FINAL REPORT

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Potential Design, Implementation, and Benefits of a Feebate Program for New Passenger Vehicles in California

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DISCLAIMER

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ABSTRACT

A team of researchers from the University of California completed a comprehensive study to assess the potential design, implementation, and benefits of a feebate program for new light-duty vehicles in California as well as possible stakeholder responses. The study's research plan applied a variety of methodologies, including: case studies of existing policies, quantitative modeling of market responses by manufacturers and consumers, focus groups, stakeholder interviews, and a large-scale survey of California households.

The study finds that feebate policies can be used in California to achieve additional reductions in greenhouse gases from new passenger vehicles beyond those projected from emission standards alone at a net *negative* social cost. Different feebate program configurations could lead to greater reductions, but require tradeoffs. Factors beyond California's direct control also determine the effectiveness of feebates. Because California is roughly 10% of the domestic new vehicle market, a California-only feebate would lack the leverage to induce major vehicle design changes, with most of the emissions reductions coming instead from sales-mix shifts. Additionally, feebates are observed to interact with the stringency of national emissions standards. If standards become very stringent, feebates offer reduced incremental benefits because only relatively expensive technology will be available for adoption in response to feebates.

With regard to stakeholders, the statewide survey of 3,000 households indicates that consumers are generally concerned about climate change and energy independence, and that, based on an initial understanding, three-fourths would be supportive of feebate programs. As for industry, modeling results suggest that new vehicle sales levels would decline under all feebate programs, resulting in industry revenues falling on the order of 1 percent (or several hundred million dollars per year). Interviews with automakers indicates that their views on feebates are mixed, with details of program design being a key determinant.

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EXECUTIVE SUMMARY

The California Global Warming Solutions Act of 2006 (AB 32) calls for California's greenhouse gas (GHG) emissions to return to 1990 levels by 2020. The California Air Resources Board, designated the lead agency to implement AB 32, produced a Scoping Plan, which specifies the evaluation of feebates as a possible complement to or substitute for California's GHG standards limiting greenhouse gas emissions from new light-duty vehicles. Feebates are market-based policies for encouraging emissions reductions from new passenger vehicles by levying fees on relatively high-emitting vehicles and providing rebates to lower-emitting vehicles. Whether or not revenue neutrality is a requirement, a feebate policy would need procedures for adjusting fees and rebates to take into account the changes in vehicle offerings and new vehicle sales mix that occur over time.

A team of researchers from the University of California completed a comprehensive study to assess the potential design, implementation, and benefits of a feebate program in California as well as possible stakeholder responses. This document is the Final Report for the study. It finds that feebate policies can be used in California to achieve additional reductions in greenhouse gases from new passenger vehicles beyond those projected from emission standards alone. Specifically, feebate policies affect the average emissions levels (measured in grams of CO_2-equivalent per mile, or g/mi) for the new vehicle fleet sold in each model year. The amount will depend on the design features of the feebate policy and other modeling assumptions. Based on study results, a moderate feebate program based on a footprint system (similar to the national emissions standards for MY2012-2016) with average rebates of $600 and average fees of $700 yields an average reduction of 9 g/mi versus a no-feebate scenario for the period 2011-2025 (a 3% improvement). This translates to 3 $MMTCO_2E$ of total emission reductions in California in 2020, about 2 percent of the reductions needed to achieve the AB 32 target or about 10 percent of reductions expected from the California Light-Duty Vehicle Greenhouse Gas Standards. By way of comparison, these reductions are on a par with the Scoping Plan's combined expected reductions from two sources: the Million Solar Roofs program, and High Speed Rail.

Different configurations of a feebate program could lead to greater reductions, but would require some tradeoffs. Specifically, the footprint-based system requires the smallest average levels of fees and rebates, but also yields the smallest emissions reductions. Of the alternatives considered in the study, a system based on a single benchmark for all new vehicles yields the largest emissions reductions, but also the largest levels of fees and rebates. The new vehicle sales shifts produced by this option also yield the largest reduction in consumer welfare. However, a more complete evaluation takes into account the cost of administering the program, as well as the social benefit from additional fuel savings over the full lifetime of a more efficient vehicle fleet (beyond those already included in the consumer welfare calculation). When all these factors are taken into account, there is a net *gain* in social benefit associated with all feebate programs we considered, with the largest gain coming from a program with a single benchmark system. In other words, feebate programs reduce emissions at a net *negative* social cost.

The automobile industry would also be affected differently depending on the program design. In general, model results suggest that new vehicle sales in California would decline under all feebate programs, resulting in industry revenues falling on the order of 1 percent or several hundreds of million dollars to one billion dollars per year. This decline is to be expected under the assumptions of our analysis, which require that feebate programs (1) cover administrative costs, (2) cover ZEV mandate vehicles that would receive rebates, and (3) be revenue neutral. Fees outweigh rebates, contributing to higher average new vehicle prices and lower new vehicle sales. Footprint-based feebates yield the smallest sales decreases, and single benchmark systems yield the largest sales decreases.

Factors beyond California's direct control determine the effectiveness of feebates for producing additional emission reductions. For example, because California is roughly 10% of the domestic new vehicle market, a California-only feebate would lack the leverage to induce major vehicle design changes. Most of the reductions from California-only feebate programs would come from consumers purchasing greater volumes of lower-emitting vehicles through sales mix shifts. The study investigates the implications for feebate programs with greater market coverage using two additional cases: (1) California plus thirteen "Opt-in States," and (2) a national feebate program. Results are summarized in Table ES-1.

