variety of taxation systems in different states. There are already significant differences among states in

[36]Motor Vehicle Information and Cost Savings Act, 15 U.S.C. §2009(a).

existing vehicle taxes, some of which are indexed according to vehicle weight. Therefore, state and federal incentive programs would be mutually reinforcing. We see no overbearing reason why they should be mutually exclusive.

Structuring State Programs

At the state level, existing sales taxes can be as the basis for feebate programs. For example, if a state has an existing vehicle sales tax of 5%, feebates could be scaled so that the range of vehicle efficiencies corresponds to a range of taxes, say, from 0% to 10%. The resulting leverage would be smaller than 5%, depending how far out on the fuel economy distribution the highest and lowest tax levels are set. Generally, the resulting feebate rates and overall program leverage would be smaller than those of a federal program. However, the relative outcomes would be essentially the same as those of the examples presented here, which can therefore be used to guide the development of a state feebate program.

For example, suppose a state currently has a 5% tax on vehicles. The feebate rate could be set so that the reference level corresponds to a 5% tax and a 10% tax is levied on vehicles whose energy efficiency is lowest. The resulting feebate would take the form of a tax ranging between 0% and 10% of a vehicle's sales price, depending on the vehicle's energy factor. Since many pickup trucks and some sport utility vehicles are relatively inexpensive, a percentage-based system would have relatively lower fees for light trucks, in spite of their poor fuel economy. A percentage-based system would also eliminate very high rebates on the most efficient cars, since the largest "rebate" would be a tax rate of zero percent. Thus, a percentage system will generally mitigate some of the car vs. light truck and domestic vs. import problems which arise with feebates directly proportional to fuel consumption.

Administrative simplicity can also be obtained by implementing the feebate in broad steps, e.g., ranges of fuel economy or energy factor which have a constant feebate level, such as the steps of the guzzler tax shown in Figure 3. A broad step in the middle--around the reference level--could be used to create a "neutral zone" or "deadband" of untaxed vehicles, effectively classified as neither guzzlers or sippers. The Maryland feebate is an example of this, with vehicles in the neutral zone (about 20% of sales) paying the pre-existing 5% tax. The main reason for such a neutral zone is political, i.e., to deflect some potential opposition by the fact that many vehicles are unaffected by the feebate system. Since many vehicles are concentrated in the middle of the distribution, however, a system with a neutral zone will be less effective than one which provides a sliding-scale incentive for all vehicles.

A state feebate program would generally be "passive," as defined above. That is, it would be managed for revenue neutrality or for particular revenue goals, without attempting to achieve specified levels of average fuel economy. The revenue balance of a state program could be managed by fixing the feebate rates and adjusting the reference levels. Alternatively, with fixed reference levels, the feebate rates could be changed to adjust for revenue deficits or surpluses. These are not mutually exclusive, of course. In either case, estimating the revenue impact from a feebate program would involve projections of vehicles sales, fuel economy, and whatever type of energy factor rating is used for the feebate program.[37] Reference levels would generally rise over the years, reflecting the fact that what is considered a "gas guzzler" or a "gas sipper" is relative to the state of the technology, which we desire to advance through time.

In the absence of a nationwide feebate program, most single-state feebate programs would have a small effect on overall fleet composition. However, state feebates could be influential in a large state such as California and more so if many states had similar programs. For example, if adopted as part of California-option clean air programs in several Northeastern states plus California, a DRIVE+ program could have a larger impact on overall fleet composition.

Surrogates for Fuel Economy

Feebates could also be based on a vehicle attribute related to fuel economy, without any explicit legal linkage to fuel economy or CO_2 emissions. The District of Columbia and sixteen states have vehicle registration fees based on weight; Missouri has a fee based on horsepower (Miller 1992). It is common for state registration fees to differ by vehicle weight class (particularly for trucks). Using weight or some other attribute as a surrogate for fuel economy might be attractive for state feebate programs because it is likely to avoid the pre-emption issue and will generally have a beneficial energy conservation impact. Other attributes physically linked to fuel economy are engine displacement, horsepower, vehicle size (e.g., using volume or footprint alone), and combinations such as horsepower-to-weight ratio. A technical drawback of using surrogates for fuel economy is that not all efficiency improvements would get credited. For example, there would not be an incentive for improved aerodynamics under a feebate based on weight or engine displacement. However, given broader-based federal policies for improving automotive fuel economy, this drawback is not of serious concern for state programs.

Engineering considerations lead us to suggest engine displacement as a particularly attractive attribute on which to base a feebate. Other things being equal, a car with a smaller displacement engine will have a higher mechanical efficiency because of lower losses under part-load conditions, when most driving is done. Displacement reduction is therefore a key strategy for fuel economy improvement (Ross *et al.* 1991). Low displacement with a high power output is indicative of a technologically advanced engine. As shown in Figure 4, progress in fuel economy improvement has tracked falling engine displacement. Figure 9 is a nameplate-level plot of light vehicle fuel consumption versus engine displacement, showing the strong correlation. A given nameplate is often offered with several engine options and the more fuel-efficient configurations are generally those with the lower engine displacements. The main trade-off is power performance (i.e., acceleration and top speed ability). Of course, smaller cars tend to have smaller displacement engines, and so a displacement-based feebate would favor economy cars over full-size cars. Engine displacement has also been used in some European countries as the basis for vehicle taxes (Schipper *et al.* 1992).

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[37] The U.S. EPA reports fuel economy and emissions data by configuration for every model year in what is known as the "Test Car List" (publicly available as a computer printout or on magnetic media). Sales data are available from commercial sources; also, most states would have access to data based on their existing sales tax, registration, and vehicle titling programs.

The average 1990 light duty vehicle engine displacement was 3.1 liters, or 188 cubic inches (Heavenrich *et al.* 1991). Roughly, for a revenue-neutral feebate program based on an existing sales tax of 5% and an average vehicle price of $15,000, this would imply a feebate rate of $250/liter. An engine displacement based vehicle tax might also be an attractive way to develop a revenue-raising system at the state level. For example, the existing tax would be unchanged on vehicles having engine displacement at or below the average. The tax would then progressively increase in proportion to increased displacement above the average. This formulation is more akin to a gas guzzler tax than a feebate and it would certainly serve to promote improved fuel economy. It also has the virtue of simplicity.

CONCLUSION

Improving the energy efficiency of cars and light trucks is essential for controlling transportation oil use and its accompanying environmental and security costs in the United States. Feebates--new vehicle purchase fees and rebates linked to fuel consumption--would provide a market incentive favoring greater energy efficiency and are an intuitively appealing approach to improving fleetwide fuel economy. Vehicle tax mechanisms have been used in other countries as a way to affect the makeup of vehicle fleets. However, only the relatively modest Ontario feebate program has been applied in the North American market. Thus, there are limited data to guide the development of feebate programs appropriate for U.S. market conditions. Automakers regularly use rebates as an incentive for stimulating sales of certain models; these provide one credible guide to the magnitude of feebates that can be expected to significantly sway purchase decisions.

We identified eight general issues that need to be addressed in developing a workable feebate program: (1) how to deal with light trucks in light of their historically lower fuel economy and past regulatory lenience; (2) the domestic vs. import problem, which is closely related to the light truck issue because of the importance of trucks in domestic automakers' fleets; (3) more generally, how to treat manufacturers equitably, ensuring that all have an incentive to improve their fleets without creating unfair competitive advantages because of particular fleet characteristics; (4) the administrative costs, revenue impacts, and tax equity implications of a feebate program; (5) how feebates should address alternatively fueled vehicles; (6) insuring that the program is understandable to consumers; (7) how large the feebate rate should be in order to significantly affect decision making by both automakers and consumers; (8) insuring that the program achieve the desired fleetwide improvement targets, e.g., by means of adjustment procedures or a complementary CAFE standards program.

A feebate system is inherently a very flexible mechanism which can provide many programmatic options, particularly for addressing issues (1-3) above. There are a number of different ways to measure efficiency for the purpose of setting a feebate. A particular efficiency measure is termed an energy factor. The most straightforward energy factors are a vehicle's fuel economy or fuel consumption rate. Energy factors can also incorporate other vehicle attributes (size, emissions, etc.) as appropriate for various classes of vehicles. There are two basic parameters which determine the structure of a feebate. The reference levels specify the neutral points of a feebate, that is, the energy factors at which vehicles receive neither a fee nor a rebate. The feebate rate specifies the marginal decrease in fee and increase in rebate as a vehicle's energy efficiency factor increases. The feebate rate may be uniform (the same for both fees and rebates and for all vehicle classes) or rates may be adjusted according to various program objectives. It is the feebate rate which largely determines the strength of the market incentive to improve efficiency. Raising or lowering a uniform feebate rate changes the strength of the incentive, but does not the change the relative ranking of vehicles within a feebate program. Therefore, a feebate's differential effects on manufacturers is independent of any uniform feebate rate. The effects on different manufacturers does, however, depend strongly on the definition of the energy factor and the choice of reference levels by vehicle class.

Feebate programs could be implemented at either federal or state levels, or both. A federal feebate program can be thought of as an extension of the existing U.S. federal gas guzzler tax. State feebate programs could involve tax surcharges and tax credits developed as a modification of existing sales tax or licensing programs. State programs could also be based on other vehicle attributes, such as engine displacement, which relate to efficiency. Feebates can be designed to be revenue neutral or revenue generating. For analytic purposes, it is easiest to consider feebates that generate zero excess revenue, where excess is defined net of both rebates paid out and the revenues needed for administrative overhead or other purposes. Management of a feebate program for revenue stability can be achieved by adjusting the reference levels and one of the feebate rates.

A "dynamic" feebate program is appropriate at the federal level. In this case, reference levels are pegged to targeted future improvements in fleetwide fuel economy and the rebate rate is adjusted according to whether the fleet is above or below the targets. For example, if the fleet falls behind the targets, excess revenue will be generated that can be used to increase the rebates, providing a positive feedback that increases the incentive for reaching the target.

A "static" feebate program is more appropriate for state implementation, since few states alone are likely to have sufficient market leverage to reach pre-set fuel economy targets. In this case, the reference levels of the program would be managed for revenue neutrality or for revenue generation without regard to fleet average fuel economy achievement.

After systematically examining a number of feebate structures, we settled on size-adjsuted approaches as promising bases for legislative proposals. Such approaches address the domestic vs. import transfer problem presented by feebates based only on fuel consumption due to the historical product mixes offered by domestic and import manufacturers. Our proposed size-adjusted feebate schemes also involve separate reference levels for cars and light trucks. The first system (Tables 7-8) uses vehicle footprint as the fuel consumption normalization factor for all light vehicles. A second system (Tables 10-11) is a hybrid approach, using volume normalization for cars and footprint normalization for light trucks. The footprint-only system substantially mitigates the domestic vs. import revenue transfer problem and has the advantage of providing a uniform approach for all light vehicles. The hybrid system eliminates the revenue transfer problem, but provides less consistent treatment across vehicle classes. Both approaches deserve further exploration by policy makers; there is enough flexibility in the feebate mechanism that some variation on these proposals is likely to result in a workable system.

Size-based feebates make sense because size provides a measure of vehicle utility, and so a physically-based energy-efficiency index can be constructed as a ratio of size to fuel consumption (or to CO_2 emissions, which would provide a way to address alternative fuels). Size-based energy factors are already in use for appliance efficiency standards and rebate programs. In a size-based system, vehicles of all classes can qualify for rebates while liability of inter-class gaming is minimized. There are large variations in the feebates among different configurations of the same model, which would motivate consumers to choose significantly more efficient models of essentially the same size and style.

A program with an average feebate rate of about $300/mpg, consistent with both the existing gas guzzler tax rate and typical levels of manufacturer rebates, would yield fees and rebates that average 7%-8% of new vehicle purchase price. Such a program is promising for implementation at the federal level. If implemented either as a "dynamic" feebate, following an announced schedule of fleetwide fuel economy improvement, or in conjunction with increased fuel economy standards, then a federal feebate program can make a substantial contribution to reaching nationwide goals for reducing motor vehicle fuel consumption. Similar programs using lower rates could be implemented at the state level, providing a valuable complement to the federal incentives.

Feebates are an inherently progressive tax/subsidy system since the fees will tend to fall on upper-income car buyers while the rebates will tend to go to moderate or lower income car buyers. A revenue-neutral feebate system could also enhance overall new vehicle sales and accelerate fleet turnover.

The energy-saving effect of a feebate program is difficult to estimate, particularly if the feebate is the sole mechanism used to encourage greater vehicle efficiency. Existing studies suggest that the consumer part of the response will be modest at best. A greater effect of a feebate program will be its influence on manufacturers' product planning. To the extent that a feebate is technology forcing, it can result in the timely application of advances in automotive engineering toward fleetwide fuel economy improvement. A feebate implemented with rates averaging 7%-8% of new vehicle price, either as a complement to CAFE standards or with a strong adjustment mechanism to correct for falling behind target, has a high likelihood of achieving fleetwide fuel economy targets set on the basis of technical feasibility. Quantification of all of the response to feebate programs is a subject for ongoing analysis, as is further discussion regarding the major issues identified here.

In spite of uncertainties about the exact response to feebates, there is little doubt that a comprehensive federal feebate program, providing a significant incentive covering all classes of cars and light trucks, would move the new light vehicle fleet toward higher fuel economy. State feebate programs would be a beneficial reinforcement of federal policies for improving fuel economy and provide a new approach for revenue generation that is both progressive and supportive of environmental goals. Feebates can therefore play a valuable role in reducing transportation oil use and deserve serious consideration by policy makers at both state and federal levels.

APPENDIX

This appendix provides technical details on fuel economy ratings and their use in the construction of feebates. The specific formulas used to define the feebate systems analyzed in the report are given here, along with a discussion of the relationships among various formulations of feebates.

Fuel Economy Ratings

Throughout this report, fuel economy values are based on unadjusted EPA weighted average ratings, as used for compliance with existing U.S. CAFE standards. EPA test procedures are based on two driving cycles, the urban and highway cycles, and the CAFE compliance rating represents a composite of 55% urban and 45% highway driving. "Unadjusted" refers to the use of laboratory dynamometer driving cycle measurements, not adjusted for differences that occur in actual on-road driving. The nameplate averages as used for analysis in this report are sales weighted, using a harmonic average to properly reflect expected fuel consumption.

In developing feebate programs, it is essential to base energy factors and feebate levels on fuel economy ratings at the configuration (submodel) level. A weakness of the current Gas Guzzler Tax is that it allows the use of a "representative" configuration for the fuel economy rating, and implied tax level, applicable to all configurations of a given model. The chosen configurations are not necessarily representative of the actual sales-weighted average fuel economy for the model, creating a loophole for evading some or all of the tax. This type of abuse would be likely to worsen under a feebate system covering all vehicle classes. Furthermore, as discussed in the text, chosing more efficient configurations is an important part of the consumer response to a feebate, which would be lost if the energy factor ratings used to compute specific fees and rebates were averaged to the nameplate or "representative configuration" level.

