Size-Based Fees and Rebates for Reducing Light Vehicle Energy Use and Carbon Dioxide Emissions

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Vehicle purchase price incentives in the form of fees and rebates ("feebates") linked to vehicle efficiency are a potential mechanism for reducing U.S. transportation energy consumption and greenhouse gas emissions. General principles for formulating feebates are described, and issues to be addressed in developing a workable feebate program are identified, particularly treatment of light trucks and differential impacts on manufacturers. Size-adjusted feebates are introduced as a way to mitigate the intermanufacturer equity concerns that arise with a system based only on fuel consumption. The impacts of various feebate formulations are examined by a nameplate-level static analysis of the 1990 fleet. By separating cars from light trucks and choosing an appropriate size-adjusted approach, it is possible to develop a feebate system that does not disadvantage U.S. automobile makers. The data base analyzed also reveals a significant variation among different configurations of a given nameplate. Although further analysis is needed, the size-based feebate concepts presented here may serve as a foundation for designing vehicle price incentives to reduce energy use and carbon dioxide emissions.

Concerns about oil imports, greenhouse gas emissions, and other adverse economic and environmental impacts associated with U.S. transportation energy consumption continue to motivate the development of new policies for improving the fuel economy of light vehicles (cars and light trucks). 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 vehicle buyers who highly value fuel economy. The average fuel economy of new light vehicles in the United States has been essentially unchanged for 12 years, averaging 25 (± 1) mpg from 1982 to 1993 (*1*). Further improvements appear unlikely given the market conditions that have prevailed since oil prices fell in 1986.

Fuel pricing, regulation, and vehicle pricing all have their pros and cons as policies for controlling motor fuel consumption. Fuel pricing is directed mainly toward consumers' decision making and can affect both vehicle choice and travel behavior. Vehicle regulation is directed toward manufacturers' planning. Of course, both types of policies involve responses by the other parties in the market. Vehicle pricing policies, such as a variable tax and subsidy (fee and rebate, or "feebate") scheme linked to fuel economy, affect consumers and manufacturers as well as car dealers. In any case, the long-term fuel economy response, which is of most interest for policy development, is dominated by technology improvements in vehicles rather than changes in consumer choice among vehicle size class. This understanding is based on examination of historical changes in the light-duty market as well as on detailed modeling of prospective feebate systems (*2,3*). For a policy change of given magnitude (e.g., percentage change in current pricing), feebates are likely to be more influential than higher fuel taxes in reducing overall motor fuel consumption (*4*). Summaries of existing or proposed feebate programs, policy issues, and energy savings estimates are given in recent reports sponsored by the U.S. Department of Energy (*3,5*). The recent study by Davis et al. (*3*) is the most comprehensive analysis to date of the likely market response to feebates.

In the United States, feebates can be viewed as an extension of the existing gas guzzler tax, which has an observable but small effect on new car fuel economy. Among the reasons that the coverage of the U.S. gas guzzler tax has been limited to a small portion of new cars was concern about effects on the market position of U.S. automobile makers. This concern motivates the exploratory analysis reported here, which is based on a longer technical report (*6*). Since adjusting fees and rebates according to vehicle size can change their impacts on manufacturers, the effects of varying formulations of size-adjusted feebates were examined. A data base was assembled containing vehicle characteristics and sales volumes for 224 nameplates covering the market in model year 1990. The analysis of various feebate schemes was static, that is, the authors did not attempt to evaluate market response (changes in manufacturer designs or consumer choice). However, given the dominance of technology change over shifts among vehicle types in achieving fuel economy improvements, a static analysis is valuable in revealing the likely manufacturer impacts of various feebate designs and identifying the issues that need to be addressed to develop a workable program.

CONSUMPTION-BASED FEEBATES

Generally, a feebate is defined as the product of a feebate rate and the difference between a factor representing a vehicle's energy consumption and some reference level relative to which vehicles are judged:

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

This convention yields negative fees and positive rebates. In the most straightforward formulation, the energy factor would be given in gallons per mile or liters per 100 km, and a vehicle's feebate would be proportional to the location of its fuel consumption above or below some reference fuel consumption. For example, the refer-

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ence level could be the fleet average fuel consumption rate. The reference level is also called the zero point since vehicles having an energy factor at this level have zero fee or rebate in a revenue-neutral program.

Examining a consumption-based feebate reveals issues that need to be addressed in developing a workable proposal. A fuel consumption–based feebate is also equivalent to a carbon dioxide (CO_2) emission–based feebate for gasoline vehicles. For illustrative purposes, a consumption-based feebate can be constructed by extending the existing U.S. gas guzzler tax. The tax schedule is shown as the step function in Figure 1, with the resulting consumption-based feebate extension shown as the curve. Plotted against fuel consumption rather than fuel economy, the tax would follow a straight line with slope $749/Liter/100 km and intercept 9.56 L/100 km (24.6 mpg) (this line is shown for reference in Figures 2 and 3). The mpg-based feebate (longer dashed line) is tangent to the consumption-based feebate curve at the zero-feebate intercept of 24.6 mpg with a slope of $291/mpg. 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.