Table ES- 1. Effect of Feebate Programs For Three Levels of Market Coverage

Scenario	Reduction of Average New Vehicle Emission Rates in CA MY2011-2025 (g/mi)	Percent Change in Average New Vehicle Emission Rates in CA MY2011-2025	Average Fee per New Vehicle	Average Rebate per New Vehicle	Total Emission Reductions from Feebates in 2020 in CA ($MMTCO_2E$)
California-only	9 g/mi	3% reduction	$700	$600	3 MMT
California + 13 "Opt-In" States	12 g/mi	5% reduction	$675	$550	5 MMT
Entire U.S.	24 g/mi	10% reduction	$600	$500	9 MMT

Note: All scenarios assume a feebate program based on vehicle footprint. Fees and rebates are established based on a rate of $20 per g/mi (roughly equivalent to a carbon price of $200 per tonne of CO_2) and a benchmark that maintains revenue neutrality. Opt-in States are those that have adopted California's GHG standards and together with California represent between 35% and 40% of the U.S. automobile market.

The study finds that expanding a feebate program to a broader market will induce manufacturers to design vehicles with lower emission rates, leading to greater emission reductions. For example, under a national feebate program the new vehicle emissions average in California would be reduced by an average of 24 g/mi, about a 10 percent reduction, versus 9 g/mi for a California-only program. Much of this improvement occurs due to vehicle redesign decisions, and these greater reductions can be obtained with lower levels of fees and rebates than with a California-only program.

Additionally, the stringency of the performance standards is an important factor in the additional reductions generated by feebates. The steeper the decline of allowable emissions over time, the smaller the incremental benefit from feebates. However, the lowest absolute emission levels occur through a combination of feebates with tighter standards. Feebates offer reduced incremental benefits with the tighter standards because the standards force the adoption of lower cost technology, leaving only the relatively more expensive technology available to the feebate program. The relative cost of technologies also results in the incremental benefit from feebates diminishing over time in any scenario where standards continue to tighten. Feebates could also be used to offset some of the shortfall in emission reductions if standards cannot continue to be tightened in later years.

The results from this study are consistent with lessons learned from Denmark, France, the Netherlands, and Norway that have already implemented similar programs. Consumer car purchasing behavior in these countries has demonstrated a clear shift towards lower emission vehicles following the establishment of their respective feebate programs. The extent to which consumers have differentially purchased lower emitting cars in these countries has varied somewhat with economic conditions (e.g., typically increasing with higher gasoline prices), but the net effect of reducing emissions has been unambiguous.

The stakeholder response portion of the study involved a survey and focus groups of households as well as interviews with automobile manufacturers and automobile dealers, which yielded additional insights related to implementing a potential feebate program. The statewide survey of 3,000 households indicates that consumers are generally concerned about climate change and energy independence and that three-fourths of respondents would be supportive of a feebate program. However, program design would need to consider the issue of fairness raised in focus groups.

Interviews with a sample of automakers representing 72 percent of US sales show they are more cautious in their support for feebates, the specific program design being a key determinant. Though in all cases, a national program would be favored over a state or regional program. Automobile dealers are generally opposed to feebate programs due to concerns about administrative burdens, potential revenue losses, and perceived reductions in consumer choice by the government.

Overall, our study suggests that feebates do have the potential to provide California with additional greenhouse gas emission reductions at negative cost, however this effect will depend on the design of the feebate program and stringency of concurrent GHG standards. Considerations in designing this program include not only incremental benefits but also impacts on consumer welfare, vehicle sales, and stakeholder concerns. Designing the program in a way to assure revenue neutrality in light of uncertain future economic conditions is also a key consideration. In addition, any program would need to be carefully coordinated with other state and federal policies to reduce greenhouse gas emissions from passenger vehicles.

1. SUMMARY FOR POLICY MAKERS

The California Global Warming Solutions Act of 2006 (AB 32) calls for California's greenhouse gas (GHG) emissions to return to 1990 levels by 2020. The California Air Resources Board, designated the lead agency to implement AB 32, produced a Scoping Plan, which specifies the evaluation of feebates as a possible complement to or substitute for California's GHG standards limiting greenhouse gas emissions from new light-duty vehicles. To meet this need for evaluation, a team of researchers from the University of California completed a comprehensive study to assess the potential design, implementation, and benefits of a feebate program in California as well as possible stakeholder responses. This document is the Final Report for the study. Because of its comprehensive nature, the material presented in this report is divided into two main parts: Summary for Policy Makers (Chapter 1), and Research Report (the remaining Chapters). The Summary gives a complete but high-level view of the study and its findings. The Research Report is a more detailed treatment that provides complete documentation of the study, including additional background material, detailed descriptions of the methodologies employed, and a comprehensive review of results and findings that are beyond the scope of the summary. The Summary includes "pointers" to later chapters and sections to allow the interested reader to explore particular aspects in more detail.

1.1. Why Feebates? – Background and Research Objectives

This research project is concerned with a specific type of economic incentive policy known as feebates. Although there are many possible types of feebate policies, for this project they all share the following basic definition:

> A **feebate** is a market-based policy for encouraging greenhouse gas (GHG) emission reductions from new passenger vehicles by levying fees on relatively high-emitting vehicles and providing rebates to lower-emitting vehicles.

The purpose of the project is to provide a comprehensive study of feebates that meets the decision-making needs of ARB by addressing issues essential to the practical design and implementation of a potential feebate program for California. ARB commissioned a request for proposals in fall 2008. Proposals from two University of California research teams (Davis and Berkeley) were combined into a single research project, and work began in February 2009. The remainder of this section gives additional background, and reviews project tasks and objectives. For a more detailed version, see Chapters 2-4.