For consumer information purposes, the EPA fuel economy test results are adjusted downward to better reflect on-road driving conditions. Since 1984, the urban (city) fuel economy ratings in the EPA Gas Mileage Guide and printed on a vehicle's sales sticker are reduced by 10% from the urban test cycle results. The corresponding highway fuel economy ratings are reduced by 22% from the highway test cycle results. An adjusted 55% city and 45% highway would average 15% lower than the unadjusted composite value. This average adjustment is commonly known as fuel economy shortfall.

It has long been recognized that changing driving conditions have resulted in a divergence between the unadjusted EPA ratings used for compliance purposes and actual on-road average fuel economy (EPA 1980). Westbrook and Patterson (1989) projected that the shortfall would grow from 15% to 30% by 2010. Recent analysis by Mintz *et al.* (1993) confirms an increase in shortfall even as of 1985, and revealed that the shortfall of light trucks is worse on average than that of passenger cars. In spite of uncertainty regarding the national average value, all recent evidence suggests that shortfall is presently larger than 15%. For the purpose of computing energy factors for feebates, we have adopted a 20% shortfall for all vehicles. Since it is applied as a constant factor for all energy factor calculations, the exact value of shortfall is immaterial for the outcome of feebates analysis; equivalent programs could, in fact, be formulated on the basis of unadjusted fuel economy ratings. However, we wish to be able to interpret feebate values as relating to expected levels of fuel consumption or CO_2 emissions among different vehicles. The differences in consumption and emissions would be understated if unadjusted values are used; therefore, we have formulated the feebates presented with a shortfall adjustment that should closely reflect on-road driving conditions. Based on the analysis of Mintz *et al.*, the largest remaining bias in such an interpretation would be that between cars and light trucks.

The Maryland feebate program defined the MPG basis of its tax credits and surcharges as the 55% city and 45% highway weighted average of the adjusted fuel economy levels published in the EPA Gas Mileage Guide. In the Maryland system, the fuel economy is rounded to the nearest 1 MPG for the purpose of computing the feebate. For comparison purposes, the following box shows the guzzler/sipper threshold levels of the Maryland bill along with their corresponding federal compliance levels. The exact correspondences vary from car to car, but the values shown here are accurate to within 1 MPG.

Adjusted average MPG, as used for Maryland feebates	Unadjusted average MPG, as used for federal compliance
21	25
27	32
35	41

Feebates based on Fuel Economy

Some policy makers have expressed an interest in formulating feebates directly from fuel economy values. This was done in Maryland, and it is seen as being familiar and readily understandable to consumers, since it is the adjusted EPA fuel economy ratings which are almost exclusively reported in the press, advertisements, and magazines describing new cars and trucks. As discussed in the body of this report, there are a number of reasons why a straightforward mpg-based system would not be recommended. For the sake of comparison, however, we present a mpg-based system in Tables A1 and A2.

Table A1 shows mpg-based feebates for the top selling 1990 light vehicles, using a feebate rate based on the fit to the gas guzzler tax shown in Figure 3. Table A1 also includes the nameplate average price estimates, which form the basis for estimating percentage changes in price and feebate leverage as discussed in the body of the report. Compared to the consumption-based feebates of Table 3, the mpg-based reference level is shifted upward, from the harmonic mean of 24.8 mpg to the arithmetic mean of 25.9 mpg. The harmonic mean fuel economy is used for reporting fleet averages and corresponds to the reciprocal of the fleet average fuel consumption rate. The harmonic mean fuel economy is always lower than the arithmetic mean fuel economy but the latter is needed for revenue neutrality of an mpg-based feebate. The vehicle at the reference level now happens to be the Ford Taurus. Table A2 shows the outcome by manufacturer for an mpg-based system assuming a fixed model year 1990 fleet mix. The mpg-based system is somewhat favorable to U.S. domestic automakers than the consumption based system whose outcome is listed in Table 4. Size-normalization procedures and separate treatments for cars and light trucks could, of course, be applied to an mpg-based (such analysis was presented in the September 1992 draft of this report). However, this would mask the main virtue of the mpg-based system, which is the use of the familiar mpg measure as the basis for the fees and rebates.

"Super-sippers," with fuel economies much higher than those of the nameplate averages shown in the tables, would get larger rebates under an mpg-based system, as shown by the dashed line in Figure 3. However, such a feebate rate overvalues the relative fuel savings of increasing each unit of mpg. This reflects the fact that, for example, a 5 mpg difference between 15 mpg and 20 mpg yields a 25% fuel savings while a 5 mpg difference between 35 mpg and 40 mpg yields only a 12.5% fuel savings. Because of the inverse relation between fuel consumption and fuel economy, it can be shown that when comparing the fuel savings at different incremental fuel economy levels, the ratio of differences in expected fuel consumption increases with the square of the ratio of the respective fuel economy levels. Thus, a consumption-based feebate correctly represents avoided fuel consumption (or CO_2 emissions, for a fixed fuel) over the life of a vehicle.

While a consumption-based feebate is more technically correct from the fuel savings perspective, an mpg-based feebate might be more technology forcing. Giving very large rebates for the most efficient cars may provide an extra stimulus for technical innovation leading towards more rapid progress along the technology frontier. The mpg-based feebate also avoids very large penalties on vehicles like pickup trucks, which would tends to shift the fee burden further towards the domestic manufacturers (this explains why the D3 vs. J5 outcome is less favorable in Table A2 than it is in Table 4). The virtue of familiarity can justify the use of mpg-based feebates for a modest program, such as the one enacted in Maryland. The main goal of this program is revenue generation; since the fee and rebate rates are so low, the technical issues and manufacturer impact issues are moot. The Maryland program also has a consumer information component, but this is unlikely to substantially increase the effect on purchase decisions given the low incentive levels. For a stronger program intended to affect vehicle choice, we recommend consumption-based feebates rather than mpg-based feebates.

Relations between Feebate Parameters

This section presents formulas for the feebates analyzed in this report, discussed feebate rates based on various economic rationales, and examines the relationships among parameters for different feebate schemes. The feebate formula expressed by Equation (1) takes the form

$$F = V(E_0 - E) \qquad (A1)$$

where F is the feebate (fees negative, rebates positive), V is a feebate rate, E is an energy factor, and E_0 is a reference level of the energy factor. Thus, the parameters that determine the structure of a feebate program are the feebate rate, V, and the definition of the energy factor, E. Equation A1 expresses feebates based on fuel consumption, using an energy factor for which "lower is better"--it might more specifically be called an energy-consumption factor or emissions factor (for CO_2 emissions). The feebate rate, V, specifies the value assigned to differences in the energy factor, expressed in dollars per unit energy factor.

For a given fuel produced from a specified resource, the CO_2 emission rate (e.g., grams/km) is equivalent to the fuel consumption rate (e.g., liters per 100 km), since they are in direct proportion to one another. Our CO_2 rate is based on a 12 kg/gallon of full fuel cycle CO_2-equivalent emissions from gasoline (DeLuchi 1991); we also assume a 120,000 mile vehicle lifetime and 20% on-road fuel economy shortfall. The $749 per liters/100 km rate derived from the gas guzzler tax then corresponds to $18.90/(g/km) or $89 per ton of CO_2-equivalent emissions over a vehicle lifetime. The feebate rate can also be expressed as dollars per mpg difference by matching the slope of the curve at 24.6 mpg, which is the intercept of the curve fit. This yields a slope of $291 per mpg, which is shown as the dashed line in Figure 3. The 24.6 mpg intercept of the guzzler tax curve fit is only coincidentally close to the overall light duty vehicle sales-weighted harmonic mean fuel economy of 24.8 mpg, which is the appropriate reference level for a revenue-neutral consumption based feebate.

We constructed our consumption-based energy factor in terms of expected on-road CO_2 emissions. Given an unadjusted EPA compliance fuel economy rating in miles per gallon (MPG) and using the gasoline emissions factor of 12 kg/gal and 20% fuel economy shortfall, the energy factor (with subscript "C" for consumption-based) is defined as

$$E_C = \frac{(12000 g/gal)}{(0.80)MPG(1.609 km/mi)} = \frac{9320.57(mi/gal)(g/km)}{MPG} \qquad (A2)$$

As discussed in the body of this report, our primary rationale for setting a feebate rate is judgement regarding the levels of fees and rebates sufficient to significantly affect market decisions. This resulted in a rate which happened to closely match that of the existing gas guzzler tax. Denoting this rate by V_C, the feebates of Tables 3 and 4 were computed using V_C = $749 per rated (unadjusted) liter/100 km.

A consumption-based feebate rate may be directly related to the value of avoided fuel consumption. If D represents the expected lifetime travel distance (miles) of a vehicle and t represents a unit fuel cost ($/gallon), the undiscounted value of fuel use is

$$V_C = tD \qquad (A3)$$

Assuming such an interpretation with 120,000 miles of lifetime travel and 20% shortfall, solving for t shows that a $749 per cl/km feebate rate corresponds to an undiscounted fuel cost of $1.17/gallon. With a CO_2 emissions factor of 12 kg/gallon (0.0132 tonsCO_2 per gallon) for gasoline, the equivalent feebate rate of $18.90 per (g/km) corresponds to a tax of $89/ton ($CO_2$ mass basis) on expected vehicle lifetime emissions.

Equation A3 can also be used to set a feebate rate based on a given fuel or emissions tax rate. For example, a carbon tax of $25/ton ($CO_2$ mass basis) would imply a tax of $0.33 per gallon of gasoline. The corresponding feebate rate would be $5.32 per (g$CO_2$/km), or somewhat less than one-third of the rate based on an extension of the gas guzzler tax. If desired, feebate rates based on lifetime fuel consumption or emissions could be discounted by a present worth factor. This would tend to lower the rates even further. Further discussion of such economic derivations of feebates is provided by Davis and Gordon (1992).

For a fuel economy (efficiency-) based feebate, the energy factor is simply vehicle fuel economy, M, in mpg. Using the subscript "M" to represent an mpg-based feebate, the formula is

$$F_M = V_M(M - M_0) \qquad (A4)$$

In this case, the value factor V_M has units of $/mpg. The relationship between efficiency-based and consumption-based feebate rates may be obtained by matching their slopes at a common reference level (as shown in Figure 3) or over some range. The efficiency-based feebate rate V_M corresponding to a given consumption-based feebate rate V_C is then given by

$$V_M = V_C / M_0^2 \qquad (A5)$$

Thus, the \$749 per cl/km (\$176,175 per gal/mi) rate derived from a fit to the gas guzzler tax with an intercept of 9.56 cl/km (M_0 = 24.6 mpg, which is slightly below the model year 1990 light duty vehicle average of 25.2 mpg) yields an efficiency-based feebate rate of \$291/mpg. This is the slope of the dashed line shown in Figure 3.

Size-based feebate rates. For a footprint- and CO_2-based feebate, as developed in this report, the energy factor of Equation A1 takes the form

$$E_U = C/U = 1/MU \qquad (A6)$$

where C represents a vehicle's fuel consumption (or CO_2 emissions) rate, M represents fuel economy ($C = 1/M$), and U represents some measure of vehicle size ("utility"). The energy factors for the footprint-normalized feebates described in the text we calculated by using vehicle footprint for U and the same conversion constant as shown in Equation A2. Size-normalized feebates are then determined by the formula

$$F = V_U(\overline{E_U} - E_U) \qquad (A7)$$

where V_U is a size-normalized feebate rate, e.g., in dollars per (g/km m^2), and $\overline{E_U}$ is the reference level of the size-normalized energy factor, e.g., the sales weighted average for a revenue-neutral feebate.

In principle, the size-normalized feebate rate can be determined by multiplying the chosen consumption feebate rate, V_C, by a fleet average value of U:

$$V_U = \overline{U} V_C \qquad (A8)$$

However, the feebate leverage for such a rate will be less than the leverage for non-size-normalized feebates, because the variation of C/U is less than the variation of C among vehicles in the fleet. We therefore increased V_U to achieve the desired leverage of 8% of vehicle price. This was done empirically by scaling up the rate according to the ratio of the mean absolute deviation of the original consumption-based feebate to that of a size-normalized feebate with a rate calculated from Equation A8. The result is the rate of \$124 per (g/km m^2) used for the size-based feebates described in the report. If we had simply assumed the formulation of Equation A7, the same rate could have been determined by a trial-and-error analysis so as to achieve the desired leverage.

Table 1. Model year 1990 Light Duty Vehicle (LDV) Corporate Average Fuel Economy (CAFE) performance by manufacturer.

CAFE Rank	Manufacturer	Total 1990 LDV sales	Car CAFE	Light truck CAFE	LDV CAFE
15	General Motors	4,337,760	27.5	19.6	24.7
17	Ford	2,709,521	26.5	20.0	23.7
16	Chrysler	1,648,822	27.7	21.4	24.0
7	Toyota	975,421	30.8	21.8	28.0
5	Honda	894,186	30.8		30.8
11	Nissan	650,871	28.5	25.3	27.6
10	Mazda	370,893	30.2	24.0	27.9
8	Mitsubishi	221,388	30.4	22.4	28.4
6	Volkswagen	153,861	29.1	20.8	28.6
9	Subaru	143,450	27.8	28.9	27.9
4	Hyundai	113,817	33.3		33.3
18	Isuzu	104,056	33.5	22.2	22.5
12	Volvo	102,037	25.1		25.1
21	Mercedes	57,561	21.4		21.4
19	BMW	56,144	22.2		22.2
1	Suzuki	24,045	46.5	32.6	37.8
2	Daihatsu	19,961	41.0	27.3	34.5
20	Porche	7,013	21.7		21.7
23	Range Rover	4,862		16.3	16.3
22	Fiat	1,906	20.1		20.1
14	Sterling	1,201	24.9		24.9
3	Yugo	1,117	34.0		34.0
13	Peugeot	688	25.1		25.1
	All	12,600,581	28.0	20.7	25.3

Market shares	Car	Light Truck	LDV
All manufacturers	70%	30%	100%
D3 (GM, Ford, Chrysler)	64%	81%	69%
J5 (Toyota, Honda, Nissan, Mazda, Mitsubishi)	29%	15%	25%

Shown here are the CAFE averages for a manufacturer's combined fleet, in contrast to the separate treatment of domestic and import fleets used for CAFE regulations. Therefore, the values shown here are not the same as those used by NHTSA for CAFE compliance purposes.

Source: NHTSA, Summary of fuel economy performance, Docket No. FE-GR-013, National Highway Traffic Safety Administration, Washington, DC, September 1991.

