Title

Feebates: An effective regulatory instrument for cost-constrained environmental policy

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Abstract

A feebate can be described as an emissions tax combined with a refunded (i.e., negative) consumption tax, the balance of which can be either positive (a fee) or negative (a rebate) depending on how a taxed product's emissions performance compares to the industry average. A successful feebate-type policy is exemplified by Sweden's nitrogen oxide program, which has motivated power plant operators in Sweden to reduce NOx emissions far below levels achieved in the U. S. and other industrial countries. A key to this success has been the fair and efficient manner by which the refund is distributed, and a similar approach could be applied to automotive vehicle feebates (for greenhouse gas reduction), making it possible to overcome limitations of political acceptability and greatly improve policy effectiveness. One such approach would distribute refunds in proportion to vehicle mass (rather than at a fixed rate per vehicle), so that the refund has at least an approximate correlation to vehicle utility and economic value. A second, alternative approach would apply separate feebates to multiple weight classes comprising limited, but overlapping, weight ranges, so that each feebate covers vehicles having similar transportation utility characteristics.

Keywords: Feebates; Refunded Emission Payments

1. Introduction

A "feebate" is an incentive-based environmental policy instrument that combines fees on high-emission products with rebates on low-emission products to incentivize development and commercialization of emission control technologies. Feebates can be applied to greenhouse gas emissions or other types of polluting emissions (e.g., nitrogen oxides, sulfur dioxide, effluent discharges, etc.), and can be applied to a diversity of emissions-intense products such as automobiles or fossil-fuel-generated electric power.

In essence, a feebate is a kind of emissions tax that has been modified to operate more effectively when regulatory policy is constrained by limitations of cost acceptability. A standard emissions tax applies to products with the best, as well as the worst, emissions performance, so its predominant effect is to penalize consumption. The consumption-restrictive portion of the emissions tax is substantially equivalent to a consumption tax, which is assessed at the same rate for all taxed products irrespective of their relative emissions performance. In a feebate system, the consumption tax is refunded to consumers. The “feebate” is the balance between the emissions tax and the refunded consumption tax, which is positive (a fee) for products with worse-than-average emissions performance, and negative (a rebate) for those with better-than-average performance. The consumption tax rate is (typically) set so that the total refund distribution matches the total emissions tax revenue, making the feebate revenue neutral.

The refund, by itself, would dilute the emission tax’s environmental effectiveness because it neutralizes the consumption-restrictive incentive. However, the refund also makes it possible to raise the “emissions price” (i.e., the emissions tax rate) within limitations of economic and political viability, thereby magnifying the incentive to shift consumption from high-emission to low-emission products. This has the effect of focusing the regulatory incentive more exclusively on technology advancement (e.g., energy efficiency improvements and renewable energy), which can typically achieve emissions reduction much more cost effectively (i.e., at less economic cost per unit of emissions abatement) than consumption restriction. Hence, what is lost by refunding the consumption tax is more than offset by the increased technology-forcing incentive.

A feebate is analogous to a “recycled” environmental tax, which refunds emissions tax revenue to consumers through reduced income taxes. However, tax recycling has a couple of drawbacks that are avoided with feebates. Consumers may spend their recycled tax income in ways that are unrelated to the tax’s environmental purpose, and which could potentially neutralize the tax’s environmental effectiveness (Bayindir-Upmann and Raith, 2003). Moreover, with a recycled emissions tax the government’s tax base, and sectors of the economy that benefit from the recycled tax, become economically dependent on continued emissions. By contrast, a revenue-neutral feebate applies the fee revenue exclusively to finance rebates, which function to accelerate market penetration of low-emission technologies; and although markets for low-emission technologies may be economically dependent on rebate revenue during their startup phase, the rebates would automatically diminish (without additional regulatory intervention) as the low-emission technologies gain market dominance.

Feebates also have an interesting relationship to cap-and-trade policies (or similarly, tradable performance standards). Both function to make emissions reduction profitable (from rebates or emissions trading), creating market incentives for firms to improve their emissions performance. In the case of feebates, a firm’s improved emissions performance will tend to increase the competitive pressure on other firms to also reduce their emissions; whereas with cap-and-trade, the betterperforming firms' actions enable other firms to *increase* their emissions. This difference in the market response to improved emissions performance is a consequence of the two regulatory approaches' differing policy objectives: Feebates employ market incentives to minimize emissions, whereas cap-and-trade uses market incentives to minimize regulatory compliance costs. (Another advantage of feebates relative to cap-and-trade is that they offer protection against emissions price spikes and volatility, because the feebate emissions price is directly regulated.)

In the following sections two specific types of feebates will be discussed: the Swedish nitrogen oxide charge (Section 2), which has been very successful at reducing NOx emissions from stationary combustion sources in Sweden (Ågren, 2000; Millock and Sterner, 2004; Wolff, 2000), and automotive vehicle feebates for greenhouse gas reduction (Section 3), which have been the subject of a number of legislative proposals and initiatives, though so far without much success (Greene et al., 2005). Section 3 analyzes the weaknesses of conventional vehicle feebate systems and discusses a couple of alternative feebate structures that could improve policy effectiveness and political acceptability, making it possible to translate the success of the Swedish NOx program to the automotive sector. Simulated performance comparisons between several vehicle feebate policy options (based on California's model year 2002 fleet) are provided in Section 4. The conclusion is summarized in Section 5, and the appendices provide supplemental technical information. (Appendix A describes feebates from a more formal and analytic perspective; Appendix B describes how multiple feebates covering different markets can be used in a complementary manner; and Appendix C provides additional technical detail on vehicle feebates.)

2. The Swedish NOx program

Sweden’s nitrogen oxide program exemplifies a successful feebate-type policy (Ågren, 2000; Barg et al., 2000; Millock and Sterner, 2004; Wolff, 2000). [In the context of the Swedish program, feebates are more commonly termed “emission charges” or “refunded emission payments” (REPs). The term “feebate” is more commonly associated with vehicle feebates.] The NOx program was enacted in 1990 with the objective of achieving 35% reduction in NOx emissions from large combustion plants by 1995. Sweden also had a sulfur dioxide program, which was based on a more conventional per-ton sulfur tax. (SO2 and NOx are the two major causes of acid rain.) But it was decided that an REP system would be more appropriate for NOx due to cost and competitiveness concerns. (The high expense of NOx emissions monitoring equipment made it impractical to regulate small power plants; but a high tax applied exclusively to large plants, while exempting small plants, would be unfair and politically infeasible.) The REP resulted in very substantial and rapid emissions reductions so that the 35% target was already achieved in 1993, and by 1995 the average emissions intensity of regulated plants had decreased by 60% relative to 1990 levels (Ågren, 2000; Barg et al., 2000). Abatement costs were lower than expected, and costs for monitoring equipment came down so that smaller plants could be incorporated in the program in 1996 and 1997. NOx emissions from Swedish coal-fired power plants in 2000 have been estimated to be about four times less than typical U. S. emissions, on a per-MWh basis – or about nine times less if cogeneration heat is included in the comparison (Millock and Sterner, 2004)[1] – and the REP-induced electricity cost increase has been estimated to be only $0.0004/kWh (Wolff, 2000).

The Swedish NOx program illustrates the efficacy of technology-focused, incentive-based regulatory policies. Had the emissions price been applied as an emissions tax with no rebate, the emissions reduction from decreased consumption would have probably only amounted to 2-3%, a very small fraction of the reduction achieved by REP-induced emission controls. Furthermore, an unrefunded tax of that magnitude would not have been politically acceptable (Sterner and Hoglund, 2000). Thus, an emissions tax based on a politically viable emissions price would have forfeited much of the technology-forcing regulatory incentive in exchange for a comparatively minuscule reduction in energy consumption.