1.1.1. Motivation

The California Global Warming Solutions Act of 2006 (AB 32) calls for the state's greenhouse gas (GHG) emissions to return to 1990 levels by 2020. On December 12, 2008 the Board approved a Scoping Plan (Plan) that provides policy recommendations and estimates of emission reductions for individual sectors of the California economy. The largest contributor is the transportation sector, which produces 38% of GHG emissions in California. Passenger vehicles are estimated to produce 74% of the emissions from California's transportation sector.

The Scoping Plan specifically discusses two policies for reducing passenger vehicle emissions through improved vehicle technology. The first (Pavley) is based on legislation (AB 1493, Pavley) passed in 2002 that sets emissions standards for new vehicles sold in California through MY2016. The second (LEV III-GHG)[1] would set additional restrictions for model years 2017-2025. The target for the combined policies is a 31.7 $MMTCO_2E$[2] reduction below 2020 business-as-usual (BAU) levels. However, these policies require waivers from the U.S. Environmental Protection Agency (EPA) under the Clean Air Act. At the time the Scoping Plan was developed, the existing Pavley policy had not received a waiver. Because of uncertainty over these policies, the Scoping Plan also directed that an alternative policy option (feebates) be considered as a possible *replacement* for Pavley and LEV III-GHG. Feebates were also to be evaluated as a possible *complement* to these policies to achieve further GHG reductions. Because the Pavley waiver was granted in 2009, use of feebates as a replacement for Pavley is now of secondary importance, with the primary emphasis of this research being on feebates as a complement to LEV III-GHG.

Although not specifically discussed in the Scoping Plan, this study also explores potential implications of California's historic leadership role in areas related to emissions reduction policy. For example, at one point in time thirteen other states (Arizona, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington, collectively referred to, along with California, as "Opt-In States") indicated intent to exercise their option under Section 177 of the Clean Air Act to adopt California's Pavley emissions standard. If California were to implement a feebate program and other states were to follow by adopting similar measures, this would be expected to have implications for the effectiveness of feebates within California, as well as reduced GHG emissions in other parts of the United States.

1.1.2. Feebate Policy Options

One simple description of the project's main research objective is: (i) formulate alternative feebate policy options, and (ii) evaluate and compare the options. To provide a basis for discussion, we review basic design elements of feebate programs that, when combined, yield specific policies.

The first requirement is an *efficiency criterion* for defining a feebate. Our study uses the CO_2-equivalent emission rate of a vehicle, measured as grams of CO_2 per mile (or simply g/mi). Generally, a feebate policy requires the following:

- A **benchmark** that defines which vehicles pay fees and which receive rebates.
- A **functional form** and a **rate parameter** (or parameters) that determine payment/credit amounts.
- A **locus of monetary transactions** to determine how and when rebates and fees are actually transferred at the time a new vehicle is purchased.

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[1] More specifically, these light duty GHG standards are to be part of the California Advanced Clean Car program, and are abbreviated as "LEV III-GHG". In some discussions, the Pavley standards might be referred to as "Pavley I," and the LEV III-GHG standards as "Pavley II."

[2] Million metric tons CO_2 equivalent.

In addition, practical details of how a program is introduced and implemented are important. The following discussion provides a review of these design elements in more detail.

Structure of benchmarks

Perhaps the simplest possible feebate policy is to use a **single benchmark** for all vehicles, combined with a single rate parameter, so that a feebate amount is given by the simple equation:

Feebate = *rate*(emissions_rate – benchmark),*

where *rate* is in units of dollars per gram per mile ($/g/mi), and the *emissions_rate* and *benchmark* are measured in grams per mile (g/mi). For example, consider a policy with a rate of $20/g/mi and a benchmark of 300 g/mi (~ 30 mpg). A new vehicle emitting at a rate of 350 g/mi (~25 mpg) emits *more* than the benchmark, and would be assessed a *fee* of 20*(350-300) = $1,000. A vehicle emitting 250 g/mi (~36 mpg) would be assessed a fee of -$1,000, i.e., it would receive a $1,000 rebate (a negative fee is the same as a rebate).

Simple movement of the benchmark changes the net flow of fees and rebates, and in many cases it would be politically attractive to set the benchmark so that **revenue neutrality** is attained. Options for benchmarks considered in this study include:

- Single benchmark
- Two benchmarks (one for passenger cars, one for light duty trucks)
- Footprint-based benchmark(s)

For a footprint-based benchmark, the benchmark is assigned on the basis of a vehicle's size as measured by its footprint, defined to be: wheelbase x track-width. The MY2012-2016 national GHG emissions standards are based on two footprint curves (one for passenger cars, and one for light-duty trucks) that assign a benchmark for each footprint value (yielding literally hundreds of benchmarks).

There are arguments for/against the benchmark options. A single benchmark is "fair" in that it represents an absolute standard that is the same for all vehicles. In addition, theory suggests that this approach could yield larger improvements than the others. However, some consider it "unfair" because some consumers (e.g., large families, self-employed service providers) are forced to pay a fee for a larger vehicle that they really "need." Moreover, there is a concern that a single benchmark could impact manufacturers in different ways, depending on the types of vehicles they sell. The footprint approach addresses both of these issues by establishing benchmarks as a function of size, although it increases the complexity of the program. The two-benchmark system can be viewed as lying between these two systems. An objective of this study is to examining the tradeoffs among these systems in more detail.