Table 2. U.S. Federal Gas Guzzler Tax

(Section 4064 of Tax Code)

If the fuel economy of the model type in which the automobile falls is:	**The tax is:**
At least 22.5	$ 0
At least 21.5 but less than 22.5	1,000
At least 20.5 but less than 21.5	1,300
At least 19.5 but less than 20.5	1,700
At least 18.5 but less than 19.5	2,100
At least 17.5 but less than 18.5	2,600
At least 16.5 but less than 17.5	3,000
At least 15.5 but less than 16.5	3,700
At least 14.5 but less than 15.5	4,500
At least 13.5 but less than 14.5	5,400
At least 12.5 but less than 13.5	6,400
Less than 12.5	7,700

Fuel economy is the unadjusted, 55% city and 45% highway weighted EPA test ratings, as used for federal compliance purposes. This differs from the fuel economy ratings appearing on a vehicle's sticker and published in the EPA Gas Mileage Guide, which are adjusted downward by an average of 15% to account for congestion and other factors which lower actual on-road fuel economy.

The tax rates shown here took effect on January 1, 1991; they are double the rates that had been in effect prior to that date.

Table 3. **Fuel consumption or CO_2-based feebates for top-selling 1990 light duty vehicles with all classes treated together.**

MAKE	MODEL	CLASS	MPG	Liters /100km	CO_2 g/km	FEEBATE ($)	PRICE CHANGE
Nissan	SENTRA	S	34.8	6.8	268	2,044	-21%
Ford	ESCORT	C	34.4	6.8	271	1,985	-23%
Honda	CIVIC	S	34.3	6.9	272	1,970	-19%
Toyota	COROLLA	S	31.7	7.4	294	1,549	-15%
GM	Geo PRIZM	S	31.4	7.5	297	1,496	-13%
GM	Chev. CAVALIER	C	30.9	7.6	302	1,405	-16%
GM	Pont. GRAND AM	C	30.0	7.8	311	1,234	-10%
Honda	ACCORD	C	29.6	7.9	315	1,155	-8%
Toyota	CAMRY	C	28.9	8.1	323	1,011	-7%
GM	Chev. CORSICA	M	28.3	8.3	329	881	-9%
Ford	PROBE	C	27.5	8.6	339	700	-5%
GM	Olds.CUTLASS CIERA	M	27.0	8.7	345	582	-4%
GM	Buick CENTURY	M	26.9	8.7	346	557	-4%
GM	Pont. GRAND PRIX	M	26.1	9.0	357	357	-2%
GM	Chev. LUMINA	M	26.1	9.0	357	357	-3%
Ford	TEMPO	C	26.0	9.0	358	331	-3%
Ford	TAURUS	M	25.9	9.1	360	305	-2%
GM	Chev. S-10	p	25.7	9.2	363	252	-3%
GM	Buick LESABRE	L	25.0	9.4	373	60	-0%
Chrysler	Dodge CARAVAN	v	24.8	9.5	376	3	-0%
Chrysler	Plym. VOYAGER	v	24.8	9.5	376	3	-0%
Ford	MUSTANG	S	24.3	9.7	384	(143)	1%
Ford	RANGER	p	24.2	9.7	385	(173)	2%
Ford	Linc. TOWN CAR	L	23.0	10.2	405	(553)	2%
GM	Chev. CAPRICE	L	23.0	10.2	405	(553)	3%
GM	Chev. BLAZER S-10	u	22.4	10.5	416	(758)	5%
Ford	BRONCO II/EXPLORER	u	22.0	10.7	424	(901)	6%
GM	Cadi.FLTWD/DEVILLE	L	22.0	10.7	424	(901)	3%
GM	Chev. ASTRO	v	21.5	10.9	434	(1,087)	7%
Chrysler	Jeep CHEROKEE	u	21.2	11.1	440	(1,203)	8%
Ford	AEROSTAR	v	21.1	11.1	442	(1,243)	9%
GM	Chev. C/K-1500	P	17.8	13.2	524	(2,791)	22%
Ford	F150	P	17.7	13.3	527	(2,847)	22%
Ford	F250	P	16.8	14.0	555	(3,380)	26%
Ford	ECONOLINE	V	16.1	14.6	579	(3,836)	28%

The 35 top-selling nameplates, which accounted for 50.3% of light duty vehicle sales in 1990, listed by decreasing sales-weighted fuel economy (MPG, composite 55% city, 45% highway, unadjusted EPA rating) as given by Williams and Hu (1991).

Class codes: C=Compact, L=Large, M=Midsize, S=Subcompact, P/p=Large/Small pickup, U/u=Large/Small utility, V/v=Large/Small van.

Liters/100km is the fuel consumption rate, based on a conversion factor of 235.2 l/100km to 1 MPG.

CO_2 emissions rate is given in grams per kilometer (g/km), based on full fuel cycle emissions of 12 kgCO_2/gallon for gasoline and 20% shortfall.

Feebate is based on a reference CO_2 emissions level of 376 g/km, derived from the sales-weighted harmonic mean fuel economy of 24.8 mpg, and a feebate rate of $18.90 per (g/km).

Price change is ratio of the feebate to the vehicle sales price (nameplate average MSRP, see Table A1).

Table 4. Fuel consumption or CO_2-based feebates, fixed 1990 fleet outcome by manufacturer with all classes treated together.

MANUFACTURER	FLEET MPG	CO_2 (g/km)	DIFFERENCE FROM AVG	NET FEEBATES (Million $)	AVG. PER MODEL ($)
BMW	21.9	425	13%	-53.292	-922
Chrysler	23.8	392	4%	-527.402	-306
Daihatsu	37.8	247	-34%	41.477	2445
Ford	23.0	406	8%	-1834.827	-567
GM	24.3	384	2%	-726.279	-150
Honda	30.4	306	-19%	1121.207	1320
Hyundai	33.3	280	-26%	256.198	1818
Isuzu	22.1	421	12%	-95.067	-851
Jaguar	21.3	438	16%	-22.333	-1165
Mazda	26.9	346	-8%	196.632	562
Mercedes	21.2	439	17%	-74.898	-1192
Mitsubishi	27.7	336	-11%	139.788	746
Nissan	27.3	342	-9%	402.482	651
Porsche	21.9	426	13%	-8.721	-949
Rover	16.0	583	55%	-18.015	-3904
Saab	25.9	360	-4%	7.762	299
Subaru	28.9	323	-14%	108.290	1007
Suzuki	33.0	283	-25%	38.641	1762
Toyota	28.1	331	-12%	880.631	846
VW	28.9	322	-14%	159.569	1011
Volvo	24.6	379	1%	-4.841	-51
Yugo	33.0	282	-25%	12.999	1768
OVERALL	24.8	376		0	1153
D3 (Chyrsler, Ford, General Motors)				-3089	8.0%
J5 (Honda, Mazda, Mitsubishi, Nissan, Toyota)				2741	Leverage

Fleet MPG is the sales-weighted overall light duty fleet fuel economy, based on nameplate-average statistics from Williams and Hu (1991); values may not match those from NHTSA (1991) as given in Table 1.

CO_2 (g/km) is fleet average full fuel cycle CO_2-equivalent emissions, based on a gasoline emission factor of 12 kg/gallon and 20% fuel economy shortfall.

Difference from Average is that of each manufacturer's fleet average fuel consumption (or CO_2 emissions) rate relative to the overall 1990 light duty vehicle average of 9.5 cl/km (376 g/km).

Net Feebates [Fees (-), Rebates (+)] gives a manufacturer's net outcome for the program, assuming a fixed 1990 sales mix and using a feebate rate of $18.90 per g/km (reference level rate of $287/mpg).

Average per Model is the manufacturer's net outcome divided by sales; the overall average per model is the sales-weighted mean absolute value of all feebates.

Table 5. Footprint-normalized consumption feebates for top-selling 1990 light duty vehicles with all classes treated together.

MAKE	MODEL	CLASS	MPG	FtPrnt (m^2)	ENERGY FACTOR	FEEBATE ($)	PRICE CHANGE
Nissan	SENTRA	S	34.8	3.49	76.64	1,948	-20%
Ford	ESCORT	C	34.4	3.59	75.54	2,084	-25%
Honda	CIVIC	S	34.3	3.63	74.83	2,172	-21%
Toyota	COROLLA	S	31.7	3.45	85.34	869	-8%
GM	Geo PRIZM	S	31.4	3.45	86.00	788	-7%
GM	Chev. CAVALIER	C	30.9	3.62	83.39	1,111	-13%
GM	Pont. GRAND AM	C	30.0	3.70	84.07	1,028	-8%
Honda	ACCORD	C	29.6	4.02	78.30	1,742	-12%
Toyota	CAMRY	C	28.9	3.81	84.61	961	-7%
GM	Chev. CORSICA	M	28.3	3.70	89.12	402	-4%
Ford	PROBE	C	27.5	3.67	92.29	9	-0%
GM	Olds.CUTLASS CIERA	M	27.0	3.92	88.10	528	-4%
GM	Buick CENTURY	M	26.9	3.90	88.73	450	-3%
GM	Pont. GRAND PRIX	M	26.1	4.08	87.57	594	-4%
GM	Chev. LUMINA	M	26.1	4.08	87.57	594	-4%
Ford	TEMPO	C	26.0	3.62	98.97	(819)	8%
Ford	TAURUS	M	25.9	4.17	86.27	755	-5%
GM	Chev. S-10	p	25.7	3.76	96.39	(499)	5%
GM	Buick LESABRE	L	25.0	4.29	86.92	673	-4%
Chrysler	Dodge CARAVAN	v	24.8	4.57	82.33	1,243	-9%
Chrysler	Plym. VOYAGER	v	24.8	4.57	82.33	1,243	-8%
Ford	MUSTANG	S	24.3	3.68	104.15	(1,461)	11%
Ford	RANGER	p	24.2	3.83	100.50	(1,009)	9%
Ford	Linc. TOWN CAR	L	23.0	4.77	84.93	921	-3%
GM	Chev. CAPRICE	L	23.0	4.58	88.48	481	-3%
GM	Chev. BLAZER S-10	u	22.4	3.62	114.84	(2,786)	18%
Ford	BRONCO II/EXPLORER	u	22.0	4.00	105.81	(1,667)	12%
GM	Cadi.FLTWD/DEVILLE	L	22.0	4.40	96.26	(483)	1%
GM	Chev. ASTRO	v	21.5	4.65	93.13	(96)	1%
Chrysler	Jeep CHEROKEE	u	21.2	3.78	116.33	(2,970)	20%
Ford	AEROSTAR	v	21.1	4.68	94.32	(243)	2%
GM	Chev. C/K-1500	P	17.8	4.87	107.47	(1,872)	15%
Ford	F150	P	17.7	4.98	105.70	(1,653)	13%
Ford	F250	P	16.8	5.66	97.96	(694)	5%
Ford	ECONOLINE	V	16.1	6.05	95.62	(404)	3%

The 35 top-selling nameplates as listed in Table 3, which gives MPG, class, CO_2 emissions, and price definitions.

Footprint ("FtPrnt") is wheelbase times track width, given in square meters (m^2).

Energy Factor is estimated on-road CO_2 emissions rate divided by footprint, given in units of g/(km m^2); the conversion factor is 9320.57 (mpg g/km).

Feebate is calculated using a reference level energy factor of 92.36 (sales-weighted arithmetic mean of all light duty vehicles) and a feebate rate of $124 per unit difference in energy factor, corresponding to a CO_2-emission based rate of $30.60 per g/km.

Table 6. Footprint-normalized consumption feebates, fixed 1990 fleet outcome by manufacturer with all classes treated together.

MANUFACTURER	FLEET MPG	FOOTPRINT (m^2)	ENERGY FACTOR	DIFF. FROM AVG.	NET FEEBATES (Million $)	AVG. PER MODEL ($)
BMW	21.9	3.96	107	16%	-108.214	-1872
Chrysler	23.8	4.07	96	4%	-872.941	-507
Daihatsu	37.8	3.21	77	-17%	32.851	1937
Ford	23.0	4.32	94	1%	-524.258	-162
GM	24.3	4.13	92	0%	-48.698	-10
Honda	30.4	3.88	79	-15%	1436.636	1691
Hyundai	33.3	3.39	82	-11%	178.012	1263
Isuzu	22.1	3.80	111	20%	-254.460	-2279
Jaguar	21.3	3.88	113	22%	-48.547	-2532
Mazda	26.9	3.75	92	-0%	14.663	42
Mercedes	21.2	4.02	109	18%	-130.270	-2074
Mitsubishi	27.7	3.65	92	-0%	9.374	50
Nissan	27.3	3.71	92	-1%	44.996	73
Porsche	21.9	3.32	129	40%	-41.849	-4554
Rover	16.0	3.81	153	66%	-34.633	-7506
Saab	25.9	3.74	96	4%	-12.638	-486
Subaru	28.9	3.59	90	-3%	35.894	334
Suzuki	33.0	2.97	95	3%	-8.356	-381
Toyota	28.1	3.69	90	-3%	346.147	332
VW	28.9	3.57	90	-2%	42.118	267
Volvo	24.6	3.93	97	5%	-49.045	-521
Yugo	33.0	2.83	100	8%	-6.783	-922
OVERALL	24.8	4.05	92.36		0	1154
D3 (Chyrsler, Ford, General Motors)					-1446	8.0%
J5 (Honda, Mazda, Mitsubishi, Nissan, Toyota)					1852	Leverage

Fleet MPG is as in Table 4.

Footprint is sales-weighted fleet average, in square meters (m^2).

Energy Factor is the fleet average footprint-normalized fuel consumption (or CO_2 emissions) rate, based on sales-weighted energy factors for each model (e.g., as defined in Table 5).

Difference from Average is that of each manufacturer's fleet average energy factor relative to the overall average.

Net Feebates [Fees (-), Rebates (+)] are manufacturers' net outcomes for the program, assuming a fixed 1990 sales mix and using a feebate rate of $124 per g/(km m^2) and reference level of 92.36 g/(km m^2), as in Table 5.

Average per Model is a manufacturer's net outcome divided by sales; the overall average per model is the sales-weighted mean absolute value of all feebates.

Table 7. Footprint-normalized consumption feebates with separate car/truck reference levels for top-selling 1990 light duty vehicles.