The emissions price is SEK 40/kg-NOx (or approximately $5.13/kg, at the current – Sept. 29, 2005 – exchange rate of SEK 7.80/$). The rate was based neither on a valuation of environmental benefits nor on a maximum-cost-acceptability criterion, but was rather determined from estimated abatement costs to achieve a legislatively mandated 30% emissions reduction target (Millock and Sterner, 2004). (The cost projections spanned a very wide range, from SEK 3 to 84/kg, and actual costs turned out to be in the range of SEK 12 to 25/kg.) Higher abatement levels might be possible if the emissions price were based on an environmental or cost-acceptability criterion.

A fundamental issue in the design of an REP or feebate system is how to distribute the refund. The refund is essentially a (negative) consumption tax, which is assessed at a fixed dollar amount per consumption unit; thus the distribution will depend on what units are chosen to measure consumption. (The emissions payment, by contrast, is an emissions tax, which is assessed at a fixed dollar amount per ton of emissions, so it does not depend on the choice of consumption units.) REPs and feebates reward or penalize firms based on their products' "emissions performance", which is defined as emissions per consumption unit.

In the case of the Swedish NOx program, a refund based on a fixed dollar rate per combustion unit clearly would not be appropriate, because combustion units (industrial boilers, stationary combustion engines, and gas turbines) vary greatly in their energy production capacity. A refund based on fuel consumption also would not be practical because the regulated combustion units use a variety of fuels (e.g., coal, oil, biofuel), and furthermore, NOx emissions are related more to the combustion process than the fuel composition. Using a monetary valuation of production output as a refund basis would be problematic because the regulated combustion units cover a wide variety of industries (electricity, heating, and various industrial processes such as paper production), and there would be no clear way to separate the value added by the combustion energy from total sales value.

The refunding method used by the NOx program is based on "useful energy" output (i.e., refunds are proportional to usable energy generated from combustion). Energy consumption is a natural valuation standard for rating emissions performance because combustion units operate fundamentally to produce energy, and furthermore, NOx emissions for a given combustion technology would tend to be proportional to energy output. Differences in emissions performance, as measured by emissions per unit energy output, are mainly a function of the combustion technology (and are minimally dependent on generating capacity); thus the regulatory incentive is primarily “technology-forcing”.

An energy-based performance metric does have limitations, however. For example, if electric energy output is used for an industrial process, the REP will incentivize efficient generation of electric power, but will not incentivize its efficient use. Looking beyond the Swedish NOx program to how such policies might be employed more generally, an REP or feebate system could be combined with complementary policies to compensate for such deficiencies. In particular, multiple feebates covering different markets could be used in a complementary manner to optimize policy effectiveness. The concept can be illustrated by considering the electric lighting market: A power generation feebate based on a ton-CO2/MWh emissions performance metric could be complemented with an electric lighting feebate based on a kW/lumen illumination performance metric in such a way that the two feebates, in combination, are approximately equivalent to a single feebate based on a ton-CO2/lumen-hour performance metric. (This method of combining complementary feebates is outlined in Appendix B.)

3. Vehicle feebates

Feebates represent an inherently technology-focused, incentive-based regulatory mechanism that could be very effective at catalyzing and accelerating the development and commercialization of low-emission automotive technologies. But unlike the Swedish NOx program, which has encountered little political opposition, vehicle feebates have not yet overcome limitations of political acceptability. For example, a feebate proposal in Canada's 2005 Budget Plan (Canada, 2005) was described in the press as "a plan to tax large vehicles and turn over the money to consumers who buy smaller cars" (Doelen, 2005). This characterization, though disparaging, is a technically accurate description of the most common type of vehicle feebate. Such feebates have the distributional characteristics of a highly progressive tax (i.e., their main effect is to transfer feebate revenue from large to small vehicles), because they rate emissions performance simply in terms of emissions per vehicle, irrespective of vehicle size or utility characteristics such as seating and load capacity.

The emissions-per-vehicle performance rating creates a strong incentive to downsize vehicles, resulting in a dilution of the feebate's technology-forcing incentive. However, economic studies of feebates (Davis et al., 1995; Greene et al., 2005) indicate that even with the downsizing incentive, only about 10% of the feebate-induced emissions reduction would actually result from a shift in the vehicle fleet mix. Most of the reduction (about 90%) would result from technology improvements. Thus, the downsizing incentive provides little benefit; but the feebate disparity between large and small vehicles, which induces the downsizing incentive, significantly limits the feebate's political acceptability and the level of technology-forcing incentive that can be induced within limits of political viability.

The feebate disparity can be mitigated by partitioning the vehicle fleet into separate classes (e.g., weight classes) and applying separate, revenue-neutral feebates to the individual classes. But class-partitioned feebates can create perverse incentives to shift vehicles between classes in order to avoid fees or capture feebates. Moreover, this approach does not address the fundamental issue that emissions-per-vehicle is an inherently inappropriate performance metric.

The refund portion of a feebate is essentially a refunded (negative) consumption tax, and like any tax it should bear some relationship to the taxed commodity's economic value. The conventional practice of distributing the refund equally between all vehicles, irrespective their economic value, is not based on a clearly articulated policy rationale. Drawing an analogy with the Swedish NOx program, this would be the equivalent of refunding the NOx charge at a fixed rate per combustion unit, irrespective of generating capacity. However, basing the refund on a vehicle's sales value (like a negative sales tax) would be impractical (e.g., a $100,000 gas guzzler would receive a huge rebate simply because it is so expensive). Clearly, the consumption units used to define the refund should be related to the vehicle's intrinsic transportation value, excluding extraneous factors such as a luxury premium.

The issue of how to best quantify emissions performance is equally relevant to emission standards and fuel economy standards (NRC 2002). U. S. CAFE standards and California's LEV standards (including the recently-enacted AB 1493 regulations for greenhouse gas emissions) are specified in terms of GHG emissions-per-vehicle limits (or equivalently, fuel consumption-per-vehicle limits), but separate limits apply to cars and light-duty trucks in order to better adapt the standard to large and small vehicles with different utility characteristics. This creates incentives for manufacturers to classify their vehicles as trucks so that they are subject to the less stringent standard (e.g. the 20.7 mpg CAFE standard for trucks, versus 27.5 mpg for cars – or in the case of AB 1493, 332 gm-CO2/mi for trucks versus 205 gm-CO2/mi for cars). Furthermore, the car/truck distinction has been subverted by the introduction of minivans, SUVs, and other “cross-over” vehicles that are technically classified as trucks but are used almost exclusively for personal transport.

One way to better specify emission standards and avoid the need for class distinctions would be to specify performance targets in terms of emissions per unit vehicle weight (vehicle-ton). The National Research Council’s CAFE analysis (NRC 2002) provides an in-depth explanation of the rationale for weight-based standards, and similar considerations apply to feebates (although the NRC report does not consider a similar approach for feebates). Emissions-per-vehicle-ton is a natural performance metric for rating vehicle emissions because vehicles function at the most basic level to move mass, and emissions tend to follow an approximately proportionate relationship to vehicle mass. Performance differences between vehicles, as measured by a weight-based metric, tend to be a function mainly of vehicle technology; thus the regulatory incentive created by a weight-based standard or feebate would be primarily technology-forcing.