Functional form and rate

A second design element is how fees/rebates vary as a function of distance away from the benchmark. In the previous simple example, the functional form is a straight line and the rate represents the marginal value of reducing a vehicle's GHG emissions by one unit. A straight-line functional form values every gram of CO_2 equally. Options for functional forms include:

- Straight line (linear)
- Piecewise linear (segments that change rate)
- Step function

These are illustrated in Figure 1.1 below. These forms can be combined to include specified maximum and/or minimum values, and also a “donut hole” where there are no feebates over a specified range. Some consider step functions to be easier for consumers to understand, and this has been a matter of some discussion. However, a drawback is that the feebate changes abruptly at certain specific values of the emissions rate, so that two vehicles that are almost identical could have very different feebate levels. The section on Lessons Learned gives examples of all three of these functional forms, and discusses tradeoffs among alternative functional forms.

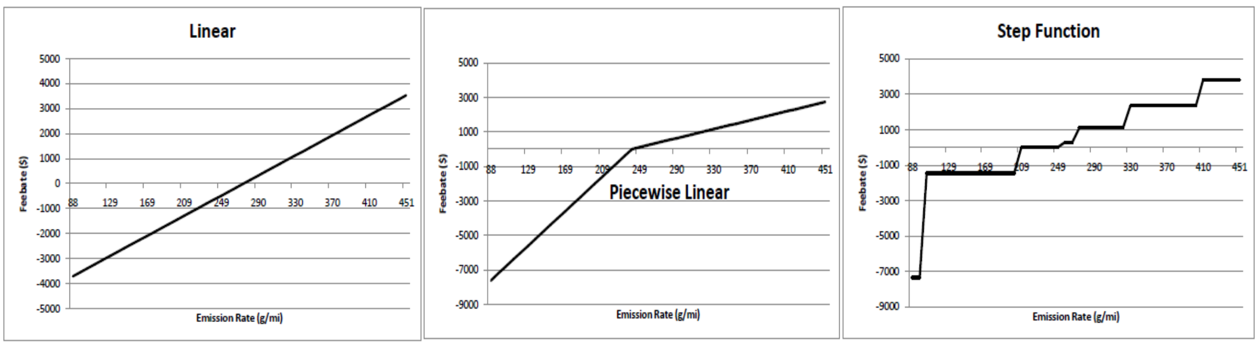

Figure 1.1 Three Feebate Functional Forms

When considering the effect of the feebate rate, the simplest case is the earlier example of a linear function with a single benchmark. The rate represents the change in vehicle purchase price per unit of improvement in the emissions rate (in g/mi). Vehicles emitting more emissions than the benchmark will be assessed a fee that will cause sales to decline, and vehicles emitting less emissions than the benchmark will receive a rebate that will cause sales to increase. All other things equal, increasing the rate will magnify the effect on sales.

Point of regulation/locus of transaction

Another essential design question is the manner in which feebates will be transacted. Feebates may be enforced at the level of the vehicle manufacturer, in which case there will be a small number of parties involved and most “transactions” will be internal to the firm. However, this does *not* mean that the feebate is being applied to the manufacturer rather than the consumer. Any feebate could appear as an additional line item on the vehicle label, and would effectively represent a change to the vehicle’s purchase price.

Alternatively, feebates could be made a part of the transaction between dealers and customers. This would greatly increase both the number of transactions and the volume of revenue flows but could possibly have a greater impact on consumer decision-making. Finally, there could be systems where consumers are required to process their feebate transactions directly with a government agency.

Implementation strategies

Another element potentially affecting the success of a feebate policy is the way that it is introduced. A feebate policy could be implemented either abruptly, or with prior notice given to manufacturers and consumers. A delay between the announcement and implementation of the policy gives manufacturers time to adapt, but could also have the initial perverse effect (in the short term) of causing consumers to buy higher emission vehicles that would soon be charged a fee. Similarly, they could delay the purchase of lower emission vehicles until the rebates become available.

Other considerations include whether to phase in different elements of the system at different times, e.g., beginning with rebates and adding fees later (or vice-versa), gradually increasing the number of vehicles subject to the program, etc. Finally, there are practical issues on how to manage revenue flows, especially if conditions in the market change dramatically due to, e.g., volatility of energy prices, technology breakthroughs, etc.

1.1.3. Overview of Research Tasks and Methodologies

The following is a brief overview of the research tasks performed in this study.

1. Compile case studies on real-world policies to identify any lessons learned. The team compiled ten case studies on a range of feebate-related policies (i.e., economic incentive-based policies related to vehicle purchase and use). These are discussed in Chapter 6, with details appearing in Appendix D. Four studies of recently implemented "true feebate systems" are summarized in this chapter—see section 1.2. These address the potential effectiveness of feebates, as well as provide insights on feebate design issues.

2. Develop specific feebate policy options to be evaluated. Feebate policy design elements are combined in different ways to generate specific policy options. There are virtually an infinite numbers of combinations that could be considered. The team developed and prioritized options based on input from a public forum, and consultation with ARB staff. Details appear in Chapter 7.

3. Compare policy options based on quantitative projections of future outcomes. A Feebate Analysis Model was developed specifically for this project. An overview is given in Chapter 5, with detailed documentation in Chapter 8. Vehicle redesign and pricing choices by manufacturers as well as consumer response in the new vehicle market are simulated under alternative policy options, yielding estimates of relative impact on average emissions rates of new vehicles, total emission reductions, and social costs and benefits. Results are summarized in section 1.3, with more details appearing in section 9.1.