MAKE	MODEL	CLASS	MPG	FtPrnt (m^2)	ENERGY FACTOR	FEEBATE ($)	PRICE CHANGE
Nissan	SENTRA	S	34.8	3.49	76.64	1,334	-14%
Ford	ESCORT	C	34.4	3.59	75.54	1,471	-17%
Honda	CIVIC	S	34.3	3.63	74.83	1,558	-15%
Toyota	COROLLA	S	31.7	3.45	85.34	255	-2%
GM	Geo PRIZM	S	31.4	3.45	86.00	173	-2%
GM	Chev. CAVALIER	C	30.9	3.62	83.39	497	-6%
GM	Pont. GRAND AM	C	30.0	3.70	84.07	413	-3%
Honda	ACCORD	C	29.6	4.02	78.30	1,128	-8%
Toyota	CAMRY	C	28.9	3.81	84.61	346	-2%
GM	Chev. CORSICA	M	28.3	3.70	89.12	(213)	2%
Ford	PROBE	C	27.5	3.67	92.29	(606)	5%
GM	Olds.CUTLASS CIERA	M	27.0	3.92	88.10	(86)	1%
GM	Buick CENTURY	M	26.9	3.90	88.73	(165)	1%
GM	Pont. GRAND PRIX	M	26.1	4.08	87.57	(21)	0%
GM	Chev. LUMINA	M	26.1	4.08	87.57	(21)	0%
Ford	TEMPO	C	26.0	3.62	98.97	(1,435)	14%
Ford	TAURUS	M	25.9	4.17	86.27	141	-1%
GM	Chev. S-10	p	25.7	3.76	96.39	755	-8%
GM	Buick LESABRE	L	25.0	4.29	86.92	59	-0%
Chrysler	Dodge CARAVAN	v	24.8	4.57	82.33	2,499	-17%
Chrysler	Plym. VOYAGER	v	24.8	4.57	82.33	2,499	-16%
Ford	MUSTANG	S	24.3	3.68	104.15	(2,077)	15%
Ford	RANGER	p	24.2	3.83	100.50	245	-2%
Ford	Linc. TOWN CAR	L	23.0	4.77	84.93	307	-1%
GM	Chev. CAPRICE	L	23.0	4.58	88.48	(134)	1%
GM	Chev. BLAZER S-10	u	22.4	3.62	114.84	(1,533)	10%
Ford	BRONCO II/EXPLORER	u	22.0	4.00	105.81	(413)	3%
GM	Cadi.FLTWD/DEVILLE	L	22.0	4.40	96.26	(1,098)	3%
GM	Chev. ASTRO	v	21.5	4.65	93.13	1,159	-7%
Chrysler	Jeep CHEROKEE	u	21.2	3.78	116.33	(1,717)	11%
Ford	AEROSTAR	v	21.1	4.68	94.32	1,012	-7%
GM	Chev. C/K-1500	P	17.8	4.87	107.47	(619)	5%
Ford	F150	P	17.7	4.98	105.70	(399)	3%
Ford	F250	P	16.8	5.66	97.96	560	-4%
Ford	ECONOLINE	V	16.1	6.05	95.62	850	-6%

Columns are as defined in Tables 3 and 5.

Feebates calculated using a reference level energy factors of 87.40 g/(km m^2) for cars and 102.48 g/(km m^2) for trucks with a common feebate rate of $124 per g/(km m^2) for both.

Table 8. Footprint-normalized consumption feebates with separate car/truck reference levels, fixed 1990 fleet outcome by manufacturer.

MANUFACTURER	FLEET MPG	FOOTPRINT (m^2)	ENERGY FACTOR	DIFF. FROM AVG.	NET FEEBATES (Million $)	AVG. PER MODEL ($)
(a) CARS:						
BMW	21.9	3.96	107	23%	-143.767	-2487
Chrysler	27.2	3.75	91	4%	-407.169	-481
Daihatsu	43.1	3.21	67	-23%	32.223	2484
Ford	26.3	4.02	88	1%	-157.887	-81
GM	27.1	3.92	87	0%	-5.355	-2
Honda	30.4	3.88	79	-10%	914.167	1076
Hyundai	33.3	3.39	82	-6%	91.330	648
Isuzu	34.5	3.47	78	-11%	5.909	1177
Jaguar	21.3	3.88	113	29%	-60.341	-3147
Mazda	28.9	3.60	90	3%	-67.792	-296
Mercedes	21.2	4.02	109	25%	-168.912	-2689
Mitsubishi	29.4	3.61	88	0%	-7.435	-50
Nissan	28.6	3.69	88	1%	-24.502	-55
Porsche	21.9	3.32	129	48%	-47.502	-5169
Saab	25.9	3.74	96	10%	-28.619	-1101
Subaru	28.9	3.59	90	3%	-30.255	-281
Suzuki	36.7	3.06	83	-5%	3.599	547
Toyota	30.0	3.66	85	-3%	272.459	356
VW	29.4	3.52	90	3%	-51.952	-343
Volvo	24.6	3.93	97	10%	-106.893	-1136
Yugo	33.0	2.83	100	14%	-11.305	-1537
CARS AVERAGE	27.6	3.86	87.40		0	736
(b) LIGHT TRUCKS:						
Chrysler	21.2	4.38	101	-1%	113.076	129
Daihatsu	27.0	3.22	107	5%	-2.340	-586
Ford	19.3	4.75	102	-0%	68.045	52
GM	20.0	4.55	103	0%	-63.429	-40
Isuzu	21.8	3.82	112	10%	-129.693	-1216
Mazda	23.9	4.05	96	-6%	93.186	772
Mitsubishi	22.7	3.80	108	5%	-25.514	-654
Nissan	24.3	3.76	102	-1%	14.352	83
Rover	16.0	3.81	153	49%	-28.849	-6252
Suzuki	31.6	2.94	101	-2%	3.251	212
Toyota	23.9	3.76	104	1%	-50.778	-184
VW	21.1	4.84	91	-11%	8.692	1390
TRUCKS AVERAGE	20.5	4.45	102.48		0	1180

(c) Net outcomes for D3 and J5 fleets (Million $):	CARS	TRUCKS	BOTH
D3 (Chyrsler, Ford, General Motors)	-570	118	-452
J5 (Honda, Mazda, Mitsubishi, Nissan, Toyota)	1087	31	1118

Columns are as defined in Table 6, using a common feebate rate of $124 per g/(km m²) for both cars and trucks, but with separate reference levels equal to their respective average energy factors.

Table 9. Volume-normalized consumption feebates for cars only, outcome by manufacturer for 1990 models.

MANUFACTURER	FLEET MPG	VOLUME ft^3	VAFE ft^3mpg	ENERGY FACTOR	DIFF. FROM AVG.	FEEBATES (M$)	AVG. PER MODEL ($)
BMW	21.9	88.5	1941	115	30%	-191.505	-3313
Chrysler	27.2	92.4	2523	89	1%	-79.195	-94
Daihatsu	43.1	80.0	3448	65	-27%	37.892	2921
Ford	26.3	96.7	2569	88	-1%	113.835	59
GM	27.1	95.5	2623	87	-2%	645.823	198
Honda	30.4	87.0	2664	85	-4%	363.662	428
Hyundai	33.3	86.9	2909	77	-13%	200.275	1421
Isuzu	34.5	80.6	2809	80	-9%	4.921	980
Jaguar	21.3	93.0	1981	112	28%	-57.824	-3015
Mazda	28.9	85.2	2482	97	10%	-254.840	-1114
Mercedes	21.2	91.2	1954	115	30%	-208.520	-3319
Mitsubishi	29.4	86.9	2561	87	-1%	14.846	100
Nissan	28.6	86.1	2530	93	6%	-279.048	-628
Porsche	21.9	59.3	1305	173	97%	-97.426	-10601
Saab	25.9	93.5	2417	92	5%	-13.113	-505
Subaru	28.9	87.6	2557	88	-0%	4.916	46
Suzuki	36.7	82.0	3009	74	-16%	11.543	1753
Toyota	30.0	83.3	2519	89	1%	-106.183	-139
VW	29.4	86.1	2547	88	0%	-0.299	-2
Volvo	24.6	92.5	2279	98	11%	-113.200	-1204
Yugo	33.0	80.0	2640	84	-4%	3.442	468
CARS AVERAGE	27.6	92.2	2577	88.10		0	995
D3 (Chyrsler, Ford, General Motors)						680	6.6%
J5 (Honda, Mazda, Mitsubishi, Nissan, Toyota)						-262	Leverage

Fleet MPG is as in Table 5.

Volume is sales-weighted arithmetic mean passenger interior volume, in cubic feet (ft^3).

VAFE (Volume Averaged Fuel Economy) is sales-weighted arithmetic mean of the volume-fuel economy product for each car (given in Table 9 for top-selling cars).

Energy Factor is average volume-normalized CO_2 emissions, scaled by the 1990 average car passenger volume-to-footprint ratio of 23.9 ft^3/m^2.

Difference from Average is that of each manufacturer's energy factor relative to the overall average (reference level) of 88.10 g/(km m^2) [scaled].

Net Feebates [Fees (-), Rebates (+)] gives a manufacturer's net outcome for cars, assuming a fixed 1990 sales mix and a feebate rate of $124 per unit difference in the energy factor [scaled g/(km m^2)] from the reference level.

Average per Model is the manufacturer's net outcome divided by sales; the overall average per model is the sales-weighted mean absolute value of all feebates.

Table 10. Hybrid feebates, based on fuel consumption normalized by volume for cars and footprint for light trucks, for top-selling 1990 light duty vehicles.

MAKE	MODEL	CLASS	MPG	FtPrnt (m^2)	Volume (ft^3)	ENERGY FACTOR	FEEBATE ($)	PRICE CHANGE
Nissan	SENTRA	S	34.8	3.49	88	72.70	1,910	-20%
Ford	ESCORT	C	34.4	3.59	85	76.14	1,483	-17%
Honda	CIVIC	S	34.3	3.63	87	74.61	1,673	-16%
Toyota	COROLLA	S	31.7	3.45	80	87.79	39	-0%
GM	Geo PRIZM	S	31.4	3.45	83	85.42	332	-3%
GM	Chev. CAVALIER	C	30.9	3.62	87	82.81	655	-8%
GM	Pont. GRAND AM	C	30.0	3.70	91	81.55	812	-6%
Honda	ACCORD	C	29.6	4.02	92	81.75	787	-5%
Toyota	CAMRY	C	28.9	3.81	89	86.56	191	-1%
GM	Chev. CORSICA	M	28.3	3.70	95	82.81	656	-7%
Ford	PROBE	C	27.5	3.67	91	88.96	(107)	1%
GM	Olds.CUTLASS CIERA	M	27.0	3.92	97	85.01	384	-3%
GM	Buick CENTURY	M	26.9	3.90	98	84.45	452	-3%
GM	Pont. GRAND PRIX	M	26.1	4.08	98	87.04	131	-1%
GM	Chev. LUMINA	M	26.1	4.08	98	87.04	131	-1%
Ford	TEMPO	C	26.0	3.62	90	95.14	(873)	8%
Ford	TAURUS	M	25.9	4.17	100	85.96	266	-2%
GM	Chev. S-10	p	25.7	3.76		96.39	755	-8%
GM	Buick LESABRE	L	25.0	4.29	106	84.01	507	-3%
Chrysler	Dodge CARAVAN	v	24.8	4.57		82.33	2,499	-17%
Chrysler	Plym. VOYAGER	v	24.8	4.57		82.33	2,499	-16%
Ford	MUSTANG	S	24.3	3.68	83	110.38	(2,763)	20%
Ford	RANGER	p	24.2	3.83		100.50	245	-2%
Ford	Linc. TOWN CAR	L	23.0	4.77	118	82.03	753	-2%
GM	Chev. CAPRICE	L	23.0	4.58	110	88.00	13	-0%
GM	Chev. BLAZER S-10	u	22.4	3.62		114.84	(1,533)	10%
Ford	BRONCO II/EXPLORER	u	22.0	4.00		105.81	(413)	3%
GM	Cadi.FLTWD/DEVILLE	L	22.0	4.40	111	91.17	(380)	1%
GM	Chev. ASTRO	v	21.5	4.65		93.13	1,159	-7%
Chrysler	Jeep CHEROKEE	u	21.2	3.78		116.33	(1,717)	11%
Ford	AEROSTAR	v	21.1	4.68		94.32	1,012	-7%
GM	Chev. C/K-1500	P	17.8	4.87		107.47	(619)	5%
Ford	F150	P	17.7	4.98		105.70	(399)	3%
Ford	F250	P	16.8	5.66		97.96	560	-4%
Ford	ECONOLINE	V	16.1	6.05		95.62	850	-6%

The 35 top-selling nameplates listed as in Tables 3 and 5, which give definitions for class, MPG, footprint, and price change.

Volume is passenger interior volume for cars, in cubic feet (ft^3) as given in the 1990 EPA Gas Mileage Guide; it is undefined for light trucks.

Energy Factor is: for cars, volume-normalized CO_2 emissions, computed by dividing the ft^3mpg product into 9320.57 (mpg g/km) and scaling the result by the 1990 average car passenger volume-to-footprint ratio of 23.9 ft^3/m^2; for trucks, the same as in Tables 5 and 7.

Feebates computed using reference levels of 88.10 g/(km m^2) [scaled] for cars and 102.48 g/(km m^2) for light trucks, with a common feebate rate of $124 per g/(km m^2) for both.

Table 11. Hybrid feebates, based on fuel consumption normalized by volume for cars and footprint for light trucks, fixed 1990 fleet outcome by manufacturer.

Net Fees (-) or Rebates (+) for Model Year, Million $

MANUFACTURER	CARS	LIGHT TRUCKS	ALL LIGHT VEHICLES
BMW	-191.505		-191.505
Chrysler	-79.195	113.076	33.881
Daihatsu	37.892	-2.340	35.552
Ford	113.835	68.045	181.880
GM	645.823	-63.429	582.394
Honda	363.662		363.662
Hyundai	200.275		200.275
Isuzu	4.921	-129.693	-124.772
Jaguar	-57.824		-57.824
Mazda	-254.840	93.186	-161.654
Mercedes	-208.520		-208.520
Mitsubishi	14.846	-25.514	-10.668
Nissan	-279.048	14.352	-264.696
Porsche	-97.426		-97.426
Rover		-28.849	-28.849
Saab	-13.113		-13.113
Subaru	4.916		4.916
Suzuki	11.543	3.251	14.794
Toyota	-106.183	-50.778	-156.961
VW	-0.299	8.692	8.393
Volvo	-113.200		-113.200
Yugo	3.442		3.442
D3	680	118	798
J5	-262	31	-231

D3 manufacturers are Chrysler, Ford, and General Motors.
J5 manufacturers are Honda, Mazda, Mitsubishi, Nissan, and Toyota.

Feebate as in Table 10 with manufacturer outcomes from Table 9 for cars and Table 8(b) for light trucks.

Car feebates are based on volume-normalized CO_2 emissions, computed by dividing the ft^3mpg product into 9320.57 (mpg g/km), scaling the result by the volume-to-footprint ratio of 23.9 ft^3/m^2, and using a reference level of 88.10 g/(km m^2) with a feebate rate of $124 per g/(km m^2).