Table 1 gives top-selling 1990 light vehicles by decreasing nameplate average fuel economy along with other statistics. These vehicles had just over half of light duty vehicle sales and an average fuel economy of 24.7 mpg, close to the 24.8 mpg average of all 1990 light vehicles. Except for the Cadillac Fleetwood/Deville, all of these models are untouched by the gas guzzler tax, which does not apply to trucks. The "consumption-only" columns list feebates calculated on the basis of fuel consumption, with cars and light trucks treated together relative to a single reference level. Under this scheme, 21 of the 35 vehicles have rebates and 14 have fees on a nameplate average basis. Feebates are also given as a percentage of vehicle sales price. The sales-weighted mean absolute value of the feebates in this example is $1,153, or 8.0 percent of the average new vehicle price of $14,500. This percentage is called the *leverage* of the feebate, since it represents the average vehicle price influence exerted by the feebate. Leverage is useful as a dimensionless indicator of the strength of the probable effect on decision making.

The outcome of a consumption-based feebate scheme depends strictly on fuel economy, favoring smaller economy vehicles over larger, more powerful or luxurious vehicles. In this example, the range is from fees of 28 percent for the Ford Econoline van to a rebate as high as 23 percent for the Ford Escort, as a percentage of price. Two-thirds of the feebates fall within ±10 percent of the vehicle price. The Chrysler minivans had fuel economies near the light-duty fleet average, implying a negligible net rebate on a nameplate average basis. 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 to 27 mpg, implying feebates ranging from −$230 (fee) to $580 (rebate) compared with the nameplate average of a $305 rebate. 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 $2,800, 22 percent of their nameplate average sales price. Table 1 thus reveals one issue for developing feebate schemes, namely, the low fuel economy of light trucks. The 1990 light truck standard was 20.0 mpg—lower than the guzzler tax threshold of 22.5 mpg. In short, most light trucks are gas guzzlers relative to cars.

Table 2 presents the impact of consumption-only feebates by manufacturer. The outcome corresponds to the manufacturers' respective corporate average fuel economy (CAFE) levels. The U.S.