4. Determine possible responses of key stakeholders to feebate programs. Focus groups and a statewide survey of consumers were conducted. Personal interviews were conducted with new vehicle dealers, vehicle manufacturers, and feebate program experts, and additional stakeholder feedback was obtained through public workshops early in the project. Results are summarized in section 1.6, with more details in section 9.3 and Appendices B and C.

5. Assess implications for feebate policies with larger market coverage beyond California. California represents only about 10% of the domestic automobile market, so the potential impact of feebate polices on manufacturer vehicle design decisions could be limited. However, if other states were to adopt feebate policies (or if there were a nationwide feebate policy), the potential could greatly increase. Our research explored this aspect of feebates. Results are summarized in section 1.3.7, with more details in section 9.1.2.

Other research tasks include the estimation of economic and fiscal impacts (including administrative costs), an exploration of equity implications, and potential interactions between feebates and other AB 32-related policy initiatives. These are summarized in sections 1.4, 1.5, and 1.7, respectively. A more detailed treatment is found in Chapter 10.

1.1.4. Assumptions, Policy Environment, and Evaluation

The likely impact of feebate programs on greenhouse gas emissions for the study's planning horizon (2011-2025) depends critically on a wide range of factors that will affect the future new vehicle market. Quantitative projections require assumptions about the decision-making behavior of both consumers and vehicle manufacturers, and also the policy environment in which these decisions are being made. Specifically, future emissions performance standards can play a major role; however, the form and stringency of these standards through 2025 are far from certain at this time. In fact, current and expected near-term policy conditions have *already changed multiple times during the course of this project*. Details about the study's working assumptions for quantitative policy analysis appear in Chapter 7. However, to provide additional background on the policy environment we review elements of the AB 32 Scoping Plan that were taken into consideration by our study.

Emissions standards can be summarized in terms of the *average emissions rate* of new vehicles sold for a given model year. The timing and amount of actual *emissions reductions* depend on how the vehicles are driven over their lifetimes. Evaluating feebate programs on the basis of these same measures requires a baseline (or reference) policy for comparison. The Scoping Plan specifies anticipated reductions in terms of both measures. The following facts are relevant for establishing a reference policy scenario:

- Pavley uses two "benchmarks". It requires that new passenger cars and trucks up to 3750 lbs on average emit less than 205 gCO_2E per mile by MY2016. For light-duty trucks 3750-8500 lb the limit for the average is 332 gCO_2E/mi. ARB anticipates the fleet-wide average to be 243 gCO_2E/mi. The emissions reductions from this policy are estimated to be 27.7 $MMTCO_2E$.

- A national standard has been finalized that goes through MY2016. It is based on two footprint curves (one for passenger cars, and one for light-duty trucks), and is expected to yield a new vehicle fleet-wide average of 250 gCO_2E/mi (roughly similar to Pavley).

- There is nothing in currently proposed policy to indicate what national emissions standards would be after MY2016, though EPA and NHTSA have filed a Notice of Intent for standards covering MY2017-2025.

- A LEV III-GHG standard, if implemented, would start in 2017 and go through 2025. Although there are rough expectations of emissions reductions from this standard (4 $MMTCO_2E$ in 2020, growing to 27 $MMTCO_2E$ by 2030), there is little information on what the form or stringency might be.

To address the need for a reference policy scenario over the entire period (2011 to 2025), the study makes the following assumptions:

- The currently proposed national standards are used for MY2011-2016. Because the national standards were designed to harmonize with the California program, we consider them to be a reasonable substitute.

- The period MY2017-2025 requires an assumption for national emissions standards. In consultation with ARB staff, our study adopted a Reference Policy that assumes a 2% reduction per year starting in 2017.[3]

This reference policy scenario, denoted as the *2% National Standard* scenario, is used to make baseline projections. Projections for the 2% National Standard *plus a feebate program* are then compared to the baseline to evaluate how the feebate program might *complement* emissions standards. There is also an interest in the feasibility of using feebates as a *substitute* for future emissions standards. To examine this, we use an alternative scenario that assumes national standards *stay at 2016 levels* for 2017-2025. Because this corresponds to a 0% reduction starting in 2017, this is denoted as the *0% National Standard* scenario. An overview of the quantitative analysis results is provided in section 1.3. More detailed quantitative analyses appear in sections 9.1 and 9.2.

We add a few final remarks about policy evaluation. As noted, one direct measure of feebate effectiveness is the reduction in average emission rates for new vehicles. The most obvious mechanism for achieving this is by inducing sales shifts to more fuel-efficient vehicles. However, the feebate literature has found that a potentially more important effect could be on manufacturers' vehicle redesign decisions over time. An important aspect of our study is that it specifically takes into account both of these mechanisms.

1.2. How well have feebates worked elsewhere?

Feebate policies have been discussed for quite some time, but until recently there has been very little real-world experience with them. Chapter 6 describes ten case studies related to economic incentives for new vehicle sales; details on the ten case studies appear in Appendix D. In this summary we focus on four "true feebate systems" (also called "bonus/malus" programs) from Denmark, France, the Netherlands, and Norway. The remaining studies (which include Canada, Germany, Spain, Sweden, and the UK) primarily document various types of vehicle-related taxation schemes.[4]

It can be challenging to draw definitive, bottom line conclusions from case studies. For example, providing detailed quantitative estimates of emission reduction totals, fee and rebate amounts for different vehicle types, etc., would be challenging under the best of circumstances, and well outside

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[3] The assumption of a 2% annual reduction in the standards was not based on a greater expected likelihood that this would be the eventual stringency of a national program, rather that it fell in the middle of the range of possible equally likely stringency levels. Since these scenarios were developed and analyzed, ARB and the federal government have indicated that MY2017-2025 standards will be in the 3-6% range.