The National Highway Traffic Safety Administration has recently proposed amendments to the CAFE standard (NHTSA 2005), which are based in part on the

NRC recommendations, but which establish fuel consumption limits based on vehicle footprint rather than weight. (A vehicle's “footprint” is the rectangular area inscribed by its tire centers.) The policy rationale for attribute-based standards is based on the premise that larger vehicles are inherently more fuel-consumptive than smaller vehicles; but the premise does not hold if vehicle “size” is quantified by a footprint metric because the footprint does not significantly influence fuel consumption. Vehicle footprint correlates with fuel consumption primarily because it correlates with attributes such as weight that do affect fuel consumption, but changing the footprint without changing other vehicle attributes will not necessarily affect fuel consumption to any significant extent. Nevertheless, the NHTSA proposal would allocate higher consumption allowances to large-footprint vehicles, creating an incentive to increase the footprint simply to reduce the regulations' stringency.

It might seem that a consumption-per-vehicle-ton or emissions-per-vehicle-ton performance metric could similarly encourage upweighting because increasing a vehicle’s weight, with all other things being equal, would improve its performance rating. However, increasing weight also tends to proportionately increase fuel consumption and emissions; and any upweighting incentive would have to overcome the tendency of vehicle costs, including manufacturing and operating costs, to increase with weight. These costs create a significant downweighting incentive, which is only countered by the economically valuable attributes (e.g., passenger seating and load capacity) that are associated with higher weight.

Vehicle weight tends to roughly correlate with value (as measured by sales price), but like the "useful energy" valuation standard of the Swedish NOx program, vehicle weight is an imperfect valuation standard, and complementary policies may therefore be needed to optimize policy effectiveness. For example, a weight-based feebate would not incentivize more efficient use of heavier vehicles' greater load-carrying capacity, but complementary policies such as carpooling incentives could compensate for this deficiency. Also, a weight-based feebate would not help incentivize commercialization of weight-reducing technologies such as lightweight, composite materials that can reduce vehicle weight, improve fuel economy and reduce emissions without compromising vehicle utility and safety attributes. However, this limitation could be overcome by allowing manufacturers "weight credits" for the use of such materials (e.g., if a manufacturer replaces 1000 pounds of structural steel with 600 pounds of high-strength composites, then the 400-pound difference would be added to the vehicle's weight for the purpose of determining the feebate).

Adopting a more appropriate emissions performance metric such as emissions per vehicle ton could substantially reduce the distributional imbalance of conventional vehicle feebates, but this objective could also be accomplished (even with an emissions-per-vehicle performance metric) by using class-partitioned feebates in a way that minimizes perverse incentives and "gaming". Rather than using disjoint (non-intersecting) vehicle classes, feebates can be applied to a large number of vehicle weight classes defined by overlapping weight ranges. A typical vehicle would be included in multiple weight classes and would accrue multiple feebates, so that the total feebate-induced competitive incentive to reduce emissions is strongest for vehicles of the same weight, and gradually decreases with increasing weight difference. In this way, large and small vehicles can be insulated from direct competition with each other, but in a way that avoids large feebate discontinuities between weight classes.

4. Vehicle feebate performance comparisons

Following are some illustrative comparisons of several feebate alternatives, using California's model year 2002 new vehicle fleet as a basis for comparison (CARB 2005). (Only the six major manufacturers – General Motors, Ford, Daimler Chrysler, Toyota, Honda, and Nissan – are considered in this comparison.) In contrast to more formal and comprehensive feebate analyses that have been reported in the literature, which typically compare feebate alternatives assuming a particular emissions price (Davis et al., 1995; Greene et al., 2005), a primary objective of the present comparison is to provide a sense of how the emissions price, as defined by a maximum-acceptable-cost criterion, depends on the choice of feebate structure.

The baseline policy for the comparison is an unrefunded emissions tax. The tax is based on fuel consumption rate, measured in gallons per mile (gpm), and the emissions price is \$10,000/gpm. This corresponds to a modest GHG price of \$5.62/tonne-CO2, using a fuel-to-GHG conversion factor of 8.9 kg-CO2/gal (this factor is used in CARB, 2005) and assuming a vehicle lifetime driving capacity of 200,000 miles (CARB, 2004). The tax's \$10,000/gpm emissions price is arbitrarily chosen and is not based on a maximum-cost-acceptability criterion, but all of the dollar-dimensioned quantities in the following analysis can be proportionately scaled to match any chosen emissions price.

The political acceptability of a tax or feebate policy not only depends on aggregate or average costs, but is also sensitive to the policy's distributional impacts (such as the feebate disparity between large and small vehicles). For the purposes of the following comparison, the policy cost acceptability will be quantified as the total tax or fee (i.e., positive feebate) revenue collected. (Based on the $10,000/gpm emissions price, this metric would have a value of approximately $600 million for the CA, MY 2002 fleet.) Rebates are neglected in the cost-acceptability metric, and it is assumed that the tax is not refunded (either through rebates or tax recycling), so the metric is representative of the tax- or feebate-induced distributional imbalance. For each feebate option considered, the emissions price is chosen to match the feebate's cost-acceptability metric to that of the tax.

Six policy options, designated A … F, are compared. Table 1 lists these options, along with the emissions price for each. (Note: The references to "Feebates.xls" in the tables refer to an Excel spreadsheet, which supplements this paper as an Electronic Annex. The spreadsheet data comes from CARB 2005.) In the "Policy" column, "per-vehicle" (options B, D, E, F) indicates a conventional (gpm/vehicle) emissions performance metric, and "per-weight" (option C) indicates a weight-based (gpm/vehicle-ton) metric. The 2-class option (D) is based on California's LEV vehicle classes. The 21-class option (E) uses 21 disjoint weight classes, and the 25-class option (F) uses 25 overlapping weight classes.

The tax-versus-feebate comparison is dramatic: the refund makes it possible to increase the emissions price, and hence the marginal incentive to reduce emissions, by over a factor of 10 relative to an unrefunded tax (cf. A and B). Eliminating the weight disparity allows for another factor of 3 increase (e.g., cf. B and C).

Fig. 1 provides a graphical illustration of how policy options A, B, and C operate. Vehicle fuel consumption (gpm) is plotted against vehicle test weight (lbs), and MY 2002 vehicles are represented by X's. ("Test weight" is the loaded vehicle weight at which emissions performance is tested.) The emissions tax (option A) is proportional to fuel consumption, and the shaded band at the bottom of the graph represents the fuel consumption range over which the tax is less than $250 per vehicle. The zero-feebate lines for feebate options B and C are indicated in the figure. The vertical offset of each "X" point in the figure relative to the zero-feebate line determines the corresponding vehicle model's feebate. The feebate is the product of the emissions price and this offset, and it is a fee if the point is above the line or a rebate if below. The shaded band centered on each zero-feebate line represents the range over which the feebate is between -$250 and +$250 per vehicle.

The data in Table 1 can be qualitatively understood with reference to Fig. 1. For policy options B and C, the total regulatory cost, as quantified by the total fees collected from vehicle models above the zero-feebate line, matches the total taxes collected under option A. However, the marginal regulatory incentive, represented by the feebate change per incremental change in gpm rating, varies dramatically between the three options. For option A, the $250 tax level is at 0.025 gpm, as implied by the $10,000/gpm emissions price in Table 1: ($250)/($10,000/gpm) = 0.025 gpm. By contrast, with option B the $250 fee level is only 0.0023 gpm above the zero-feebate level (based on the $110,097/gpm emissions price). This represents the emissions change corresponding to a $250 feebate change. With option C (emissions price = $343,291/gpm), the $250 level is just 0.00073 gpm above the zero-feebate level, so compared to option B the feebate is three times more sensitive to emissions performance.