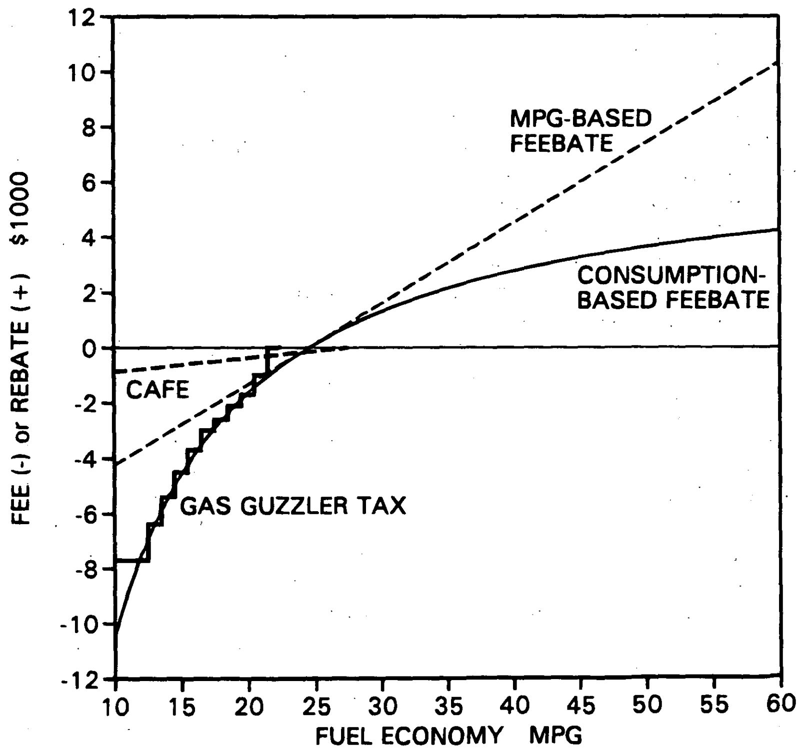

FIGURE 1 **Fee and rebate levels extrapolated from federal gas guzzler tax.**

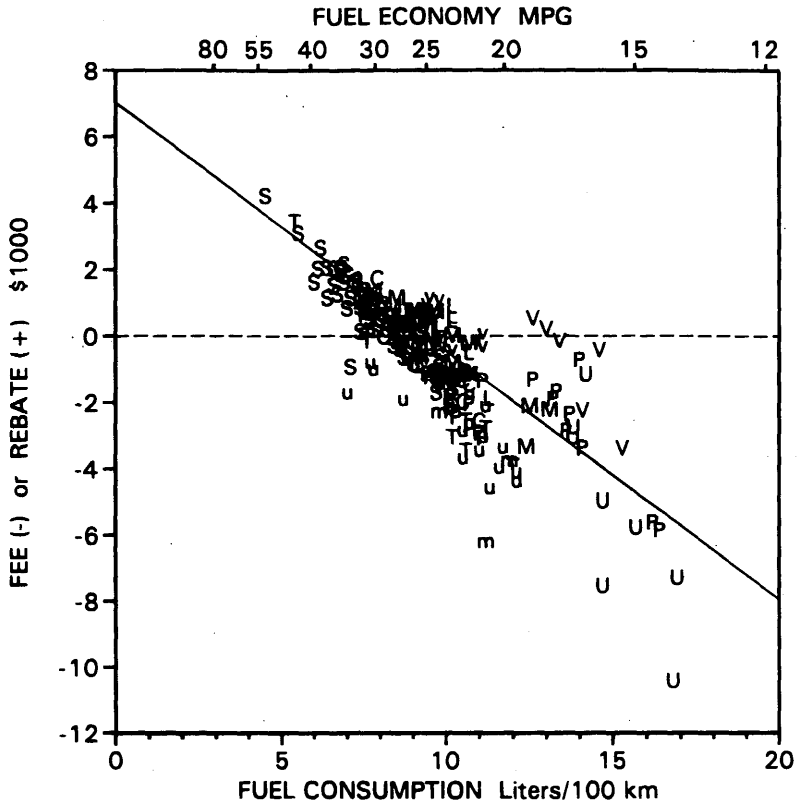

FIGURE 2 Footprint-normalized consumption feebates (all classes together) versus nameplate fuel consumption. C = compact, L = large, M = midsize, S = subcompact, m = minicompact, T = two-seater, P/p = large/small pickup, U/u = large/small utility, V/v = large/small van.

"Big Three"—Chrysler, Ford, and General Motors—accounted for 69 percent of all light-duty vehicle sales in 1990. These manufacturers are the "D3" group. The automobile makers with the next highest sales are five Japanese firms—Toyota, Honda, Nissan, Mazda, and Mitsubishi—the "J5" group. It accounted for 25 percent of 1990 sales. The D3 and J5 groups together comprised 94 percent of the market. Table 3 summarizes static feebate outcomes for these major manufacturer groupings. With the consumption-only feebate, the D3 members all pay net fees, amounting to $3.1 billion in aggregate for the 1990 model year sales mix. The J5 members receive net rebates amounting to $2.7 billion. This highlights a second major issue: the "domestic versus import" problem of net fees for the Big Three and net rebates for most Asian manufacturers. The domestic versus import problem is linked to the light truck problem, since light trucks are an important part of D3 market share.

Besides these concerns, several others would need to be addressed in developing a workable feebate program:

1. Ways to deal with light trucks;
2. Domestic versus import problem;
3. More generally, equitable treatment of manufacturers ensuring that all have incentive to improve their fleets without creating an unfair competitive advantage because of particular fleet characteristics;
4. Leverage needed to effect a desired fuel economy improvement;
5. Consumer equity;
6. Understandability to consumers;
7. Administrative costs and government revenue impacts; and
8. Alternatively fueled vehicles.

This paper introduces size-based feebates as a way to address Issues 1 through 3. Discussions of the remaining issues may be found elsewhere (*3,5,6*).

SIZE-BASED FEEBATES

Some of the drawbacks of a consumption-only formulation may be addressed by incorporating other vehicle characteristics into the calculation of the incentive. Vehicle size, pollutant emissions, and crashworthiness have all been proposed for formulating feebate proposals. Other attributes that could be considered are domestic content, payload weight, power or power/weight ratio, and alternative fuel use. Considering the variation in vehicle size among different manufacturers has also been proposed for reforming fuel economy standards (*7*). Overall, average vehicle size has been fairly stable, despite CAFE standards and changes in fuel prices. Since 1976, the average interior volume of new cars dropped only 3 percent and wheelbase dropped 7 percent, compared with much larger changes in fuel economy.