[4] The omitted cases include studies of various tax incentive plans that are not "true" feebate systems because they do not provide rebates/subsidies in conjunction with fees/taxes.

the scope of our study. Moreover, in a complex policy environment it can be difficult to disentangle outcomes and identify which ones are specifically due to a feebate program. However, we do have aggregate level data on new vehicle emission rates from both before and after the introduction of feebate policies. In all four cases these measures provide at least some evidence to suggest that feebate policies played a role in reducing average vehicle emissions. Details are reviewed below. More generally, the four cases offer real-world examples of a variety of feebate design elements adopted by policy makers (e.g. type of benchmark, functional form, feebate rate), as well as subsequent events in response to these design elements.

1.2.1. European Context

All four cases involve European countries. The European context and the complex policy landscape faced in these countries can make a direct comparison with California a bit difficult. For example, three of the four countries belong to the European Union (EU), which has its own independent policy-making activities related to greenhouse gas emissions. Policymakers must contend with conditions in their own countries, as well as the implications of belonging to the EU. More generally, European countries have been much more aggressive in this arena than the United States with regard to greenhouse gas emissions standards.

In April 2009, the European Commission enacted *mandatory* CO_2 emissions standards for passenger vehicles of 130 g/km [209 g/mi, or 42.5 mpg] by 2012 after automakers failed to achieve their voluntary reduction targets. These standards apply to 65% of each manufacturer's new passenger cars in 2012 and will increase to 100% of passenger cars in 2015. From 2020 onward, the emissions target is 95 g/km [153 g/mi, or 58.1 mpg], though the details of the path to this target have not yet been defined.

As a point of comparison, the Pavley standard is 233 g/mi in 2012 for passenger cars and 361 g/mi for light-duty trucks (3751-8500 lbs).

1.2.2. Feebate Case Fact Summary

A related discussion appears in Chapter 6, and a much more detailed treatment of each case appears in Appendix D; for this summary we provide a short list of facts from each. These give a sense of the range of feebate program design features that have been adopted by policy makers to address their own particular concerns, and also add real-world context for the discussion in later sections.

Denmark

- Introduced June 2007 as a modified registration tax
- Single benchmark = 150 g/km (241 g/mi)
- Benchmark expressed to the public in terms of fuel economy
- Two straight lines (linear) -- different rates (slopes) for fees and rebates:
    - $50/g/mi for rebates
    - $13/g/mi for fees

France

- Introduced December 5, 2007 (rebate only)
- Fee part added January 1, 2008

- Benchmark in 2009: "Donut hole"[5] from 130-160 g/km (193 – 257 g/mi)
- Benchmark in 2012: "Donut hole" from 130-140 g/km (193 – 225 g/mi)
- Functional form is a step function with 9 levels
- Shape of step function yields an approximate "rate" of $16.5/g/mi

Netherlands
- Introduced July 2006, revised February 2008
- Benchmarks based on footprint/class of vehicle
- Step function with 7 steps
- Complexity precludes simple description of a feebate rate
- While this study was being completed in 2009, it was announced that the system would be abandoned in 2010 in favor of a single benchmark

Norway
- Began taxing CO_2 in January 2007, with a rate change in January 2008
- Rebate added in January 2009 to yield a full feebate system
- Single benchmark = 120 g/km (193 g/mi)
- Functional form is four line segments with different rates
    - Rebate = $52/g/mi
    - Initial fee rate = $55/g/mi
    - Fee increases to a maximum rate of $259/g/mi

1.2.3. Comparison of Design Features

The four cases provide an opportunity to compare and contrast the relative merits of a variety of feebate system design features.

Benchmarks

Three of the four countries opted for a *single benchmark* system. The Netherlands started out with a footprint-based system, but has since abandoned it for a single benchmark. It is interesting to note that this was done due to consumer sentiment. Their research indicated that consumers thought the footprint system was too confusing and complicated. In addition, they did not like the fact that a larger, higher emitting vehicle could receive a rebate, while a smaller, lower emitting vehicle would be charged a fee. In contrast, France's single benchmark system created concerns about fairness to large families that "need a larger vehicle," and the system has since been modified to include subsidies to address this issue. With regard to the benchmarks themselves, Norway currently has the most aggressive benchmark (120 g/km, or 193 g/mi), which corresponds to the EU's original voluntary 2012 target.

Functional Forms

France is the only country with a step function rather than straight lines. This choice was based on the belief that step functions are "easier for consumers to understand." In addition, France has a donut hole for the range 130-160 g/km (note that 130 g/km is the EU's mandatory target for 2012),

[5] A donut hole is zone where vehicles would neither be charged fees nor awarded rebates.

where vehicles are exempt from both fees and rebates. One argument in the literature is that consumers might be more accepting of a feebate system if there is a range of vehicles that is unaffected by the feebate policy. A donut hole fits naturally within a step-function-based system (although it is not precluded by other functional forms).

In contrast to France, Denmark and Norway use straight lines. However, rather than use a single slope (feebate rate) both have opted for more complicated systems with multiple line segments with varying slopes. Interestingly, in Denmark fees have a lower rate than rebates, whereas in Norway rebates have a lower rate than fees. In Norway there are multiple segments for fees, with fee rates dramatically increasing for vehicles with higher emissions.