Fig. 1 clearly illustrates how vehicle emissions follow a weight-proportionate trend, and how option C, which has a zero-feebate line following this same trend, is able to accommodate an emissions price much larger than option B without increasing total fees. (Options B and C are not mutually exclusive alternatives. Appendix C provides a more technical description of these options, and explains how they could be combined to achieve any preferred balance between weight-reducing and technology-forcing incentives.)

A potential objection to feebate option C is that a car purchaser could pay a fee while the purchaser of a light-duty truck with much higher emissions receives a rebate. For example the Toyota MR2 (2625 lbs, 31.8 mpg) would pay a fee of $1628, while the GM Denali (6000 lbs, 19.7 mpg) receives a rebate of $3528. But the feebate revenue flow with option C is primarily within, and not between, weight classes, so the truck’s rebate is financed mainly by other (less efficient) trucks – not by the car – and the there could actually be a net feebate revenue transfer from trucks to cars if the latter are more competitive in terms of emissions per vehicle-ton. (This is the case in the MY 2002 example: with option C, the total feebate revenue transfer between vehicles up to a 4000-lb weight ceiling and vehicles over 4000 lbs would be 6.4% of aggregate fees, with the direction of revenue flow from large to small vehicles. On the other hand, with option B the revenue transfer across the 4000-lb ceiling would be far greater – 96.4% of total fees – so the political perception of this kind of feebate as “a plan to tax large vehicles” is wholly justified.)

Another consideration favoring option C over option B is that while option B appears to create a much stronger emissions-reducing incentive for larger vehicles, it is actually weight-neutral from the perspective of marginal competitive incentives, whereas option C subjects larger vehicles to greater emissions competition. For example, if the zero-feebate level were to drop by 1%, then under option C the resulting incremental feebate cost for a 5000-lb vehicle that has not changed its emissions performance would be twice that of a 2500-lb vehicle; but under option B the cost increment would be the same for both. It makes sense that the incremental cost should be weight-proportionate, because vehicle emissions are roughly weight-proportionate, and application of a particular emissions-reduction technology to larger vehicles will typically result in a correspondingly greater reduction in per-vehicle emissions (and greater operating cost savings).

The above considerations notwithstanding, there may be some merit to considering class-partitioned feebate structures that further minimize or eliminate feebate revenue transfer between large and small vehicles, avoiding any possibility that the policy might be perceived as an “SUV subsidy” or an “SUV tax”. Fig. 2 illustrates the operation of the class-partitioned feebate options D, E, and F. (As in

Fig. 1, zero-feebate lines are indicated, and the shaded bands represent the $250 feebate range.)

Option D is a conventional 2-class feebate based on the two vehicle classes ("cars" and "trucks") used by California's LEV program. (The "truck" class includes pickups, minivans, and SUVs. The classes are not defined strictly by weight, so there is some overlap between their weight ranges.) The LEV class partitioning mitigates the feebate disparity between large and small vehicles (allowing the emissions price to be increased – cf. options B and D in Table 1), but the separation between the zero feebate lines for cars and trucks would create a strong incentive for manufacturers and consumers to favor trucks over cars. (The feebate for a truck would be $2817 lower than that of a car with the same fuel consumption rate.)

Option E is a 21-class feebate, which is revenue-neutral for each separate test weight in the MY 2002 fleet. (The 21 test weights are listed in Table 2.) There are several advantages to this type of system: First, the elimination of feebate revenue transfer between classes makes it possible to significantly increase the emissions price within acceptable cost limits (compare options D and E in Table 1). Second, there is no need to define a common performance metric for rating large and small vehicles. (With just one test weight per class, it does not matter whether the emissions performance rating is weight-based.) Third, by using a large number of weight classes, the feebate discontinuities of the type exhibited by option D are diminished. However, with this type of system individual vehicle models can have very large market shares within their weight classes, which can diminish manufacturers’ emissions-reduction incentive and increase their incentive to shift vehicle weights in order to avoid fees or capture greater rebates. For example, the feebate is zero for the first three classes because each comprises just one model. (The 2125-lb class is the Honda Insight, the 2500-lb class is the Toyota Echo, and the 2625-lb class is the Toyota MR2.) If the Insight’s test weight were increased from 2125 lbs to 2500 lbs (and its emissions increased proportionately), it would accrue a rebate of $2624 under option E; but the rebate would be financed entirely by fees on the Echo, creating an incentive for Toyota to increase the Echo’s weight and avoid the fee. Similarly, the Prius, which has 53% market share in the 3125-lb class, would have a smaller (13%) market share if it were moved into the 3250-lb class. Even with the weight-related emissions increase, this would boost the Prius rebate from $3635 to $5132. Alternatively, if the Prius weight was not changed, then manufacturers of other models in the 3125-lb class (e.g., the Honda S2000) could substantially reduce their fees by changing their vehicle weights. (With the large increase in Prius sales since 2002, the market share effects would be that much greater.)

Option F is a 25-class feebate, which is similar to option E except that the weight classes cover wider, overlapping weight ranges. (The weight ranges are listed in Table 3.) Each weight class comprises at most five test weights, and each test weight is included in five classes. For example, the Prius (3125 lbs) is in classes 7–11. The total feebate for each model is determined by averaging the individual feebates for its five associated classes. (In this example, the individual feebates are based on an emissions-per-vehicle performance metric, which creates a moderate downweighting incentive. But because the classes have fairly narrow weight ranges it would not make much difference if weight-based feebates were used.)

Option F substantially maintains the advantages of option E, while enhancing emissions reduction incentives and diminishing the “weight gaming” incentives. For example, the Insight would receive a $3187 rebate, and increasing its test weight to 2500 lbs (with a concomitant fuel consumption increase) would only increase the rebate to $3223. Similarly, upweighting the Prius to 3250 lbs would result in a not-so-drastic rebate increase, from $4779 to $5149. Under current (2005) market conditions, the Prius’ larger market share would diminish the incentive to change its weight; however there would be an increased incentive to change competing vehicles’ weights in order to avoid fees. This incentive could be diminished by using broader weight categories (so that more vehicles compete with the Prius).

Table 4 summarizes data for the CA, MY 2002 vehicle fleet and the six policy options, for the entire fleet and disaggregated by manufacturer. The fleet characteristics include sales and sales share (by vehicle count), average vehicle test weight, average fuel consumption per vehicle, and average fuel consumption per vehicle-ton. (This last characteristic is a good measure of a manufacturer’s emissions technology performance.) For each of the policy options A … F, the data includes the average tax (option A) or feebate (options B … F) per vehicle, the average tax or feebate per vehicle-ton, and the rms (root-mean-square) tax or feebate per vehicle.

All of the policy options are normalized to the same cost-acceptability metric (aggregate taxes or fees). This cost balancing is reflected in the rms feebate values, which are close to $1000 for all five feebate options. But the rms tax ($428) is less than half this value because the tax is paid by all vehicles, whereas under the feebate options only about half of the vehicles pay fees. The tax ranges from $144 (for the Honda Insight) to $649 (for the Ford Range Rover). The maximum rebate for all feebate options is $4953 (for the Prius, with option C), and the maximum fee is $7836 (for the Dodge Viper, also with option C).

It is interesting to note that among the six major manufacturers, Honda's 2002 vehicles not only have the lowest average weight and (as expected) the lowest fuel consumption per vehicle, but also have the lowest fuel consumption per vehicle-ton. Consequently, Honda would derive a net rebate under all feebate options. This clearly indicates that small cars can compete equally with trucks on an emissions-per-vehicle ton basis.