Interior volume is the basis of the size classifications used to group vehicles in the Environmental Protection Agency's (EPA's) *Gas Mileage Guide* (*8*). However, it is difficult to compare interior

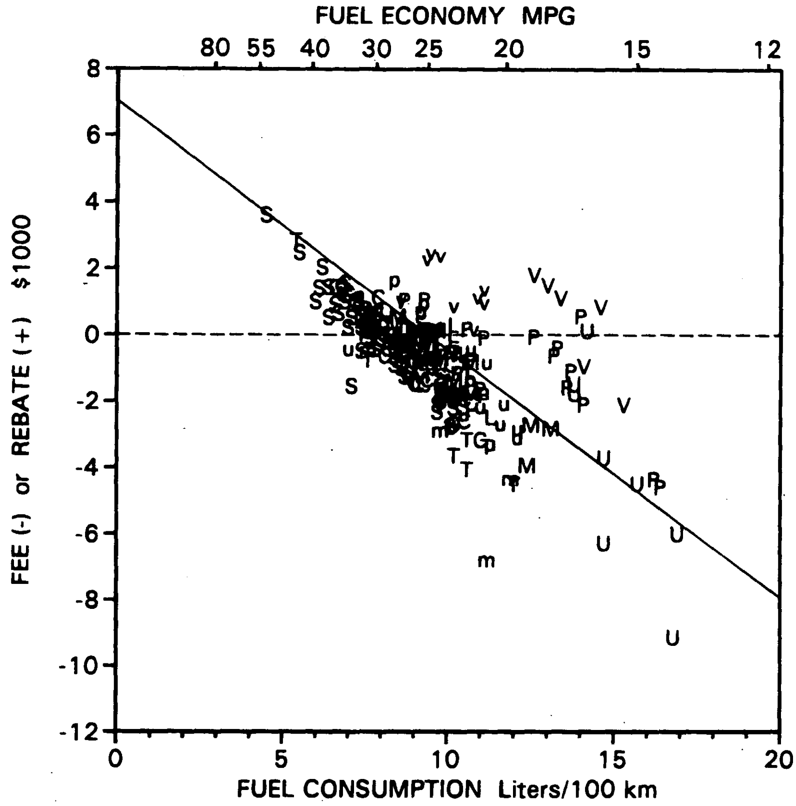

FIGURE 3 Footprint-normalized consumption feebates, (with separate car and light-truck reference levels) versus nameplate fuel consumption. Codes are as given in Figure 2; reference levels are 87.40 g/(km m^2) for cars and 102.48 g/(km m^2) for light trucks.

volume among different passenger vehicle types (e.g., cars, station wagons, vans), and it is even less valuable for comparing light trucks (pickups, sport utilities, cargo vans). Payload weight might be considered, but it is not defined for regulatory purposes. 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. A difficulty with exterior dimensions is that they are easily affected by cosmetic changes to vehicles.

Wheelbase (the distance between the front and rear axles) is a universal measure of vehicle size for which trend data are available (*9*). Track width is the distance between the right and left tire centerlines. Track width often differs slightly between the front and rear wheels, but it can be averaged readily. Footprint is defined as the product of wheelbase and average track width and has units of area. Wheelbase and track width are widely reported vehicle specifications related to vehicle structure and are not changed except during major redesigns. Neither is currently considered for regulatory purposes. In contrast with payload weight or interior volume, footprint is well-defined for all major classes of light-duty vehicle. Footprint is selected as a basis for this analysis for reasons of its convenience, universality, and likely stability. Nameplate average footprints for top-selling 1990 vehicles are given in Table 1. The 1990 sales-weighted average values are 3.86 m^2 for cars, 4.45 m^2 for light trucks, and 4.05 m^2 overall.

For light trucks, there is less certainty about the probable design response to incentives based on footprint. Light trucks have a wide variety of characteristics, and their market segment has evolved rapidly over the years. 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, in 1990 Ford F-series pickup wheelbases ranged from 117 to 208 in.; the Chevrolet standard pickup wheelbases ranged from 118 to 169 in. A concern for footprint-based incentives is the possibility of shifting sales to versions with larger wheelbases. However, a larger wheelbase can incur a weight penalty, lowering fuel economy. The relative manufacturing cost trade-offs will merit further investigation if a footprint-based incentive is pursued.

A size-adjusted feebate scheme can be developed by defining an energy factor as the ratio of fuel consumption rate to footprint. For a given fuel, this is equivalent to the ratio of greenhouse gas emissions rate to footprint, which is the formula used for this analysis, anticipating extension to alternatively fueled vehicles. For gasoline vehicles as considered here, energy factors are calculated using a full fuel cycle CO_2-equivalent emissions rate of 12 kgCO_2/gal and a fuel economy shortfall of 20 percent. For example, a vehicle rated at 30 mpg with a 4-m^2 footprint would have an energy factor of 78 gCO_2/(km m^2). Dropping the units, average footprint-based energy factors are 87 for cars, 102 for light trucks, and 92 overall for the 1990 new fleet.