Light truck feebates are based on footprint-normalized CO_2 emissions, computed by dividing the m^2mpg product into 9320.57 (mpg g/km) and using a reference level of 102.48 g/(km m^2) with a feebate rate of $124 per g/(km m^2).

Table 12. Hybrid feebates for selected configurations of 1990 models, based on fuel consumption normalized by volume for cars and footprint for light trucks.

Make Division MODEL / Class	Engine liter	cyl	Trans/ drive	Sticker MPG CITY	HIWY	Comp. MPG	Size	ENERGY FACTOR	FEEBATE $
GM Geo	1.6	4	M5	28	34	35	83	76.64	1,421
PRIZM	1.6	4	M5	25	31	32	83	83.82	530
Subcompact	1.6	4	L4	23	30	31	83	86.53	195
FORD	1.9	4	M4	32	42	42	85	62.36	3,192
ESCORT	1.9	4	M5	27	36	36	85	72.76	1,903
Compact	1.9	4	A3	27	31	34	85	77.04	1,372
	1.9	4	M5	24	30	31	85	84.49	448
GM Buick	2.5	4	L3	23	31	30	98	75.72	1,535
CENTURY	3.3	6	L4	20	29	27	98	84.14	491
Midsize	3.3	6	L3	20	27	26	98	87.37	90
Ford	3.0	6	L4	20	29	27	100	82.46	700
TAURUS	2.5	4	A3	20	26	26	100	85.63	307
Midsize	3.8	6	L4	19	28	25	100	89.05	(118)
	3.0	6	M5	18	27	24	100	92.76	(578)
Chrysler Dodge	2.5	4	M5	22	28	28	4.57	72.84	3,675
CARAVAN	2.5	4	L3	21	23	26	4.57	78.44	2,981
Small van	3.0	6	L4	19	24	25	4.57	81.58	2,592
	2.5	4	A3	19	23	24	4.57	84.98	2,170
	3.3	6	L4	18	24	24	4.57	84.98	2,170
GM Chevrolet	2.5	4	L4	21	27	28	3.76	88.53	1,730
S10 PICKUP	2.5	4	M5	23	27	29	3.76	85.48	2,108
Small pickup	2.8	6	M5	19	26	25	3.76	99.15	412
	4.3	6	L4	18	23	23	3.76	107.78	(657)
	4.3	6	M5	17	23	23	3.76	107.78	(657)
Chrysler Jeep	2.5	4	M5 4wd	21	24	26	3.78	94.84	948
CHEROKEE	2.5	4	M5	21	24	26	3.78	94.84	948
Small utility	2.5	4	M5 4wd	19	24	24	3.78	102.74	(32)
	2.5	4	L4 4wd	18	23	23	3.78	107.21	(586)
	4.0	6	M5 4wd	17	22	22	3.78	112.08	(1,190)
	4.0	6	L4 4wd	16	20	21	3.78	117.42	(1,852)
Ford	4.9	6	M5	16	20	21	4.98	89.12	1,656
F150 PICKUP	4.9	6	L4	15	20	20	4.98	93.58	1,104
Large pickup	4.9	6	L4 4wd	14	18	19	4.98	98.51	493
	4.9	8	L4	14	18	18	4.98	103.98	(186)
	4.9	6	A3 4wd	14	16	17	4.98	110.09	(944)
	5.8	8	L4	12	16	16	4.98	116.97	(1,797)
	4.9	8	A3 4wd	13	13	15	4.98	124.77	(2,764)
	5.8	8	L4 4wd	11	16	15	4.98	124.77	(2,764)

Configuration information is from the EPA 1990 Gas Mileage Guide: engine displacement in liters; number of cylinders; transmission type (A for conventional automatic, L for lockup automatic, M for manual, with number of speeds); drive is 2-wheel drive unless otherwise specified as 4wd.

Fuel economy information is also from the Gas Mileage Guide; sticker (adjusted) city and highway ratings are given followed by the compliance (weighted average unadjusted) rating.

Size is passenger volume (ft^3) for cars and footprint (m^2) for light trucks. Lacking size information by Gas Mileage Guide configuration, nameplate averages are used for all configurations even though actual sizes may vary.

Energy Factors and Feebates are calculated as specified in Table 10.

Table 13. A sampling of automobile manufacturer sales rebates.

MAKE	MODEL	Rebate	Price	Rebate /Price Ratio
Buick	LeSabre	$ 250-1000	$ 17080-18430	3.5%
Dodge	Colt Vista	500-700	11941-13167	4.8%
Subaru	Loyale	500	9500-11300	4.8%
Dodge	Ram pickup	500	7787-12885	4.8%
Chevy	Geo Metro	400	6795-9740	4.8%
Olds	Cutlass sup	1000	14995-20995	5.6%
Pontiac	Grand Am	750	10174-16544	5.6%
Mercury	Sable	750-1250	15821-17794	6.0%
Ford	Taurus	750-1250	13352-18963	6.2%
Chrysler	LeBaron	1000	13160-18955	6.2%
Cadillac	DeVille	2000	30205-33455	6.3%
Lincoln	Town Car	2000	28581-33627	6.4%
Chevy	Lumina	1000	12670-17275	6.7%
Ford	Escort	500-750	7976-11484	6.9%
Pontiac	Bonneville	1500	16834-25264	7.1%
Chrysler	Fifth Ave.	1500	20875	7.2%
Mazda	Six-two-six	1000	12009-15729	7.2%
Ford	Probe	1000	11681-14964	7.5%
Subaru	Legacy	1200	12600-19000	7.6%
Jeep	Cherokee	1500	13822-25231	7.7%
Mazda	Protege	800	9359-11239	7.8%
Buick	Riviera	2000	24560	8.1%
Hyundai	Scoupe	750	8395-9745	8.3%
Hyundai	Sonata	1000	10700-13250	8.4%
Olds	Ninety-eight	1500	17095-18795	8.4%
Mercury	Topaz	1000	10448-13008	8.5%
Mitsubishi	Mirage	750	7029-10509	8.6%
Chevy	Geo Prizm	1000	9680-12695	8.9%
Hyundai	Excel	500-1000	6275-8895	9.9%
Dodge	Dynasty	1500	13625-15065	10.5%
Plymouth	Sundance	1000	7600-10495	11.1%
Ford	Aerostar	1000-2000	12520-14376	11.2%
Plymouth	Acclaim	1500	10805-14360	11.9%
Sample median (not sales weighted):				7.2%

Rebate is given as the range of customer rebates listed in the "Incentives Watch" feature of Automotive News, p. 42, Sept. 25, 1991.

Price is given as the range of model year 1991 new vehicle list prices from "1992 Used Car Prices", Pace Publications, Inc., 1992. These prices do not include optional equipment and destination charges.

Rebate/Price ratio is average rebate divided by average list price, with averages computed as the arithmetic mean of the rebate or price values shown (i.e., the mid-range value).

Table 14. California DRIVE+ outcome by manufacturer based on 1988 sales data.

Manufacturer	Change in Sales	Net Feebates ($)
Alfa Romeo	- 1%	-2,934
AMC	4%	222,435
Audi	- 1%	-56,185
BMW	- 1%	-1,756,342
Chrysler	2%	1,252,334
Daihatsu	44%	1,708,080
Ford	- 3%	-18,713,139
Fuji Motors	- 2%	-127,392
General Motors	0%	-13,479,519
Honda	1%	2,014,718
Hyundai	22%	19,567,413
Isuzu	7%	471,069
Jaguar	0%	473,248
Mazda	- 5%	-3,555,147
Mercedes Benz	- 1%	-1,086,811
Mitsubishi	13%	3,005,573
Nissan	- 12%	-4,759,996
Peugeot	0%	7,019
Porsche	- 1%	-271,976
Renault	- 3%	-209,303
Saab	- 1%	-282,348
Suzuki	28%	2,359,819
Toyota	4%	11,092,735
Volkswagen	14%	3,160,743
Volvo	- 1%	-1,154,357
Yugo	- 24%	-482,258
D3 (GM, Ford, Chrysler/AMC)		-30,717,889
J5 (Toyota, Honda, Nissan, Mazda, Mitsubishi)		7,797,883

Source: Gordon and Levenson (1989), Table 4, "DRIVE+ program simulated short-term total sales shifts for each manufacturer."

Table 15. Leverage values implied by various rationales for setting the feebate rate

Rationale	Equivalent $/gallon	Implied Leverage
Gas Guzzler Tax extension:	1.17	8%
Manufacturer sales rebates:	1.05	7%
Externalities:		
per $1/gal valuation	1.00	6.8%
$25/ton CO_2 tax	0.33	2.3%
CA DRIVE+	0.13	0.9%
Technology cost:		
Ross *et al.* (1991)	0.30	2%
Greene and Duleep (1992)	0.71	5%
SRI (1992)	2.00+	13%

Equivalent dollars per gallon price is based on undiscounted lifetime fuel consumption, assuming 120,000 miles and a 20% shortfall between rated and on-road fuel economy.

Leverage is the sales-weighted mean absolute value of fees and rebates.

Table A1. Fuel economy and MPG-based feebates for top-selling 1990 light duty vehicles.

MAKE	MODEL	CLASS	MPG	PRICE ($)	FEEBATE ($)	PRICE CHANGE
Nissan	SENTRA	S	34.8	9,700	2,670	-28%
Ford	ESCORT	C	34.4	8,500	2,550	-30%
Honda	CIVIC	S	34.3	10,300	2,520	-24%
Toyota	COROLLA	S	31.7	10,500	1,740	-17%
GM	Geo PRIZM	S	31.4	11,200	1,650	-15%
GM	Chev. CAVALIER	C	30.9	8,600	1,500	-17%
GM	Pont. GRAND AM	C	30.0	12,800	1,230	-10%
Honda	ACCORD	C	29.6	14,800	1,110	-8%
Toyota	CAMRY	C	28.9	14,500	900	-6%
GM	Chev. CORSICA	M	28.3	9,900	720	-7%
Ford	PROBE	C	27.5	13,000	480	-4%
GM	Olds.CUTLASS CIERA	M	27.0	13,400	330	-2%
GM	Buick CENTURY	M	26.9	14,100	300	-2%
GM	Pont. GRAND PRIX	M	26.1	16,100	60	-0%
GM	Chev. LUMINA	M	26.1	13,200	60	-0%
Ford	TEMPO	C	26.0	10,300	30	-0%
Ford	TAURUS	M	25.9	14,700	0	0%
GM	Chev. S-10	p	25.7	9,300	(60)	1%
GM	Buick LESABRE	L	25.0	17,300	(270)	2%
Chrysler	Dodge CARAVAN	v	24.8	14,500	(330)	2%
Chrysler	Plym. VOYAGER	v	24.8	15,400	(330)	2%
Ford	MUSTANG	S	24.3	13,500	(480)	4%
Ford	RANGER	p	24.2	11,100	(510)	5%
Ford	Linc. TOWN CAR	L	23.0	30,700	(870)	3%
GM	Chev. CAPRICE	L	23.0	16,700	(870)	5%
GM	Chev. BLAZER S-10	u	22.4	15,300	(1,050)	7%
Ford	BRONCO II/EXPLORER	u	22.0	13,900	(1,170)	8%
GM	Cadi.FLTWD/DEVILLE	L	22.0	32,400	(1,170)	4%
GM	Chev. ASTRO	v	21.5	15,700	(1,320)	8%
Chrysler	Jeep CHEROKEE	u	21.2	15,100	(1,410)	9%
Ford	AEROSTAR	v	21.1	13,700	(1,440)	11%
GM	Chev. C/K-1500	P	17.8	12,500	(2,430)	19%
Ford	F150	P	17.7	12,700	(2,460)	19%
Ford	F250	P	16.8	13,000	(2,730)	21%
Ford	ECONOLINE	V	16.1	13,900	(2,940)	21%

The 35 top-selling nameplates, listed here by decreasing MPG, accounted for 50.3% of light duty vehicle sales in 1990.

Class codes: C=Compact, L=Large, M=Midsize, S=Subcompact, P/p=Large/Small pickup, U/u=Large/Small utility, V/v=Large/Small van.

MPG is the sales-weighted fuel economy, given as the 55% city, 45% highway, unadjusted EPA rating, from Williams and Hu (1991).

Prices are estimated as medians of base price (MSRP) for the nameplate configurations listed in the Automotive News 1990 Market Data Book.

Feebate is based on a reference level of 25.9 mpg (sales-weighted arithmetic mean) and a feebate rate of $300/mpg.

Price change is the effect of the feebate, based on its ratio to the base vehicle sales price.

Table A2. MPG-based feebates outcome by manufacturer, uniform program for all 1990 light duty vehicles.

MANUFACTURER	FLEET MPG	DIFFERENCE FROM AVG.	NET FEEBATES (Million $)	AVG. PER MODEL ($)
BMW	21.9	-15%	-66.215	-1146
Chrysler	23.8	-5%	-683.453	-397
Daihatsu	37.8	52%	68.310	4027
Ford	23.0	-7%	-1822.701	-563
GM	24.3	-2%	-765.337	-158
Honda	30.4	19%	1280.886	1508
Hyundai	33.3	30%	333.775	2368
Isuzu	22.1	-13%	-108.453	-971
Jaguar	21.3	-18%	-26.387	-1376
Mazda	26.9	6%	157.250	450
Mercedes	21.2	-17%	-83.297	-1326
Mitsubishi	27.7	9%	127.628	681
Nissan	27.3	8%	403.750	653
Porsche	21.9	-15%	-10.782	-1173
Rover	16.0	-38%	-13.685	-2966
Saab	25.9	0%	0.326	13
Subaru	28.9	13%	112.071	1042
Suzuki	33.0	28%	47.832	2181
Toyota	28.1	11%	905.171	869
VW	28.9	13%	162.694	1031
Volvo	24.6	-5%	-35.072	-373
Yugo	33.0	27%	15.691	2134
OVERALL	24.8		0	1211
D3 (Chyrsler, Ford, General Motors)			-3271	
J5 (Honda, Mazda, Mitsubishi, Nissan, Toyota)			2875	

Fleet MPG is the sales-weighted overall light duty fleet fuel economy, based on nameplate-average statistics from Williams and Hu (1991); values may not match those from NHTSA (1991) as given in Table 1.

Difference from Average is that of each manufacturer's fleet MPG relative to the overall average (24.8 mpg).

Net Feebates [Fees (-), Rebates (+)] gives a manufacturer's net outcome for the program, assuming a fixed 1990 sales mix and using a feebate rate of $300/mpg with a reference level of 25.9 mpg (the sales-weighted arithmetic mean, which insures revenue neutrality for an MPG-based system).