Figure 1.2 depicts the feebate systems of Denmark, France, and Norway (the complexity of the footprint-based Netherlands system precludes its inclusion in this comparison). Note that the fee rates for Norway are so steep that most of the function cannot be included in the figure. For comparison purposes, we have also added a linear feebate function with a $20/g/mi rate and a single benchmark (274 g/mi) similar to those used in our quantitative modeling for California. This illustrates the general similarity between the type of feebate policies in our study and those currently in use.

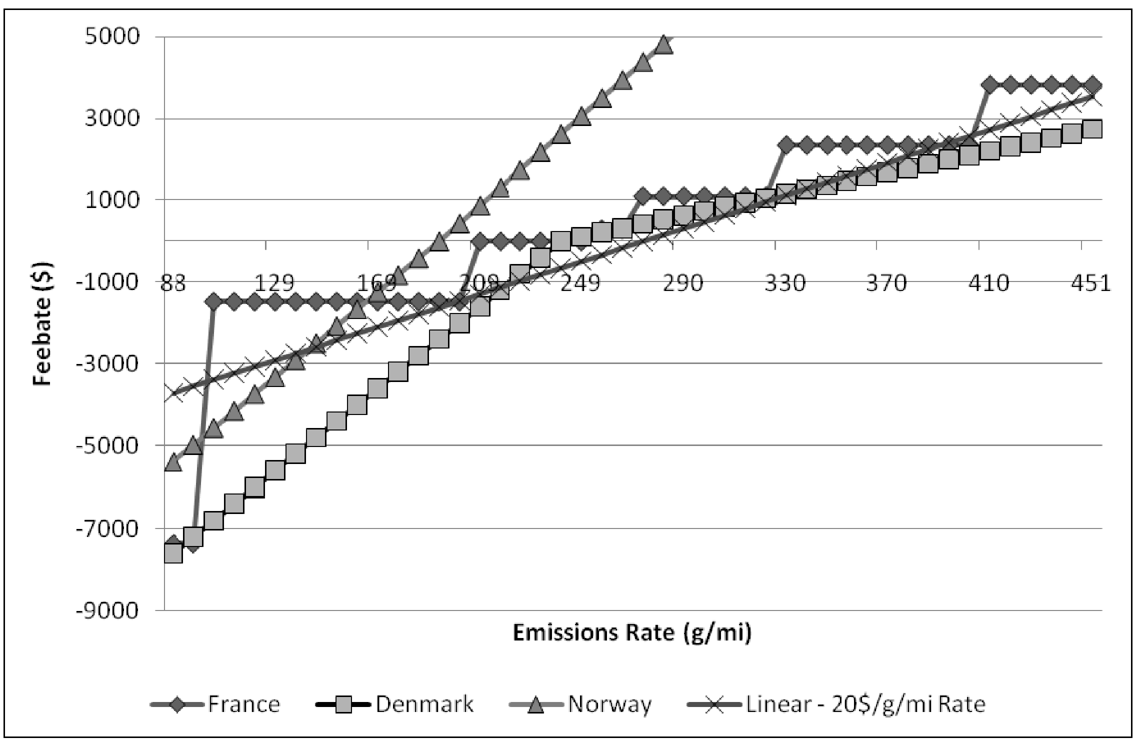

Figure 1.2 Comparison of Feebate Functions

1.2.4. Assessment of Effectiveness

Given available data, the most practical approach to assessing feebate program effectiveness uses average new vehicle emission rates. For the time frames considered here, a successful feebate program would yield a decrease in average new vehicle emissions by causing a shift in consumer purchases. The following figures show average new vehicle emissions before and after the introduction of feebate programs in Denmark, France, and Norway, respectively. One complication is that there were also sizeable changes in fuel prices during this period. Even so, the basic shapes of the curves suggest clear shifts associated with the introduction of feebate programs.

Emissions averages for Denmark are provided in Figure 1.3 for gasoline and diesel separately, and also combined. The shift is smaller for diesel than for gasoline, with the latter taking on a value of roughly 18 g/km (26 g/mi). Figures 1.4 and 1.5 for France and Norway suggest shifts of 7 g/km (~11 g/mi) and 10 gm/km (~16 g/mi) respectively. Note: The data for Norway correspond to the the conversion of the vehicle registration tax in January 2007 to include CO_2, followed by the offer of rebates beginning in January 2009. The case of the Netherlands is a bit more complicated—for details, see Appendix D. However, those results also suggest that their feebate policy helped to reduce greenhouse gas emissions.

So, to conclude: Our study has compiled data to support the position that feebate programs in other countries have led to a reduction in average new vehicle emissions.