TABLE 1 Feebates for Top-Selling 1990 Light-Duty Vehicles Using Consumption-Only and Size-Adjusted Formulations

MAKE	MODEL[a]	CLASS[b]	MPG	Foot-print (m²)	CONSUMPTION-ONLY Feebate ($)	CONSUMPTION-ONLY price change	SIZE-ADJUSTED Feebate ($)	SIZE-ADJUSTED price change
Nissan	SENTRA	S	34.8	3.49	2,044	-21%	1,334	-14%
Ford	ESCORT	C	34.4	3.59	1,985	-23%	1,471	-17%
Honda	CIVIC	S	34.3	3.63	1,970	-19%	1,558	-15%
Toyota	COROLLA	S	31.7	3.45	1,549	-15%	255	-2%
GM	Geo PRIZM	S	31.4	3.45	1,496	-13%	173	-2%
GM	Chev. CAVALIER	C	30.9	3.62	1,405	-16%	497	-6%
GM	Pont. GRAND AM	C	30.0	3.70	1,234	-10%	413	-3%
Honda	ACCORD	C	29.6	4.02	1,155	-8%	1,128	-8%
Toyota	CAMRY	C	28.9	3.81	1,011	-7%	346	-2%
GM	Chev. CORSICA	M	28.3	3.70	881	-9%	(213)	2%
Ford	PROBE	C	27.5	3.67	700	-5%	(606)	5%
GM	Olds.CUTLASS CIERA	M	27.0	3.92	582	-4%	(86)	1%
GM	Buick CENTURY	M	26.9	3.90	557	-4%	(165)	1%
GM	Pont. GRAND PRIX	M	26.1	4.08	357	-2%	(21)	0%
GM	Chev. LUMINA	M	26.1	4.08	357	-3%	(21)	0%
Ford	TEMPO	C	26.0	3.62	331	-3%	(1,435)	14%
Ford	TAURUS	M	25.9	4.17	305	-2%	141	-1%
GM	Chev. S-10	p	25.7	3.76	252	-3%	755	-8%
GM	Buick LESABRE	L	25.0	4.29	60	-0%	59	-0%
Chrysler	Dodge CARAVAN	v	24.8	4.57	3	-0%	2,499	-17%
Chrysler	Plym. VOYAGER	v	24.8	4.57	3	-0%	2,499	-16%
Ford	MUSTANG	S	24.3	3.68	(143)	1%	(2,077)	15%
Ford	RANGER	p	24.2	3.83	(173)	2%	245	-2%
Ford	Linc. TOWN CAR	L	23.0	4.77	(553)	2%	307	-1%
GM	Chev. CAPRICE	L	23.0	4.58	(553)	3%	(134)	1%
GM	Chev. BLAZER S-10	u	22.4	3.62	(758)	5%	(1,533)	10%
Ford	BRONCO II/EXPLORER	u	22.0	4.00	(901)	6%	(413)	3%
GM	Cadi.FLTWD/DEVILLE	L	22.0	4.40	(901)	3%	(1,098)	3%
GM	Chev. ASTRO	v	21.5	4.65	(1,087)	7%	1,159	-7%
Chrysler	Jeep CHEROKEE	u	21.2	3.78	(1,203)	8%	(1,717)	11%
Ford	AEROSTAR	v	21.1	4.68	(1,243)	9%	1,012	-7%
GM	Chev. C/K-1500	P	17.8	4.87	(2,791)	22%	(619)	5%
Ford	F150	P	17.7	4.98	(2,847)	22%	(399)	3%
Ford	F250	P	16.8	5.66	(3,380)	26%	560	-4%
Ford	ECONOLINE	V	16.1	6.05	(3,836)	28%	850	-6%

[a]The 35 top-selling 1990 nameplates (50.3% of light duty sales), listed by decreasing sales-weighted fuel economy (unadjusted EPA composite rating) as given by the ORNL MPG and Market Shares Report (8).

[b]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.

The resulting feebates, computed relative to a single reference level for the 224 nameplates analyzed here, are plotted in Figure 2. This graph shows the variation created by footprint adjustment compared with feebates based on fuel consumption alone, which follow a straight line. Feebates are calculated as on-road CO_2 emissions rate divided by footprint, using a conversion constant of 9321 (mpg g/km), a rate of $124 per unit difference in energy factor, and a single reference level of 92.36 g/(km m^2) for both cars and light trucks. For comparison, the line shows a consumption-only feebate extension of the gas guzzler tax. Size adjustment alone does not eliminate the efficiency gap between cars and light trucks, which accounts for much of the disparity between the D3 and J5 fleets. The residual imbalance is shown in the second line of Table 3. Aggregate D3 fees are halved compared with the consumption-only case, but a substantial net transfer remains.