The conventional feebate options (B and D) would strongly penalize manufacturers of larger vehicles, whereas the alternatives (C, E, and F) tend to be more weight-neutral and technology-forcing (i.e., the latter feebates correlate more to fuel consumption per vehicle-ton rather than per vehicle). For example, under option B General Motors would incur net fees of $338 per vehicle because its products are generally specialized in the heavier weight categories. However, GM's fuel efficiency is actually fairly good within its vehicles' weight categories, almost equaling Toyota's performance on a per-vehicle-ton basis. Hence under option C GM would receive a modest net rebate of $117. (Under option F GM would incur a small net fee of $82, but this would become a rebate if the individual feebates were weight-based.)

5. Conclusion

The Swedish NOx program demonstrates how a well-designed, feebate-type regulatory instrument can effectively focus regulatory incentives on the most cost-effective, technology-based emissions reduction strategies in a way that motivates industry to achieve maximum emissions reduction within defined cost-acceptability limits. This kind of success can be achieved by appropriately defining the class of products covered by each feebate, and defining a measure of emissions performance that is appropriate for those products. In the case of automotive vehicle feebates, policy efficacy and political acceptability could be greatly improved by either rating vehicle emissions performance in terms of a weight-based valuation metric (analogous to the “useful energy” valuation metric used by the Swedish NOx program), which correlates with transportation utility, or by using multiple feebates, each of which applies to a limited class of vehicles (e.g. weight classes) having similar transportation utility. Under typical market conditions this approach could make it possible to increase emission reduction incentives by a factor of three relative to a conventional feebate that treats all vehicles as functionally equivalent commodities.

Appendix A. Revenue-neutral feebates: general principles

A feebate applies to a class of product categories (e.g., vehicle models, or electric power from different generating sources) that are sold into a particular market sector, and it is equivalent to an emissions tax combined with a refunded (negative) consumption tax. The emissions tax per consumption unit applied to product category i, denoted as $t_i^{(e)}$, is proportional to that category's "emissions intensity", which is defined as emissions per consumption unit and is denoted as μ_i,

$$t_i^{(e)} = p^{(e)}\,\mu_i\,. \tag{A.1}$$

The proportionality constant $p^{(e)}$ is a mandated "emissions price", which is measured in dollars per emissions unit. The consumption tax is refunded at a fixed rate $t^{(c)}$ per consumption unit for all product categories, irrespective of their emissions performance.

The total sales quantity for product category i, measured in consumption units, is denoted as q_i. (q_i could be defined as, e.g., annual sales of a particular vehicle model, or annual energy sales from a particular power generating source.) The consumption tax $t^{(c)}$ is defined so that the total consumption tax revenue matches the total emissions tax revenue,

$$\sum_i t^{(c)}\,q_i = \sum_i t_i^{(e)}\,q_i \quad \rightarrow \quad t^{(c)} = p^{(e)}\,\mu^{(0)}\,, \tag{A.2}$$

wherein $\mu^{(0)}$ is a "zero-feebate level", defined as the sector-wide aggregate emissions intensity,

$$\mu^{(0)} = \frac{\sum_i q_i\,\mu_i}{\sum_i q_i}\,. \tag{A.3}$$

The feebate f_i per consumption unit assessed to product category i is the balance of the emissions tax and the refund,

$$f_i = t_i^{(e)} - t^{(c)} = p^{(e)}\,(\mu_i - \mu^{(0)})\,. \tag{A.4}$$

Based on definition (A.3), the feebate is revenue-neutral,

$$\sum_i q_i\ f_i = 0\,. \tag{A.5}$$

(In practice, the definition of $\mu^{(0)}$ may be modified to deviate from strict revenue neutrality. For example the Swedish NOx program retains about 0.6% of the fee revenue to cover administrative costs.)

The feebate approach greatly reduces distributional costs relative to an unrefunded emissions tax with the same emission price. However, the marginal incentive to improve emissions performance is similar to that of a tax. The marginal change in the feebate f_i for product category i, per marginal change in emissions intensity μ_i (with consumption quantities q_i held constant), is

$$\frac{\partial\, f_i}{\partial\, \mu_i} = p^{(e)}\,(1 - \frac{q_i}{Q})\,, \tag{A.6}$$

wherein Q is the total market size,

$$Q = \sum_i q_i\ . \tag{A.7}$$

The factor $q_i\,/\,Q$ in Eq. (A.6) represents the market share of category i. If this factor is very small ($q_i << Q$) it can be neglected and the marginal incentive is equal to the emissions price $p^{(e)}$, the same as that of an unrefunded emissions tax,

$$\frac{\partial\, t_i^{(e)}}{\partial\, \mu_i} = p^{(e)}\,. \tag{A.8}$$

If product category i has significant market share, the marginal abatement incentive represented by Eq. (A.6) is diminished by the factor $(1 - q_i / Q)$, but this “market share” effect is counterbalanced by the marginal change in other products’ feebates,

$$\frac{\partial f_j}{\partial \mu_i} = -p^{(e)} \frac{q_i}{Q} \qquad (j \neq i)\,. \tag{A.9}$$

This change represents a pure “competition” effect, in that a firm’s feebate gain or loss can change through no action of its own, but solely due to its competitors’ actions. (Economic analyses of feebates (Fischer, 2003; Sterner, 2000) generally do not take into account the competition effect.) The competition effect does not exist with an emissions tax,

$$\frac{\partial t_j^{(e)}}{\partial \mu_i} = 0 \qquad (j \neq i)\,. \tag{A.10}$$

The feebate-induced competitive incentive, as defined by a firm’s marginal feebate change *relative to its competitors,* does not depend on market shares,

$$\frac{\partial (f_i - f_j)}{\partial \mu_i} = p^{(e)} \qquad (j \neq i)\,. \tag{A.11}$$

An identical result holds for an emissions tax,

$$\frac{\partial (t_i^{(e)} - t_j^{(e)})}{\partial \mu_i} = p^{(e)} \qquad (j \neq i)\,. \tag{A.12}$$

Thus, from the perspective of competitive incentives a feebate is equivalent to an emissions tax.

To illustrate the effect of the feebate-induced competitive incentive, consider a market that is dominated by two competing products: product 1, which has 90%

market share, and product 2, which has the remaining 10% share. If the emissions price is $100/ton, then a 1-ton reduction in per-unit emissions from product 1 will yield a $10 per-unit feebate gain. If it costs $20 to achieve the 1-ton abatement, the manufacturer of product 1 would not be motivated to make the investment based solely on an analysis of its own costs and benefits. However, the $10 feebate gain would be financed by a $90 increase in per-unit feebates from product 2, which may give the first product's manufacturer a sufficient competitive advantage to justify the extra abatement cost. On the other hand, the feebate will not motivate the manufacturer to make an investment that increases its own costs more than that of its competitor; hence the feebate-induced abatement cost will be guaranteed not exceed the mandated $100/ton emissions price.

As indicated by Eqs. (A.6) and (A.9), a firm's emissions performance will affect its competitors' as well as its own feebates, and the feebate changes will be apportioned between products in such a way that those with small market shares are most affected, while those with large market shares are least affected. This distributional characteristic of feebates has a couple of positive policy implications: First, because the feebate tends to have minimal effect on dominant products and product technologies with large market shares, consumers of the dominant products would not see significant price increases – at least not unless and until a significantly less emissions-intense alternative has gained market acceptance and achieved significant market share. This price stabilization tendency would tend to minimize adverse economic effects and would enhance feebates' political acceptability. Second, because the feebate incentive is focused on products with small market shares, entry-level products with high emissions will face a significant barrier to market entry, while market penetration of new, low-emission products and technologies will be significantly accelerated by the rebate subsidy. As low-emission products gain market share and attain economies of scale, their rebate subsidies will automatically diminish without additional regulatory intervention.