Average per Model is the manufacturer's net outcome divided by sales; the overall average per model is the sales-weighted mean absolute value of all feebates.

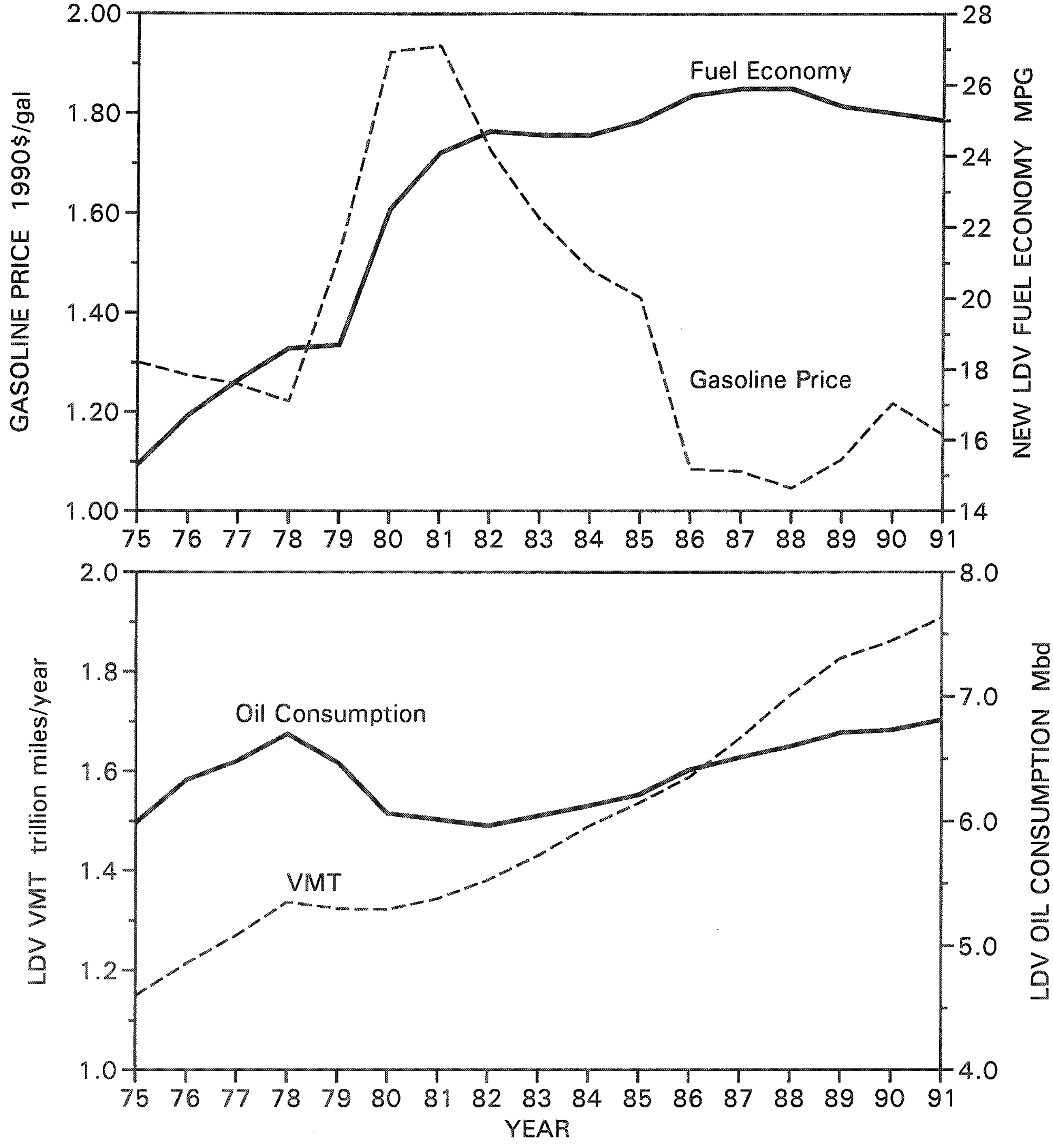


Figure 1. **Gasoline price, new vehicle fuel economy, VMT, and fuel consumption by light duty vehicles, 1975-1991.**

Gasoline prices are from EIA (1991); fuel economy is the new light duty vehicle average from Heavenrich *et al.* (1991); VMT is from FHWA (1991); oil (gasoline) consumption is based on Davis and Hu (1991), extrapolated for 1989-91 based on MPG and VMT trends.

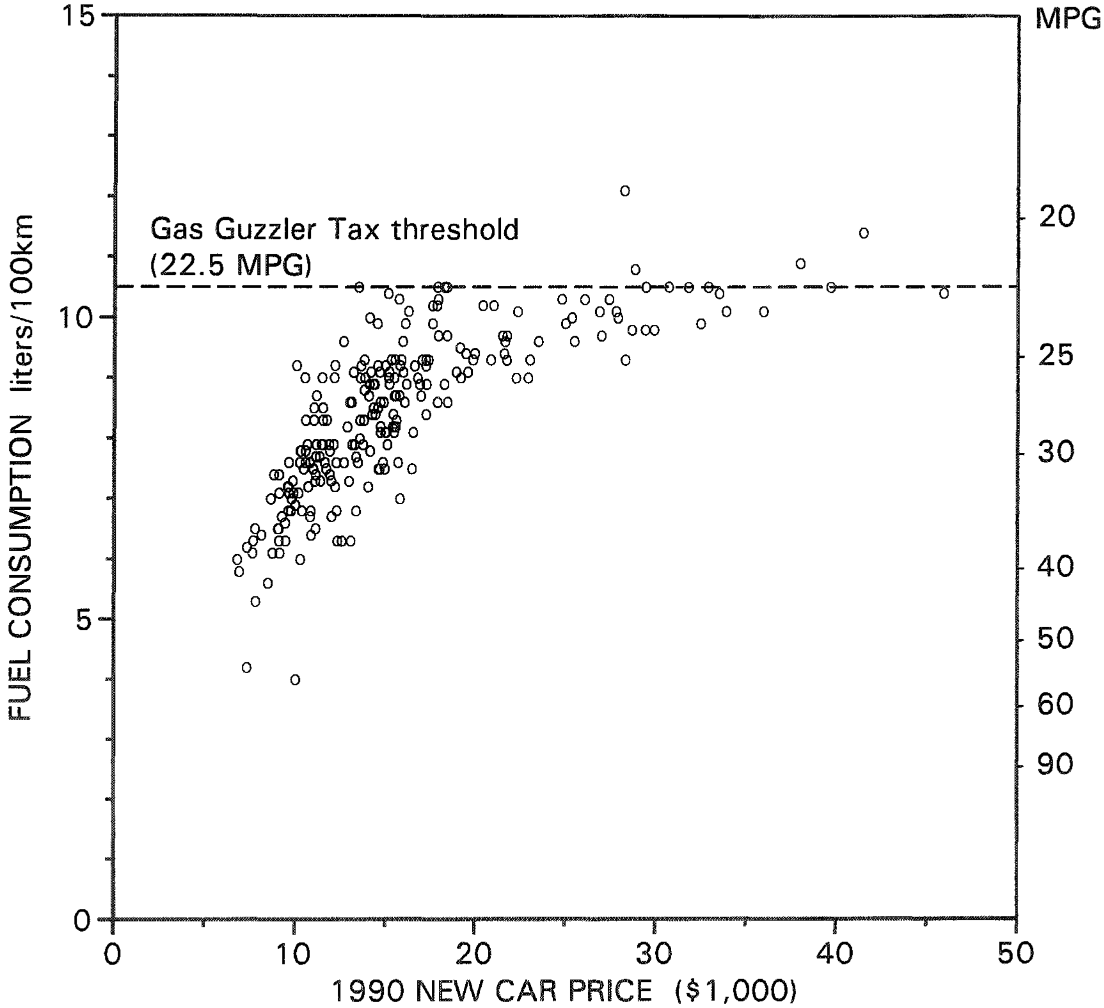


Figure 2. Fuel consumption versus price for 1990 new cars

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 (1991). The estimated average price of 1990 new light trucks was $13,200 and the overall 1990 light duty vehicle average was $14,500.

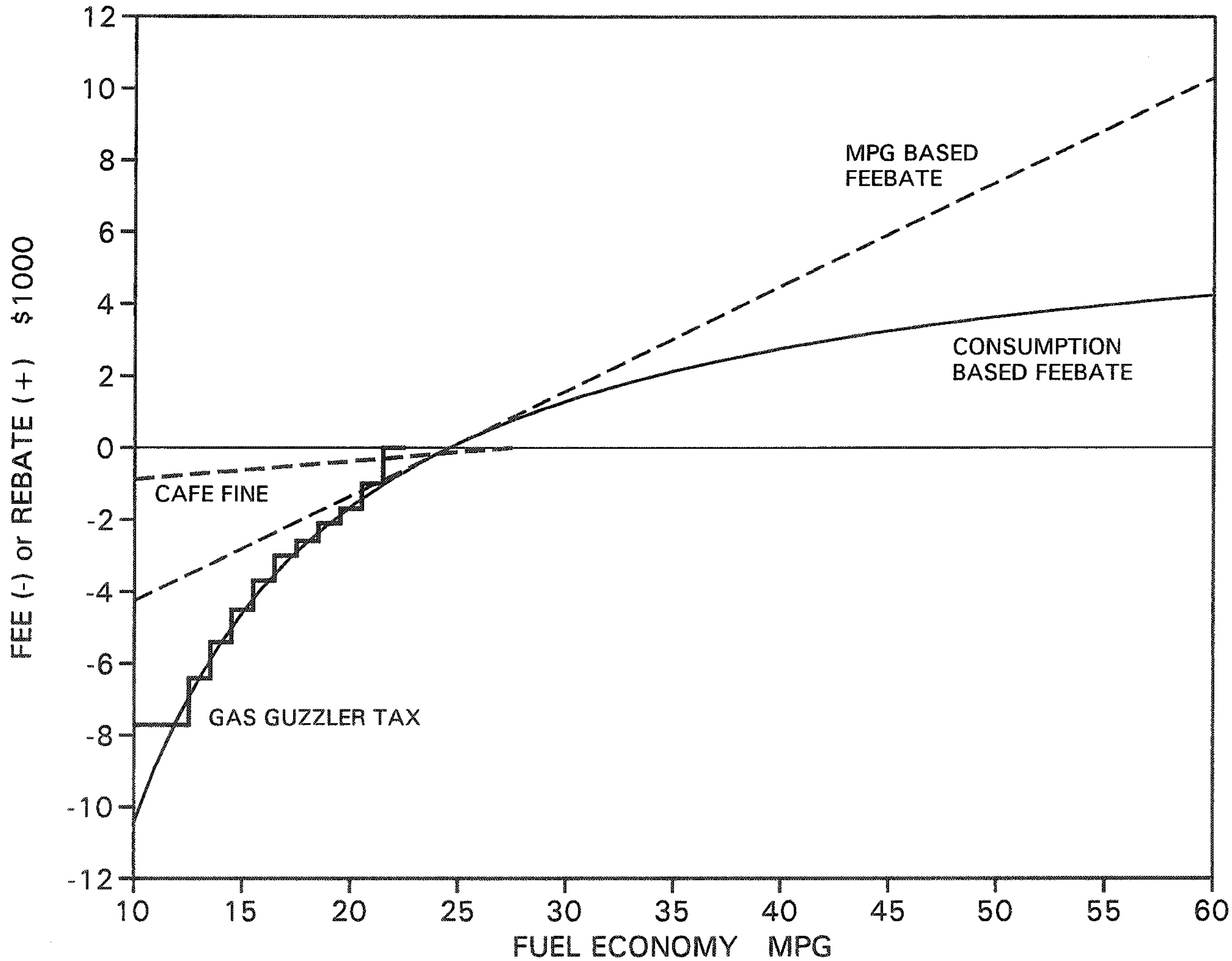


Figure 3. Fee and rebate levels extrapolated from the federal gas guzzler tax

The U.S. federal gas guzzler tax schedule, which applies only to passenger automobiles, is shown as the step function. The threshold for the gas guzzler tax is 22.5 mpg; below that level, the tax increases in 1 mpg steps to a maximum of $7700 for vehicles rated below 12.5 mpg.

The consumption-based feebate (solid curve) is based on a fit to the gas guzzler tax, which indicates a slope of $749 per liter/100km ($1.17 per gallon of undiscounted 120,000-mile vehicle lifetime fuel consumption) and an intercept of 9.56 liters/100km (24.6 mpg; the 1991 overall light duty fleet average was 25.0 mpg; fit $r^2 = 0.997$).

The mpg-based feebate (longer dashed line) is tangent to the consumption-based feebate curve at the zero-feebate intercept of 24.6 mpg. The slope of the line is $291/mpg, corresponding to the slope of the consumption-based feebate curve at the point of intercept, which is also taken as the feebate reference level.

The CAFE fine rate ($5/mpg) is shown as the shallow dashed line, relative to the 1991 CAFE standard of 27.5 mpg for automobiles. The fine applies to a manufacturer's fleet as a whole, rather than to individual vehicles, based on the extent to which the fleet average falls below the standard.