The next step is to analyze a scheme with separate reference levels for cars and trucks, using the average car and light-truck energy factors noted earlier. The feebate rate is kept the same for both fleets, maintaining a common incentive level per unit of size-adjusted fuel consumption. The resulting feebates are plotted in Fig-

TABLE 2 Fuel Consumption–Based Feebates, Fixed 1990 Fleet Outcome by Manufacturer

MANUFACTURER	FLEET MPG	GHG[a] (g/km)	DIFFER[b] FROM AVG	NET FEEBATES[c] (Million $)	AVG. PER[d] MODEL ($)
BMW	21.9	425	13%	-53	-922
Chrysler	23.8	392	4%	-527	-306
Daihatsu	37.8	247	-34%	41	2445
Ford	23.0	406	8%	-1835	-567
GM	24.3	384	2%	-726	-150
Honda	30.4	306	-19%	1121	1320
Hyundai	33.3	280	-26%	256	1818
Isuzu	22.1	421	12%	-95	-851
Jaguar	21.3	438	16%	-22	-1165
Mazda	26.9	346	-8%	197	562
Mercedes	21.2	439	17%	-75	-1192
Mitsubishi	27.7	336	-11%	140	746
Nissan	27.3	342	-9%	402	651
Porsche	21.9	426	13%	-9	-949
Rover	16.0	583	55%	-18	-3904
Saab	25.9	360	-4%	8	299
Subaru	28.9	323	-14%	108	1007
Suzuki	33.0	283	-25%	39	1762
Toyota	28.1	331	-12%	881	846
VW	28.9	322	-14%	160	1011
Volvo	24.6	379	1%	-5	-51
Yugo	33.0	282	-25%	13	1768
OVERALL	24.8	376		0	1153

[a]Fleet average full fuel cycle greenhouse gas emissions, based on an emissions factor of 3.2 kg/liter (CO_2-mass equivalent) for gasoline and 20% fuel economy shortfall.

[b]Difference of each manufacturer's fleet average GHG emissions rate relative to the 1990 light duty vehicle average of 376 g/km.

[c]Manufacturer's net outcome [Fees (-), Rebates (+)] assuming a fixed 1990 sales mix and a feebate rate of $18.90 per g/km .

[d]Manufacturer's net outcome divided by sales; the overall average per model is the sales-weighted mean absolute value of all feebates.

ure 3, with the straight line of a consumption-only feebate again shown for comparison. It turns out that a footprint-based system results in no net fee transfer from light trucks to cars. There is still a net D3 to J5 transfer, as shown in the third line of Table 3. However, with net D3 fees of $0.5 billion and net J5 rebates of $1.1 billion, the transfer is mitigated greatly compared with the consumption-only case.

Separating the car and light-truck fleets results in a marked difference in the treatment of vehicles, as shown in the last two columns of Table 1. Rebates on subcompacts are reduced. Some cars that received rebates when compared with the overall light-vehicle average now get fees, since their adjusted fuel consumption is above average for cars. For example, the "m" outlier below the line in Figure 3 at 11 L/100 km is the Porsche 911, a high-powered luxury sportscar classified as a minicompact. Its fee is over $6,000 since it is so inefficient for its size relative to other passenger 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 to 17 percent of their price, and even the Ford Econoline now shifts to a rebate. This is also illustrated in Figure 3, which shows van rebates well above the line. There are still large fees on the sport utilities; for example, nameplate average fees are 10 to 11 percent of price for the Chevy Blazer and Jeep Cherokee. In contrast, some minivans (plotted by small "v") earn rebates of more than $1,000, because their footprints are much larger and they are compared with the class of all light trucks.

TABLE 3 Summary of Outcomes for Various Feebate Formulations with Static 1990 Fleet Mix

	Aggregate rebates (fees) billion (10^9) dollars	
Type of Feebate Formulation	D3	J5
Consumption only, treating all light vehicles together	(3.089)	2.741
Footprint-adjusted, treating all light vehicles together	(1.446)	1.852
Footprint-adjusted, with separate reference levels for cars and light trucks	(0.452)	1.118
Separate formulas, volume-adjusted for cars and footprint-adjusted for light trucks	0.798	(0.231)

One way to improve the outcome for U.S. domestic manufacturers is with a hybrid feebate system, using volume adjustment for cars and footprint adjustment for light trucks. Further details on such a system are given elsewhere (*6*). In this case the range of size-based feebates for vehicles having the same fuel economy becomes quite large, as much as ±$7,000. For example, there would be a $14,000 difference between a minivan and a relatively inefficient sports or luxury minicompact. A hybrid system using the 1990 fleet mix results in aggregate net rebates of $0.8 billion for the D3 and gives all of the domestics a net positive outcome. The J5 groups end up slightly negative, with aggregate net fees of $0.2 billion. Thus, by separating cars from light trucks and choosing an appropriate size adjustment procedure, it is possible to develop a feebate system that would not disadvantage U.S. automobile makers on the basis of a recent fleet mix.