Appendix B. Complementary feebates

Feebates can be combined in a complementary manner to improve emissions-reducing technology in all processes leading from emissions to economically useful end products. For example, Section 2 discusses the complementary use of an energy production feebate and an electric lighting feebate, the combination of which functions to minimize GHG emissions per illumination unit. A similar approach could be used in the automobile industry, for example, to combine low-emission electric power generation with energy-efficient, plug-in hybrid vehicles, or to combine low-emission hydrogen fuel production with efficient fuel cell vehicles.

To illustrate this approach we start with Eq. (A.4), which can be stated as

$$f_i = p^{(e)}\left(\mu_i - \frac{E}{Q}\right), \tag{B.1}$$

wherein E is the total emissions generated by all products covered by the feebate,

$$E = \sum_i q_i \, \mu_i \, . \tag{B.2}$$

Returning to the electric lighting example, the product categories are illumination products, each of which has a lifetime illumination capacity rated in lumen-hours;

and the quantity factors q_i and Q are measured in lumen-hours. The emissions intensity μ_i represents GHG emissions per lumen-hour. This “illumination emissions intensity” comprises two factors: an “energy emissions intensity”, which will be denoted as μ_i' and which has units of GHG emissions per MWh, and an “illumination energy intensity”, which will be denoted as μ_i'' and which has units of MWh per lumen-hour,

$$\mu_i = \mu_i' \, \mu_i'' \, . \tag{B.3}$$

The total quantity of electric energy (MWh) used to generate illumination quantity Q is denoted as Q', and Eq. (B.1) is restated as follows,

$$\begin{aligned} f_i &= p^{(e)} \left(\mu_i' \, \mu_i'' - \frac{E}{Q'} \frac{Q'}{Q} \right) \\ &= p^{(e)} \left(\mu_i' - \frac{E}{Q'} \right) \left(\mu_i'' - \frac{Q'}{Q} \right) + p^{(e)} \left(\mu' - \frac{E}{Q'} \right) \frac{Q'}{Q} + p^{(e)} \, \frac{E}{Q'} \left(\mu'' - \frac{Q'}{Q} \right). \end{aligned} \tag{B.4}$$

The first term on the right side of this expression is typically small in relation to the second and third terms and will be neglected. Also, the factor E / Q' in the remaining terms, which represents the aggregate energy emissions intensity of electricity energy that is used for illumination, can be approximated as the aggregate energy emissions intensity across the entire electric power industry. With these two simplifications, the second and third terms represent two separately administered feebates. The factor $p^{(e)} \, (\mu' - E / Q')$ in the second term represents a feebate that is applied to electric power generation. This feebate would be included in consumers’ utility bills or in utilities’ operating costs. (The factor Q' / Q converts the feebate from per-MWh units to per-lumen-hour units.) The third term represents a feebate that is applied to electric lighting. This feebate would be included in the prices of lighting products. The feebate is based on electricity consumption, and the factor $p^{(e)}\, E / Q'$ is an electricity price (\$/MWh) representing the monetized environmental cost of electricity.

Appendix C. Vehicle feebate options B and C

The feebate option B discussed in Section 4 can be described by Eqs. (A.4) and (A.3),

$$f_i = p^{(e)} \left(\mu_i - \frac{\sum_j q_j\, \mu_j}{\sum_j q_j} \right), \quad \text{option B}\,, \tag{C.1}$$

wherein vehicle model i is characterized by its emissions per vehicle, μ_i, and its sales volume, q_i (in vehicle units); and f_i is the feebate per vehicle. Option C is described by a similar Eq.,

$$f_i' = p^{(e)} \left(\mu_i' - \frac{\sum_j q_j'\, \mu_j'}{\sum_j q_j'} \right), \quad \text{option C}\,, \tag{C.2}$$

wherein the primes indicate weight normalized values: μ_i' is the emissions per vehicle-ton for model i; q_i' is its sales volume in vehicle-ton units; and f_i' is the feebate per vehicle-ton. Denoting the vehicle weight for model i as w_i (in tons), these quantities are

$$\mu_i' = \mu_i / w_i\,, \tag{C.3}$$

$$q_i' = q_i \, w_i \,, \tag{C.4}$$

$$f_i' = f_i \, / \, w_i \,. \tag{C.5}$$

Making these substitutions in Eq. (C.2) yields

$$f_i = p^{(e)} \left(\mu_i - \frac{\sum_j q_j \, \mu_j}{\sum_j q_j \, w_j} w_i \right), \quad \text{option C}. \tag{C.6}$$

Feebate options B and C are not mutually exclusive alternatives; they can be linearly interpolated to define a range of intermediate options. Denoting the interpolation factor as c, the interpolated feebate is

$$f_i = p^{(e)} \left(\mu_i - (1-c) \frac{\sum_j q_j \, \mu_j}{\sum_j q_j} - c \frac{\sum_j q_j \, \mu_j}{\sum_j q_j \, w_j} w_i \right). \tag{C.7}$$

For any value of c the feebate will be revenue-neutral, and c can be chosen to achieve any preferred balance between weight-reducing and technology-forcing incentives. With $c = 0$ Eq. (C.7) reduces to option B (Eq. (C.1)); and with $c = 1$ it reduces to option C (Eq. (C.6)) If c is chosen to maximize the emissions price (subject to the cost-acceptability constraint defined in Section 4, and assuming the CA, MY 2002 vehicle fleet), the result is $c = 0.9885$, almost identical to option C, and the emissions price only increases by 0.25% relative to option C. Thus, in this case the interpolation provides no significant benefit over option C.

Endnote (page 6):

[1] Millock and Sterner (2004) erroneously state the NOx emissions of Swedish coal power plants as 0.246 lbs/MWh thermal, or 0.56 lbs/MWh electric (p. 126). These

values should be 0.246 kg/MWh, and 0.56 kg/MWh, respectively, or equivalently 0.542 lbs/MWh and 1.230 lbs/MWh. By comparison, typical U. S. coal plant emissions are 5 lbs/MWh.

References

Ågren, C., 2000. Nitrogen oxides: Emissions charge works well. Acid News 2, 1-4.
http://www.acidrain.org/
http://www.acidrain.org/pages/publications/acidnews/2000/AN2-00.pdf

Barg, S., Duraiappah, A., Exan, V. E., 2000. Economic Instruments for Environmental Policy Making in Ontario. Published by the International Institute for Sustainable Development. Published by the International Institute for Sustainable Development. pp. 48-50.
http://www.ene.gov.on.ca/envision/ergreport/downloads/report_paper2.pdf

Bayindir-Upmann, T., Raith, M. G., 2003. Environmental Taxation and the Double Dividend: A Drawback for a Revenue-Neutral Tax Reform. Institute of Mathematical Economics, Working Paper No. 274.
http://www.wiwi.uni-bielefeld.de/~imw/Papers/
http://www.wiwi.uni-bielefeld.de/~imw/Papers/files/imw-wp-274-revised.pdf

Canada Department of Finance, 2005 Budget Plan.

http://www.fin.gc.ca/access/budinfoe.html

http://www.fin.gc.ca/budget05/pdf/bp2005e.pdf

(CARB) California Air Resources Board, 2004. Estimation of Average Lifetime Vehicle Miles of Travel, in Notice of Public Availability of Modified Text, including Attachment II: Additional Supporting Documents and Information, posted October 19, 2004.

http://www.arb.ca.gov/regact/grnhsgas/grnhsgas.htm

http://www.arb.ca.gov/regact/grnhsgas/vmt.pdf

(CARB) California Air Resources Board, 2005. The California, model year 2002 fleet data is tabulated in the following two CARB-supplied Excel files,

for_costeffect,_inventory,etc_082404.xls (see "std_regressions" tab)

Corporate Fleet Average Weights (2002).xls

This data can be obtained by sending an information request to CARB (per the instructions at http://www.arb.ca.gov/html/recordsaccess.htm?PF=Y, with a copy to phughes@arb.ca.gov), specifying the "data and calculations supporting the AB 1493 regulations" and identifying the above files. Also, the Electronic Annexes accompanying the online version of this paper include copies of the above files, along with explanatory notes from CARB and this author's calculations based on above files.