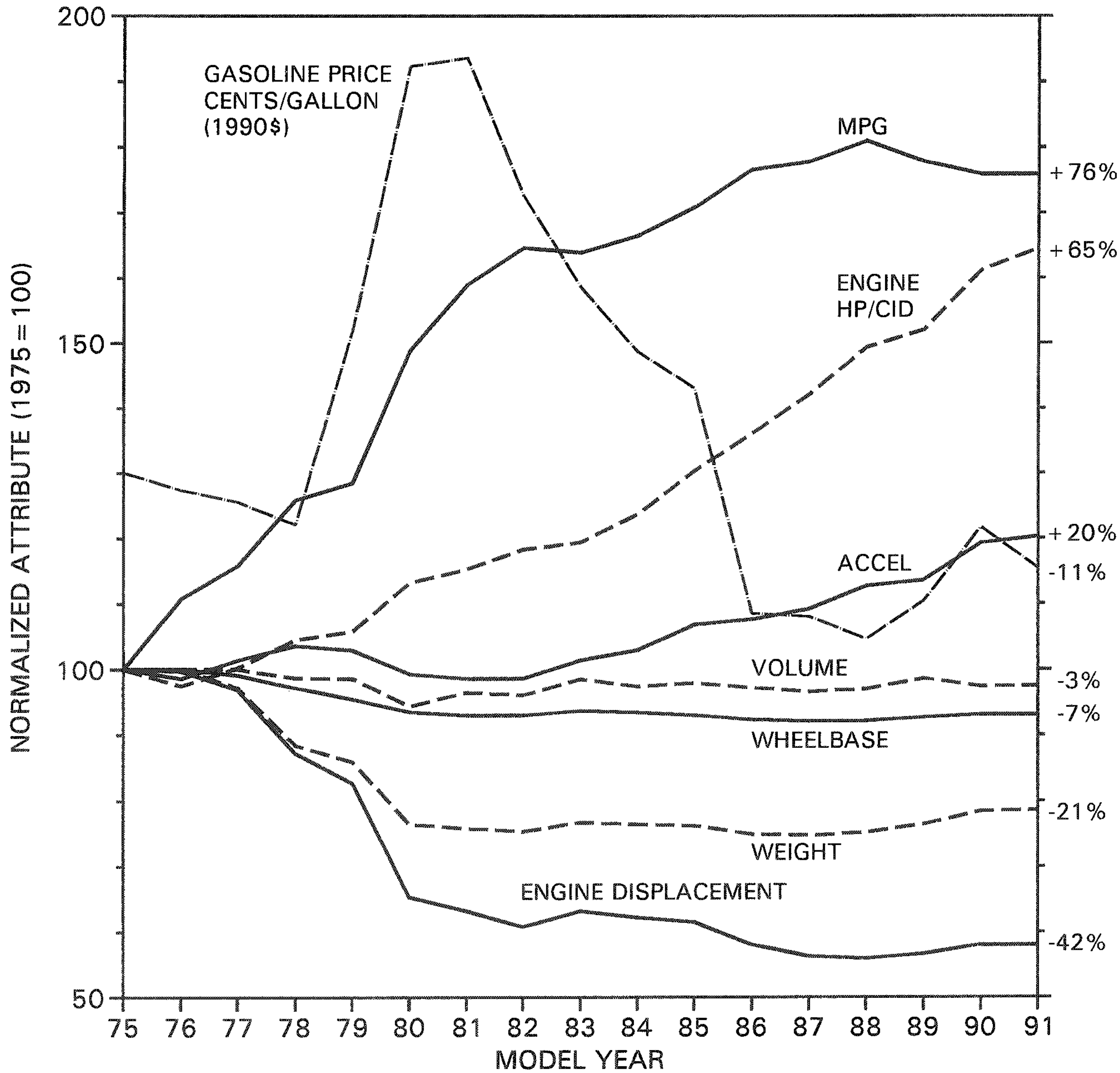


Figure 4. Trends in fuel economy related attributes of new cars

Statistics from Heavenrich *et al.* (1991), except wheelbase from Williams and Hu (1991) and gasoline price from EIA (1991). "ACCEL" is inverse of 0-60 mph acceleration time; "HP/CID" is engine power to displacement ratio.

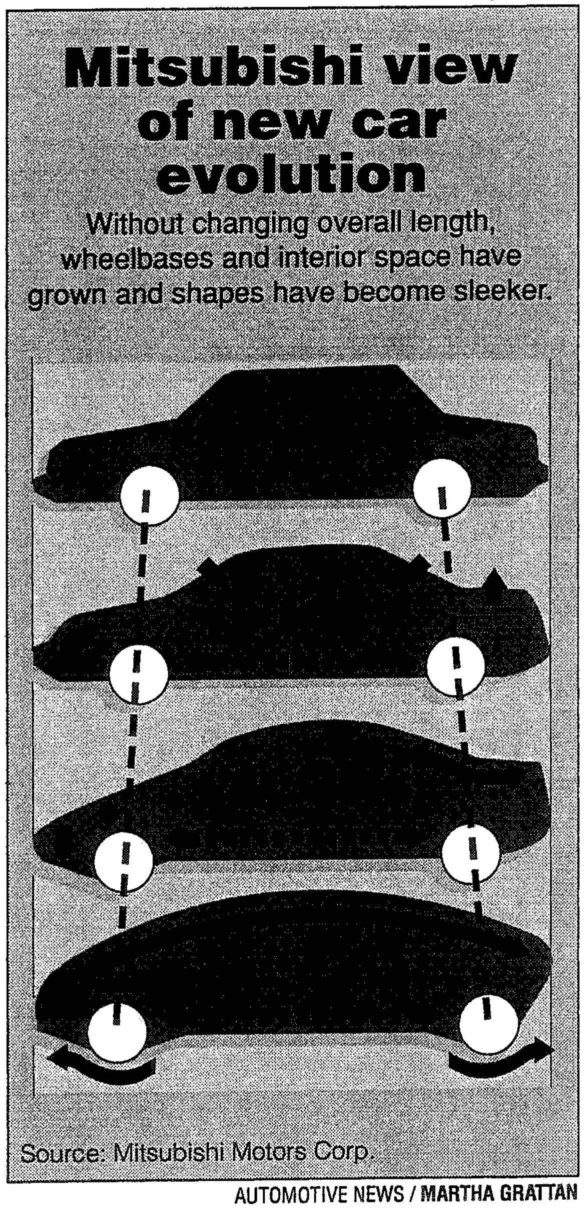
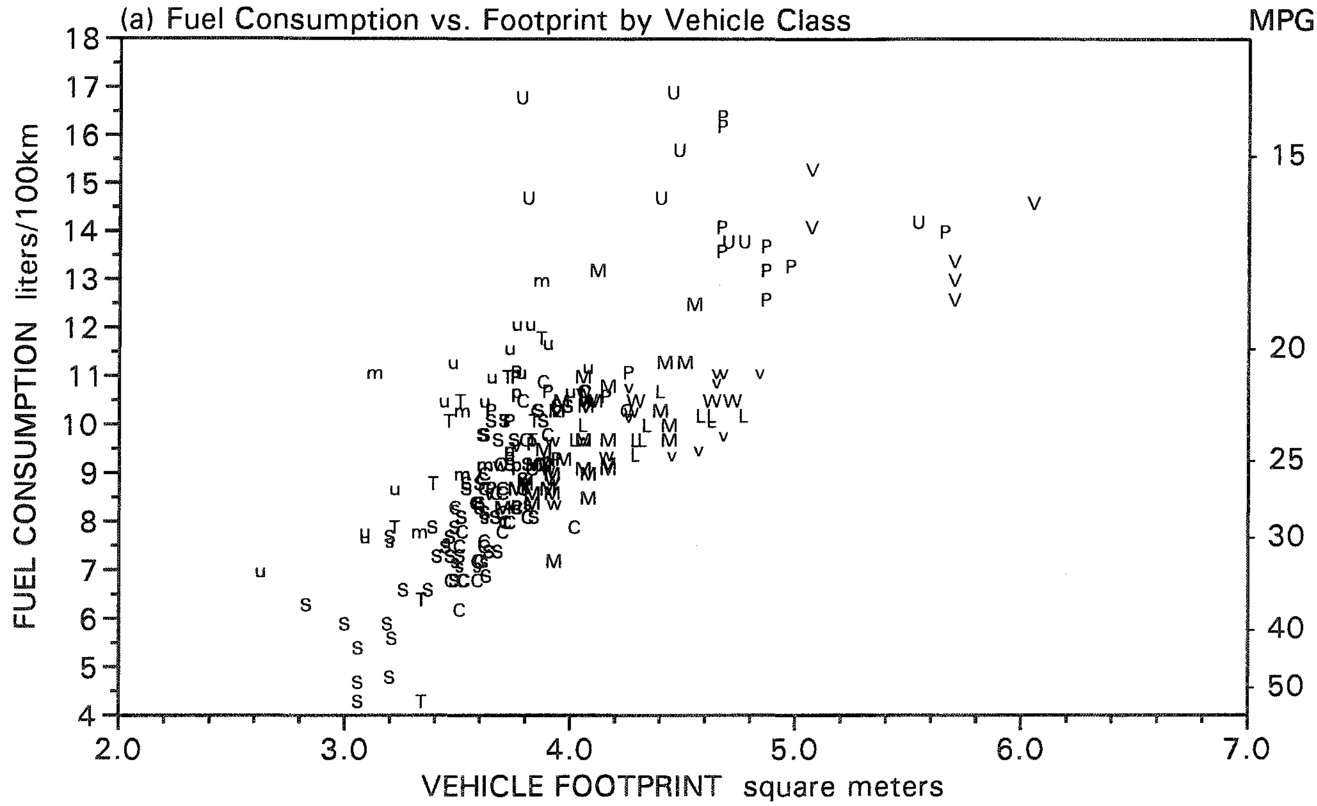


Figure 5. Trends in passenger car design geometry



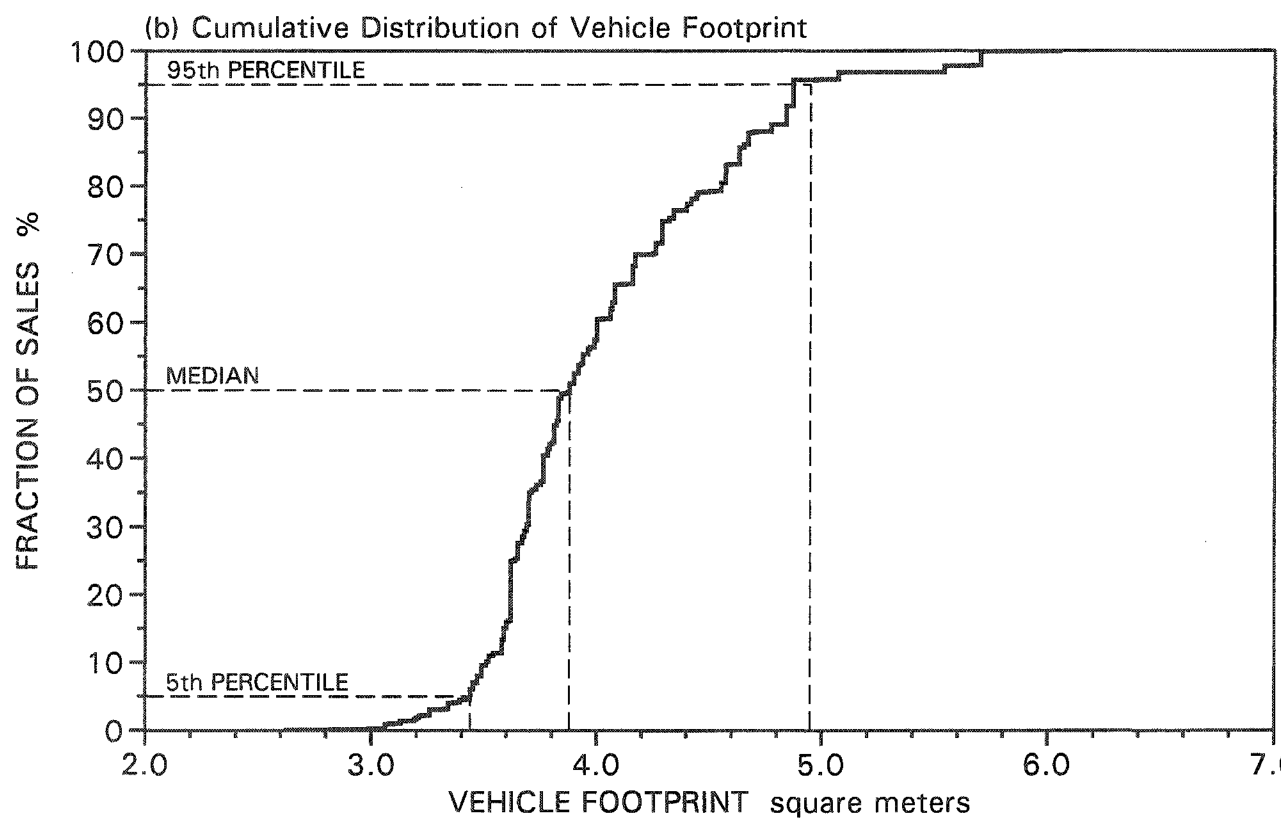


Figure 6. Footprint versus fuel consumption and distribution of footprint for 1990 new light duty vehicles (see Figure 7 for class letter codes).

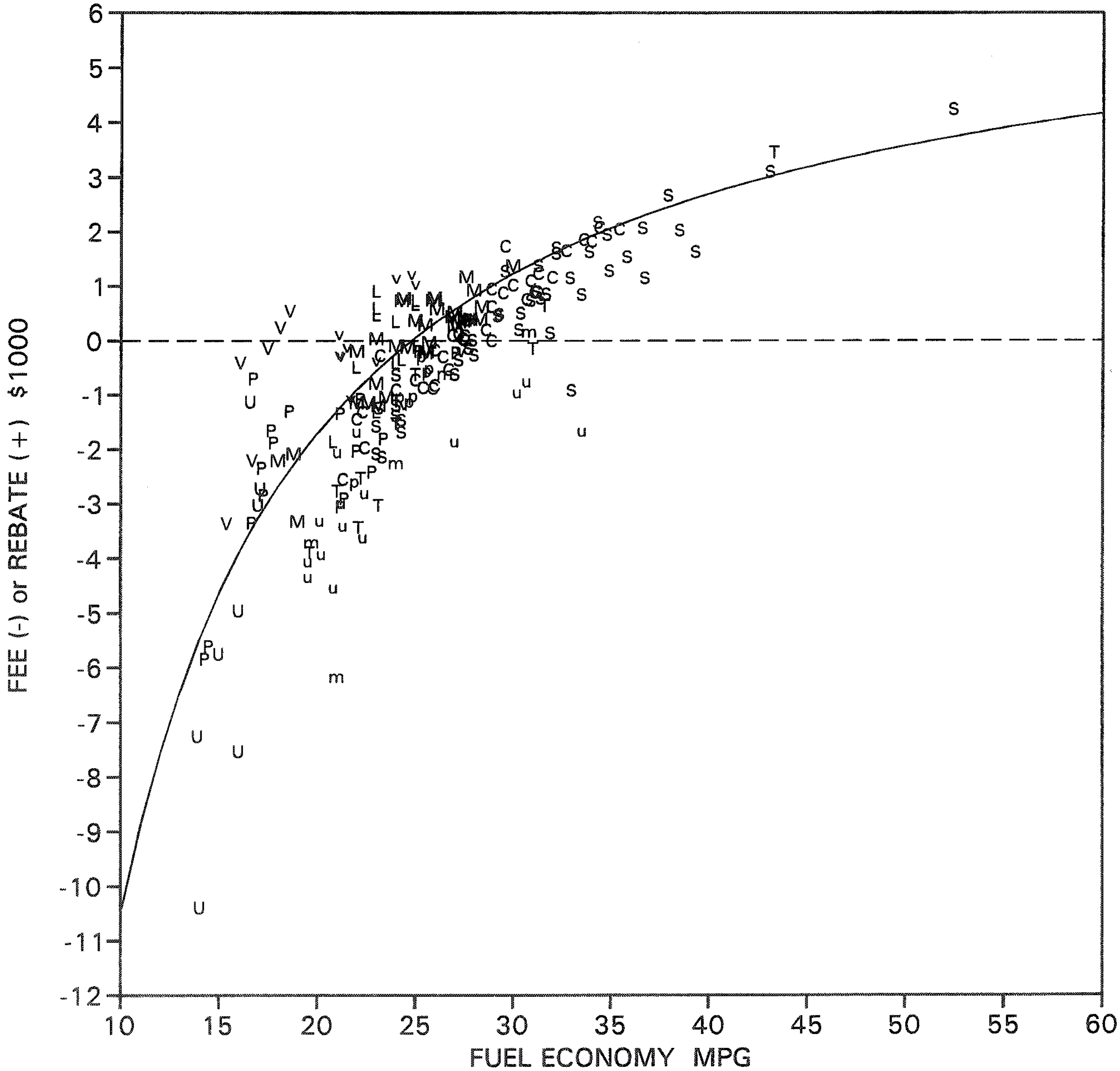


Figure 7. Footprint-normalized consumption feebates, all classes treated together, versus fuel economy.