OTHER ISSUES

It is beyond the scope of this paper to probe all of the issues raised when considering the design of feebate programs for the United States. The data base does permit brief examination of two additional issues: the variation of feebates with respect to vehicle configuration and the question of setting the rate (or "slope") of a feebate system.

Configuration Choice

A nameplate-level analysis masks the way in which feebates might affect choices among different configurations (submodels) of a nameplate. Configuration refers to the exact specification of a vehicle regarding attributes that affect emissions and fuel economy, such as engine displacement and transmission type. Table 4 presents fuel economy ratings and hybrid size-based feebate values for various configurations of several top-selling 1990 nameplates. For each nameplate, the most efficient configuration is 10 to 40 percent more fuel efficient than the least efficient configuration. Lacking size (volume or footprint) data by configuration, nameplate average sizes are used for these estimates, so that the feebate variability by configuration in Table 4 depends entirely on fuel economy variability. This limitation may overstate feebate variability, particularly for light trucks if more efficient confirmations have wheelbases smaller than the nameplate average.

The subcompact Geo Prizm, for example, was available in configurations ranging from 31 to 35 mpg in 1990. Its nameplate average was 31.4 mpg, implying an average rebate of $332. However, the Prizm's most efficient configuration, rated at 35 mpg, would earn a substantially larger rebate of $1,421. There is a similarly large variability among different configurations of nearly every model. 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 $1,852 fee.

Ford pickup trucks are an important example of the way that a feebate would influence configuration choice. The Ford F150 series full-size pickup trucks were the top-selling light vehicle in 1990 and had a nameplate average fuel economy of 17.7 mpg. The fuel economy of various F150 configurations ranges from 15 to 21 mpg. With a separate footprint-normalized scale for light trucks, some of the F150s get rebates, as indicated in Table 4. Thus, a customer might opt for a small-displacement engine for his or her chosen make and model. For many customers, four-wheel drive and a large engine might be superfluous (but marketable) niceties, not warranted by their use of the truck, since most light trucks are used strictly for personal transportation. A feebate would make it more likely that buyers would forego unnecessary options detrimental to fuel economy. In aggregate, many such decisions could compound the positive response to a feebate program. Nevertheless, a configuration-level analysis is unlikely to substantially affect manufacturers' net fee and rebate burdens, as examined here without modeling market response.

Rationales for Feebate Rate

A key question in designing a feebate program is how to set the feebate rate, which determines the relative magnitude of fees and rebates. Several rationales might be used (Table 5).

A federal program could be designed as an extension of the gas guzzler tax, as in the examples presented earlier. Figure 1 illustrated such a feebate curve, which yields a feebate rate equivalent to $1.17/gal over 120,000 mi of vehicle usage (undiscounted). The corresponding feebate leverage is 8 percent. Similarly, a state program could be derived from an existing sales tax (e.g., by converting a flat 5 percent tax to a sliding scale between 0 and 10 percent tax). This would have a lower leverage, roughly 2 percent.

TABLE 4 Feebates for Selected Configurations of 1990 Models Based on Fuel Consumption (*18*)

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

[a] Size is passenger volume (ft^3) for cars and footprint (m^2) for light trucks (assumed the same for all configurations).

Another approach would be to estimate the rate needed to achieve a specified fuel economy improvement. This question is the inverse of estimating the expected market response to a feebate. Little experience is available to guide such estimation. Vehicle choice modeling indicates that consumption-based feebates with a leverage of about 2 percent would improve new fleet fuel economy by 12 percent (average of cars and light trucks) over a 20-year period (*3*).

The dominant effect of a feebate is expected to be manufacturers' making technology-based efficiency improvements across the fleet. Thus, guidance can be inferred from the estimated cost of technology improvement, which partly underlies the estimates of Davis et al. (*3*). The improvements in miles per gallon achieved over the past two decades were estimated to have cost $30 to $60/mpg (*10,11*). The cost of future improvements is a controversial subject. Independent estimates range from $40 to $110/mpg for a 30 to 40 percent improvement over 10 or 15 years (*12,13*). Automobile manufacturers give much higher cost estimates (*14*). As indicated in Table 5, implied feebate leverages range from 2 to more than 10 percent.