Davis, W.B., Levine, M.D., Train, K., Duleep, K.G., 1995. Effects of Feebates on Vehicle Fuel Economy, Carbon Dioxide Emissions, and Consumer Surplus, DOE/PO-0031. Office of Policy, US Department ofEnergy, Washington, DC, February.
http://eetd.lbl.gov/ea/teepa/pdf/DOE-PO-0031.html

Doelen, C.V., 2005. ‘Feebates’ scare carmakers, in The Windsor Star, Feb. 24, 2005, p. A1.

Fischer, C., 2003. Market Power and Output-Based Refunding of Environmental Policy Revenues. Discussion Paper 03-27, published by Resources for the Future.
http://www.rff.org/Documents/RFF-DP-03-27.pdf

Greene, D.L., Patterson, P.D., Singh, M., Li., J., 2005. Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy. Energy Policy 33, 757–775.
http://www.sciencedirect.com/science/journal/03014215

Millock, K., Sterner, T., 2004. NOx Emissions in France and Sweden, in: Harrington, W., Morgenstern, R.D., Sterner, T. (Eds.), Choosing Environmental Policy: Comparing Instruments and Outcomes in the United States and Europe. Resources for the Future, Washington, DC, pp. 117-132. http://www.rff.org/rff/RFF_Press/CustomBookPages/Choosing-Environmental-Policy.cfm

(NHTSA) National Highway Traffic Safety Administration, 2005. Average Fuel Economy Standards for Light Trucks Model Years 2008-2011. http://www.nhtsa.gov/ (Select Laws/Regulations → CAFE → Notice of Proposed Rulemaking.)

(NRC) National Research Council, 2002. Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards. National Academy Press, Washington, DC.
http://books.nap.edu/catalog/10172.html

Sterner, T., Hoglund, L., 2000. Output-Based Refunding of Emission Payments: Theory, Distribution of Costs, and International Experience. Discussion Paper 00-29, published by Resources for the Future.
http://www.rff.org/rff/Documents/RFF-DP-00-29.pdf

Wolff, G.H. 2000. When Will Business Want Environmental Taxes? Published by Redefining Progress.

http://www.redefiningprogress.org/publications/

Table 1. Tax and feebate policy options (cf. Feebates.xls, cells CA8:CF8)

	Policy	Emissions price, $/gpm ($/tonne-CO2)
A	Unrefunded emissions tax	10,000 (5.62)
B	feebate, per-vehicle, 1-class	110,097 (61.85)
C	feebate, per-weight, 1-class	343,291 (192.86)
D	feebate, per-vehicle, 2-class (LEV)	191,182 (107.41)
E	feebate, per-vehicle, 21-class (disjoint)	377,069 (211.84)
F	feebate, per-vehicle, 25-class (overlapping)	348,971 (196.05)

Table 2. 21-class feebate (cf. Feebates.xls, column M and cells CM3:DG4)

Class	Test weight (lb)
1	2125
2	2500
3	2625
4	2750
5	2875
6	3000
7	3125
8	3250
9	3375
10	3500
11	3625
12	3750
13	3875
14	4000
15	4250
16	4500
17	4750
18	5000
19	5250
20	5500
21	6000

Table 3. 25-class feebate with overelapping weight ranges (cf. Feebates.xls, cells DH3:EF4)

Class	Test weights (lb)
1	2125
2	2125 2500
3	2125 2500 2625
4	2125 2500 2625 2750
5	2125 2500 2625 2750 2875
6	2500 2625 2750 2875 3000
7	2625 2750 2875 3000 3125
8	2750 2875 3000 3125 3250
9	2875 3000 3125 3250 3375
10	3000 3125 3250 3375 3500
11	3125 3250 3375 3500 3625
12	3250 3375 3500 3625 3750
13	3375 3500 3625 3750 3875
14	3500 3625 3750 3875 4000
15	3625 3750 3875 4000 4250
16	3750 3875 4000 4250 4500
17	3875 4000 4250 4500 4750
18	4000 4250 4500 4750 5000
19	4250 4500 4750 5000 5250
20	4500 4750 5000 5250 5500
21	4750 5000 5250 5500 6000
22	5000 5250 5500 6000
23	5250 5500 6000
24	5500 6000
25	6000

Table 4. Summary data for CA, MY 2002 fleet and policy options A-F (cf. Feebates.xls, cells BX11:CF34)

		All	GM	Ford	DC	Toyota	Honda	Nissan
	sales (vehicles)	1425731	347379	294168	209747	325638	178785	70014
	sales share	100.0%	24.4%	20.6%	14.7%	22.8%	12.5%	4.9%
	avg test wt (lbs/vehicle)	4114	4450	4313	4260	3911	3471	3761
	fuel consumption (gpm/vehicle)	0.0419	0.0449	0.0442	0.0454	0.0392	0.0333	0.0402
	fuel consumption (gpm/vehicle-ton)	0.0203	0.0202	0.0205	0.0213	0.0201	0.0192	0.0214
A	avg tax, $/vehicle	419	449	442	454	392	333	402
	avg tax, $/vehicle-ton	203	202	205	213	201	192	214
	rms tax, $/vehicle	428	458	450	460	402	339	411
B	avg feebate, $/vehicle	0	338	261	385	-289	-939	-184
	avg feebate, $/vehicle-ton	0	152	121	181	-148	-541	-98
	rms feebate, $/vehicle	1009	1024	956	947	997	1163	966
C	avg feebate, $/vehicle	0	-117	117	693	-193	-684	660
	avg feebate, $/vehicle-ton	0	-53	54	325	-99	-394	351
	rms feebate, $/vehicle	1111	1123	925	1460	995	1032	1255
D	avg feebate, $/vehicle	0	268	226	418	-320	-778	-58
	avg feebate, $/vehicle-ton	0	121	105	196	-164	-448	-31
	rms feebate, $/vehicle	1045	817	1107	1126	1109	1213	724
E	avg feebate, $/vehicle	0	-202	156	574	-207	-395	595
	avg feebate, $/vehicle-ton	0	-91	73	269	-106	-228	317
	rms feebate, $/vehicle	1098	1115	1033	1511	855	919	1221
F	avg feebate, $/vehicle	0	82	162	565	-343	-667	522
	avg feebate, $/vehicle-ton	0	37	75	265	-176	-384	278
	rms feebate, $/vehicle	1100	984	1008	1511	1054	1004	996