Plot of model year 1990 nameplate averages; class codes are: C=Compact, L=Large, M=Midsize, S=Subcompact, m=Minicompact, T=Two-seater, P/p=Large/Small pickup, U/u=Large/Small utility, V/v=Large/Small van.

Feebates based on an energy factor of on-road CO_2 emissions rate divided by footprint, using a conversion constant of 9320.57 (mpg g/km), a rate of $124 per unit difference in energy factor, and a reference level energy factor of 92.36 g/(km m^2) (sales-weighted mean of all light duty vehicles). The curve is the underlying fuel consumption-only based feebate with a rate of $1.17 per gallon of undiscounted lifetime fuel consumption, as in Figure 3.

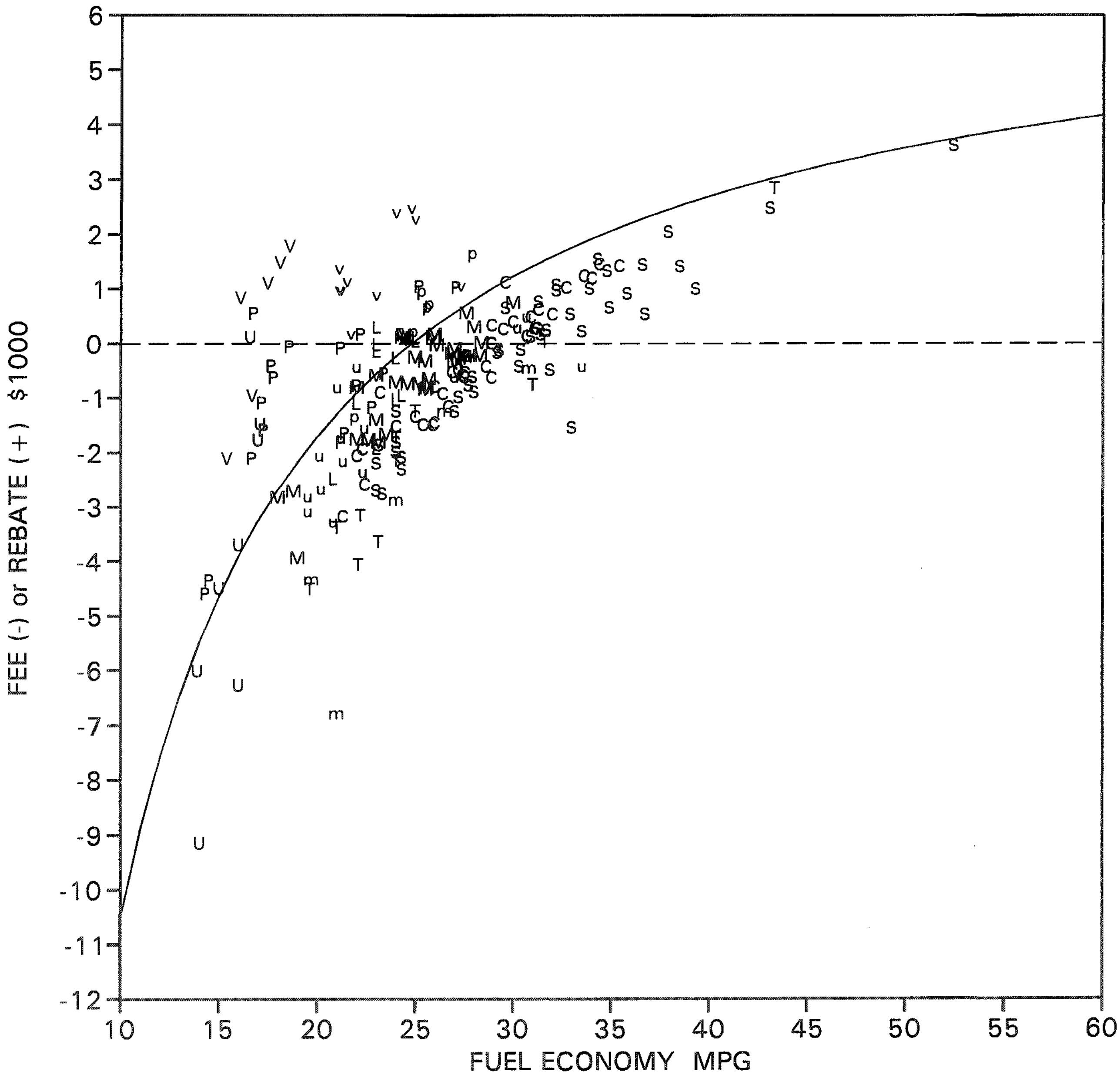


Figure 8. Footprint-normalized consumption feebates, with separate car and light truck reference levels, versus fuel economy.

Plot of model year 1990 nameplate averages; class codes are: C=Compact, L=Large, M=Midsize, S=Subcompact, m=Minicompact, T=Two-seater, P/p=Large/Small pickup, U/u=Large/Small utility, V/v=Large/Small van.

Feebates calculated for an energy factor of on-road CO_2 emissions rate divided by footprint, using a conversion constant of 9320.57 (mpg g/km), a rate of $124 per unit difference in energy factor, and reference levels energy factors of 87.40 g/(km m²) for cars and 102.48 g/(km m²) for light trucks. The curve is the underlying fuel consumption-only based feebate with a rate of $1.17 per gallon of undiscounted lifetime fuel consumption, as in Figure 3.

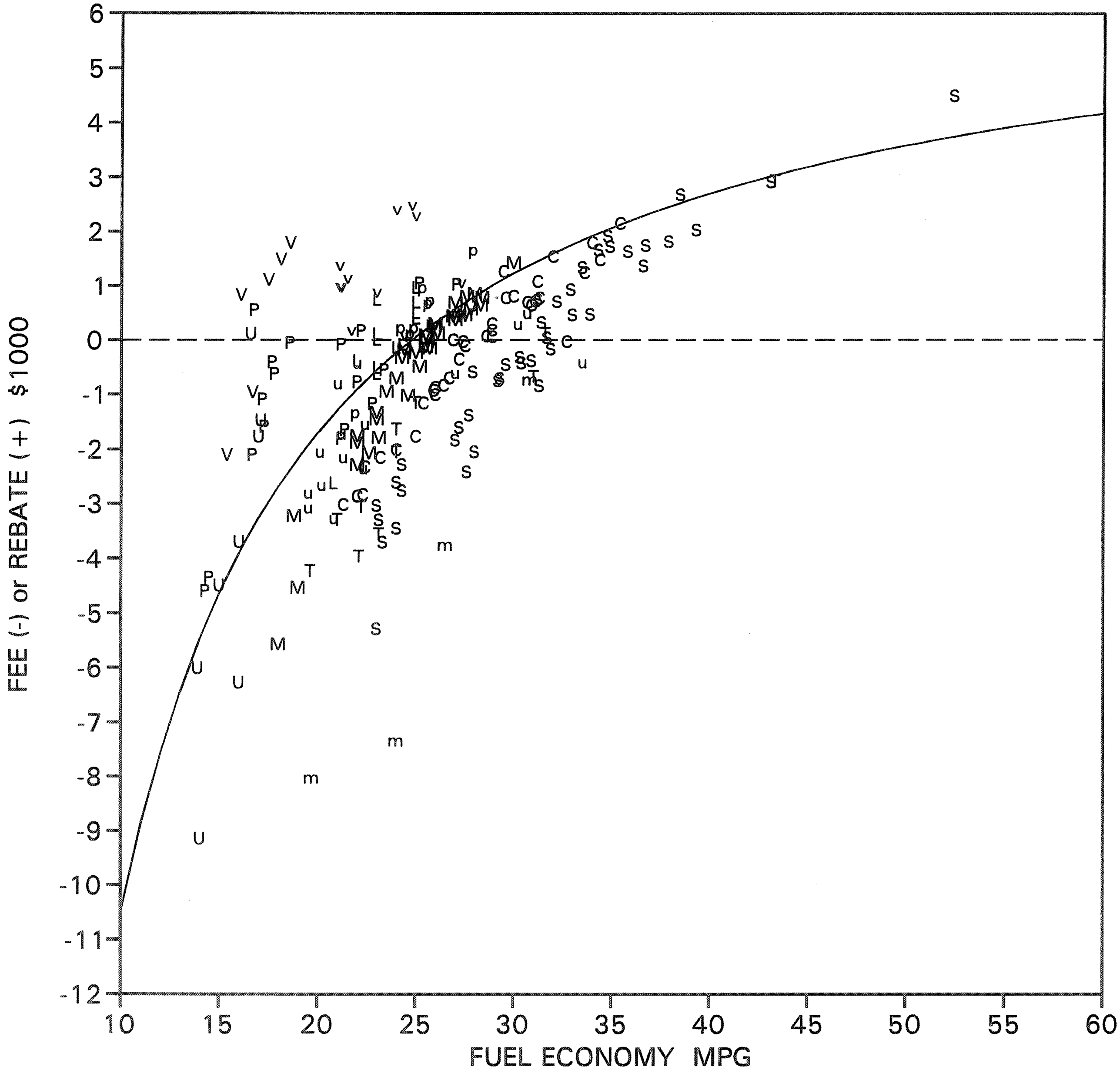


Figure 9. Hybrid feebates vs. fuel economy for 1990 light duty vehicles, based on passenger volume for cars and footprint for light trucks.

Based on nameplate average fuel economy, plotted by class of vehicle. Class codes are: C=Compact, L=Large, M=Midsize, S=Subcompact, m=Minicompact, T=Two-seater, P/p=Large/Small pickup, U/u=Large/Small utility, V/v=Large/Small van.

Feebates are calculated based on volume for cars and footprint for light trucks, as specified in Table 10. The curve is the underlying fuel consumption-only based feebate with a rate of $1.17 per gallon of undiscounted lifetime fuel consumption, as in Figure 3.

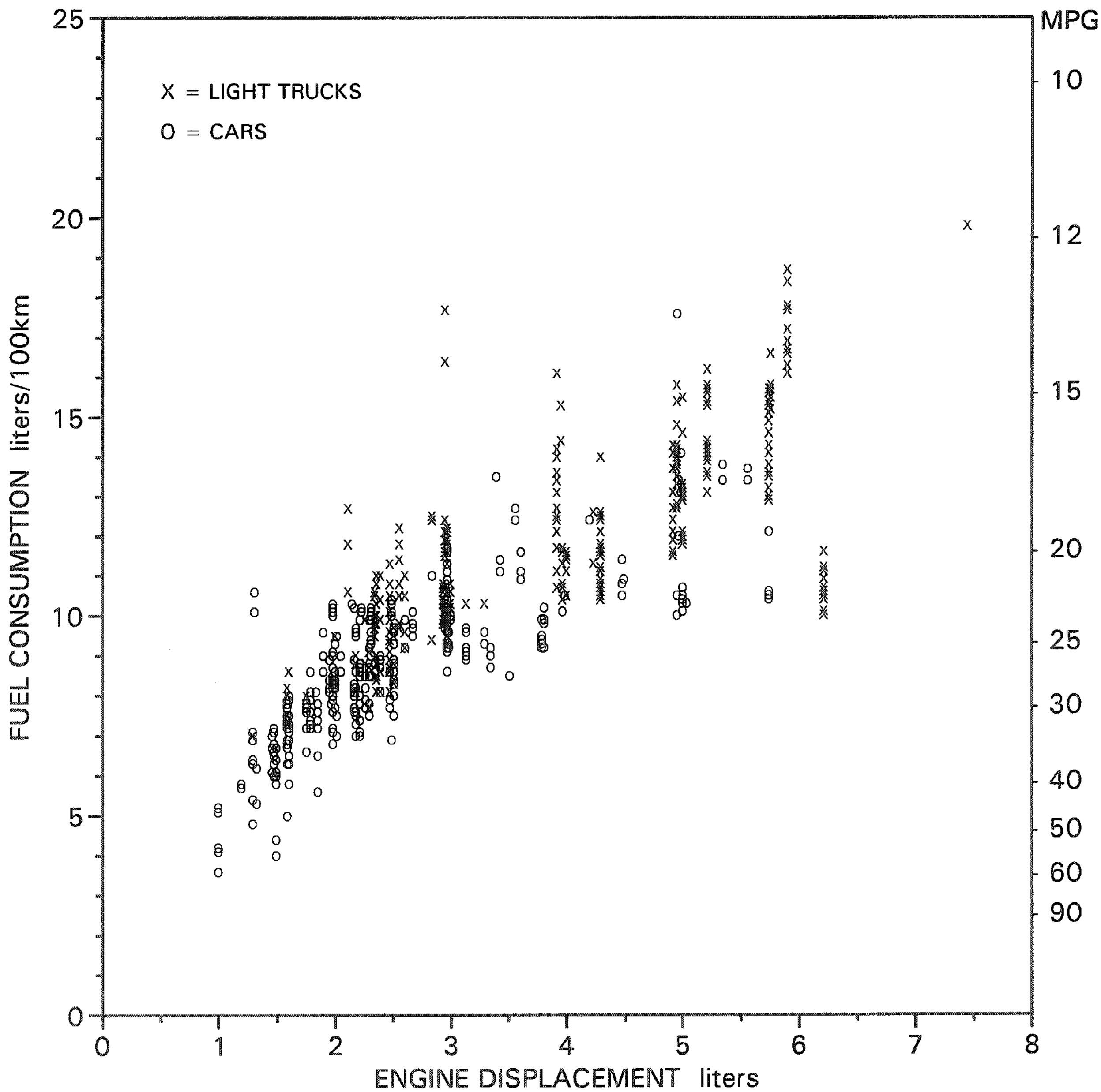


Figure 10. Fuel consumption versus engine displacement for 1990 new light duty vehicles

Data from EPA 1990 Gas Mileage Guide diskette provided by Office of Mobile Sources, Ann Arbor, Michigan.

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