A fourth rationale for setting the feebate rate is based on the externalities of fuel consumption. Feebates can be viewed as a way to front-load external costs that occur over the life of a vehicle (*15*). For example, assuming an undiscounted externalities cost of $1/gal over a vehicle lifetime implies a leverage of 6.8 percent. A green-

TABLE 5 Leverage Values Implied by Various Rationales for Setting Feebate Rate

Rationale	Equivalent \$/gallon[a]	Implied Leverage[b]
Extension of existing taxes		
U.S. Gas Guzzler Tax	1.17	8%
A state 5% sales tax	0.30	2%
For a 12% new fleet fuel economy improvement, from Davis et al. (3)	0.30	2%
Technology cost:		
Industry/SRI (13)	2.00+	13%
Greene and Duleep (11)	0.70	5%
DeCicco and Ross (12)	0.30	2%
Externalities:		
per \$1/gal valuation	1.00	6.8%
\$100/tonne carbon tax	0.33	2.3%
CA DRIVE+ (15)	0.13	0.9%
Manufacturer sales rebates	1.05	7%

[a]Based on undiscounted lifetime fuel consumption, assuming 120,000 miles and a 20% shortfall between rated and on-road fuel economy.

[b]Sales-weighted mean absolute value of fees and rebates.

house gas emissions tax of \$100/T (carbon mass basis) would imply a leverage of 2.3 percent. This type of rationale was also used in the design of California's DRIVE+ proposal, which had a carbon emissions component as well as components based on external costs of tailpipe criteria pollutant emissions (*16*).

Finally, rebates used by automobile makers to promote sales range from 4 to 12 percent of new vehicle price. The median of a sample is 7 percent of price, suggesting that feebates with such a leverage would be influential; however, public information on the response to manufacturer rebates is unavailable. In January 1992 the Monsanto Company offered its employees a \$1,000 incentive for buying a North American–made car; this program reportedly generated \$53 million in new car sales (*17*). Rebates are 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 percent of new product price. These rebates have been successful in influencing manufacturer product planning and dealer marketing strategies as well as consumer purchasing decisions (*18*).

Thus, the information at hand leaves a large uncertainty about how to set the feebate rate. Modeling analyses and modest externality values suggest relatively low rates (e.g., a 2 percent leverage). Larger leverages, comparable to that of an extended gas guzzler tax, are implied by rebates used in other sales promotions. Further analysis is needed to develop better guidance on this critical design element of a feebate program.

CONCLUSION

Feebates—new vehicle purchase fees and rebates linked to fuel consumption—would provide a market incentive favoring greater energy efficiency and are an appealing approach to improving fleetwide fuel economy and reducing CO_2 emissions. This paper identified a variety of issues that should be addressed in developing a feebate program for the United States. A feebate system is an inherently flexible mechanism that can provide many programmatic options for addressing the issues at hand.

Examining a straightforward consumption-based feebate scheme served to highlight a number of these issues, particularly the car versus truck effects and the relative burdens on different manufacturers. Size-based feebates were introduced as a way to address intermanufacturer equity. Computing feebates as the ratio of fuel consumption to vehicle footprint and assigning separate reference levels for cars and light trucks substantially mitigates the domestic versus import revenue transfer problem and has the advantage of providing consistent treatment across vehicle classes. There are large variations in the feebates among different configurations of the same model, which would motivate consumers to choose the more efficient models among those having similar size and style.

The energy-saving and emission-reduction effects of a feebate program are difficult to estimate; a review of existing studies shows that the effects are dominated by manufacturers' responses in designing vehicles for higher efficiency. The response depends mainly on the feebate rate and should be independent of classifications and size adjustments used to address manufacturer equity issues. This analysis examined hypothetical feebate schemes having a rate based on an extension of the existing U.S. gas guzzler tax. Other bases for the rate were also identified, including the level estimated to produce a desired fleetwide fuel economy improvement; the cost of technology improvement; the value of avoided fuel consumption, including externalities; and comparability to manufacturers' sales rebates.

Despite uncertainties about the response, the feebate concept is flexible enough that it should be possible to design a system providing a strong incentive to improve the fuel economy of all classes of cars and light trucks while addressing the issues that arise. Thus, feebates appear to be a promising way to help reduce gasoline use and CO_2 emissions by the U.S. light-vehicle fleet. Better quantifying the likely effects of feebate programs, especially manufacturer responses, is a worthy subject for ongoing study.

ACKNOWLEDGMENTS

Howard Geller and John Morrill coauthored the report on which this paper is largely based and made many substantive contributions to the results described here. Bart Davis of Lawrence Berkeley Laboratory and Deborah Gordon of the Union of Concerned Scientists assisted with information for the light-vehicle data base and provided many helpful suggestions. John German, Karl Hellman, and Dill Murrell of EPA shared information, wisdom, and many constructive criticisms. Work on this subject was supported by the Energy Foundation.

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The author assumes responsibility for contents and conclusions.

Publication of this paper sponsored by Committee on Transportation Energy.