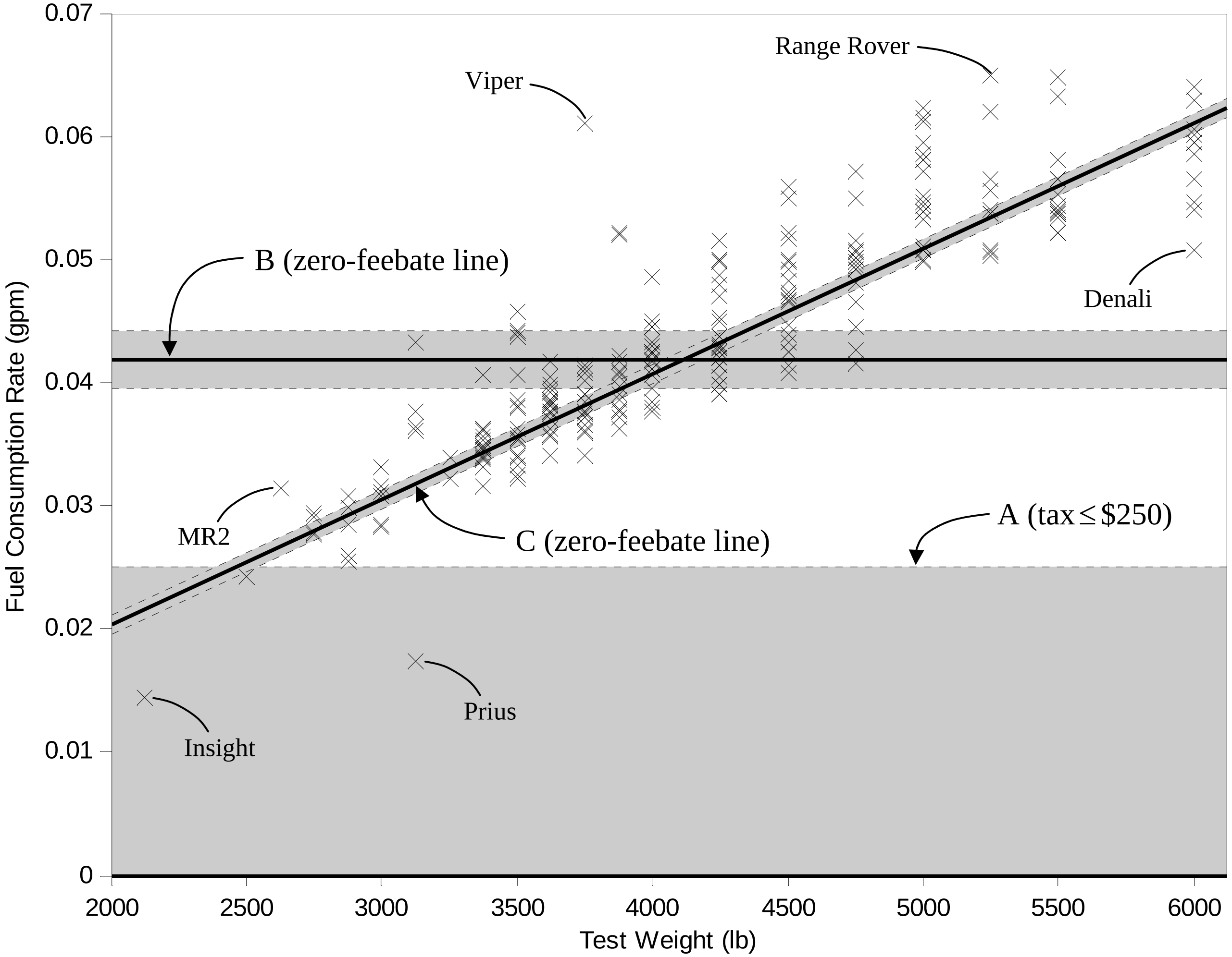

Fig. 1. Fuel consumption versus weight for policy options A, B, and C (cf. Feebates.xls, columns L and M and cells CI5:CJ5)

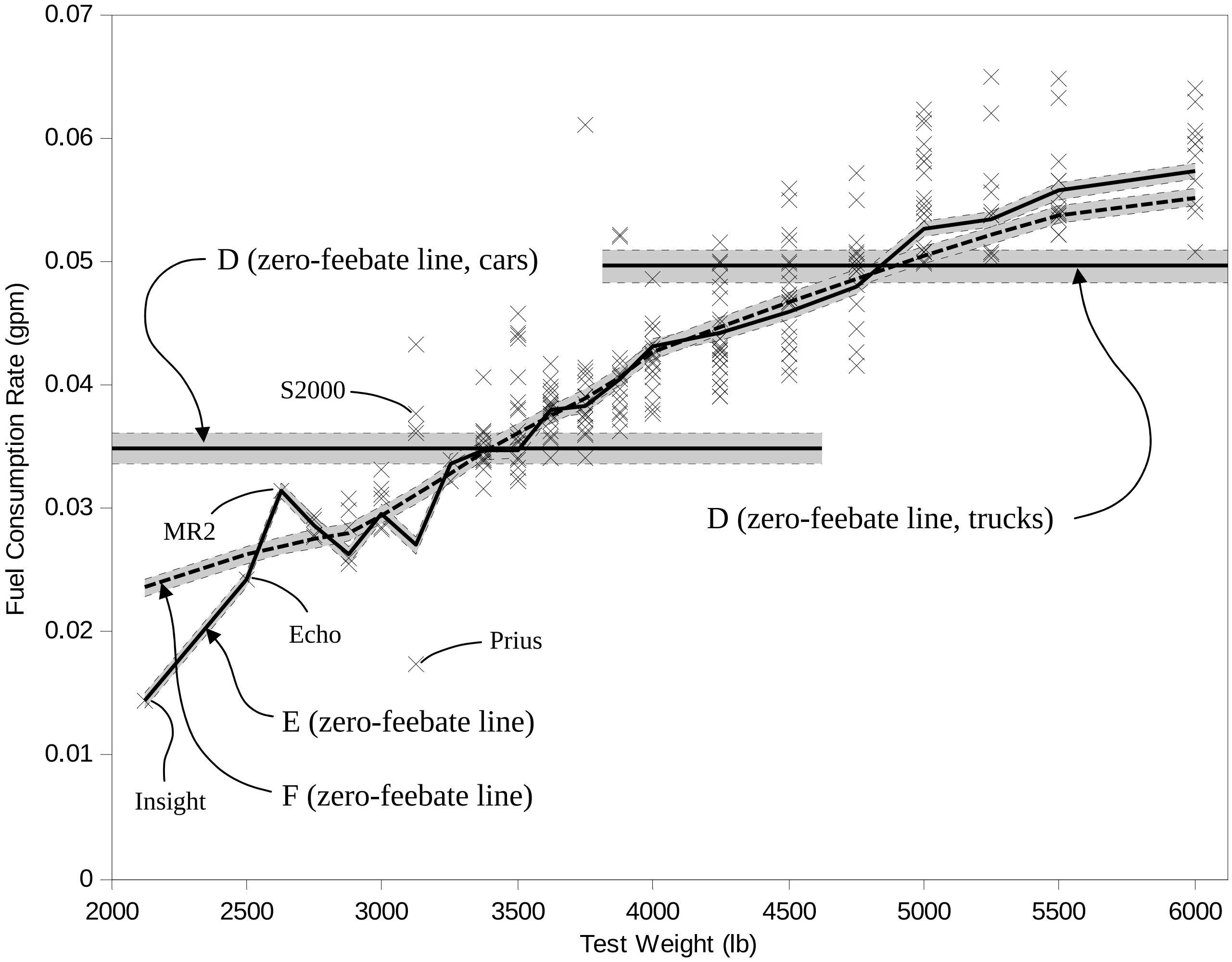

Fig. 2. Fuel consumption versus weight for policy options D, E, and F (cf. Feebates.xls, columns L and M and cells CK5:EF5)