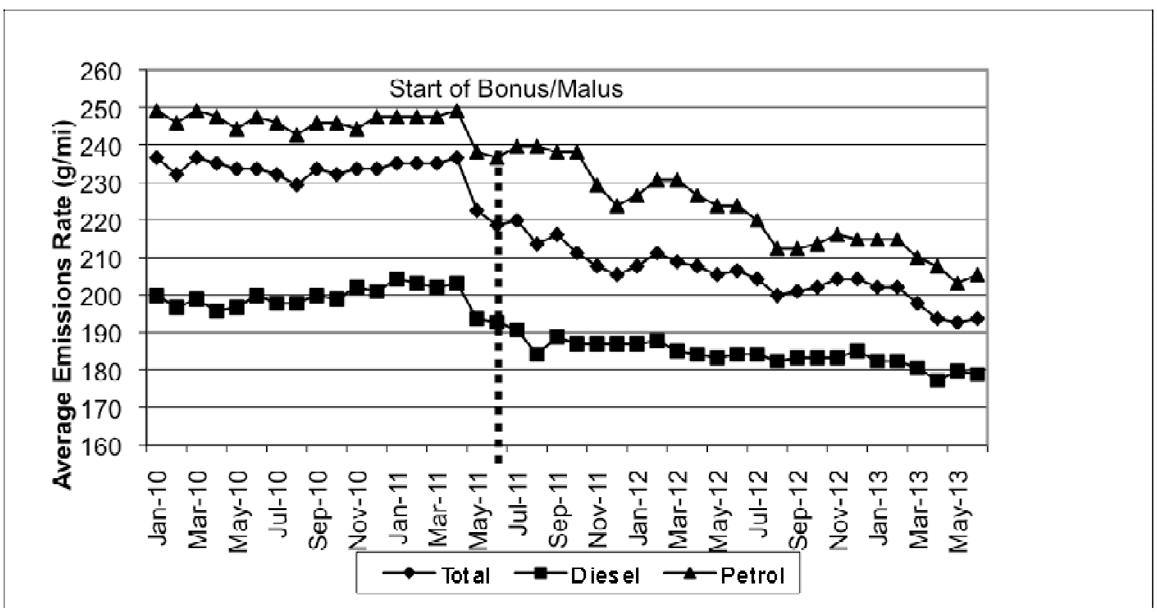

Figure 1.3 Effect of Bonus/Malus in Denmark on New Vehicle Average Emissions Rates

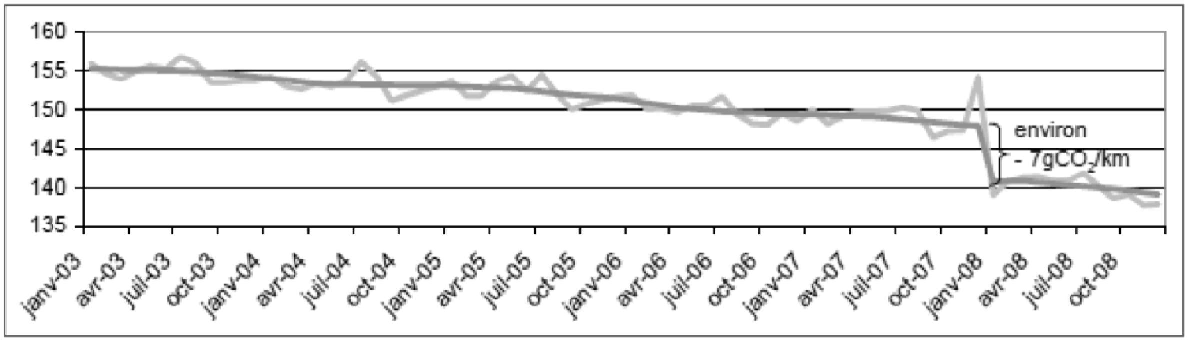

Figure 1.4 Effect of Bonus/Malus in France on New Vehicle Average Emissions Rates (grams CO2 per km)

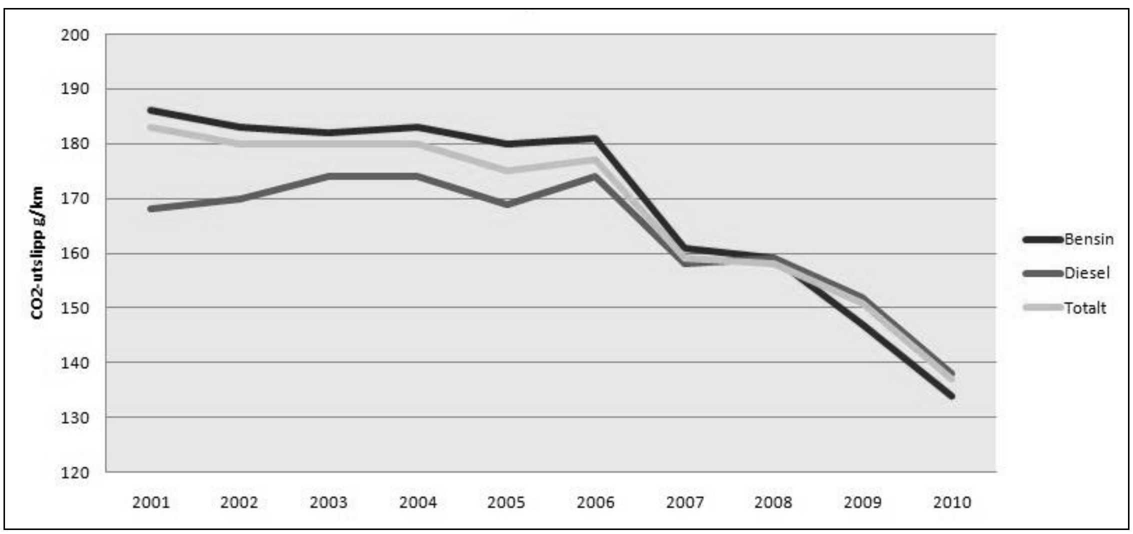

Figure 1.5 Effect of Conversion to CO2 Registration Tax and Feebate Program on Average New Vehicle Emissions in Norway through January 2010 (Bensin = Gasoline)

1.3. How well can feebates work to reduce emissions in California?

Under the assumptions adopted in this study, feebate policies *can* be used in California to achieve *additional reduction of greenhouse gases* from new passenger vehicles beyond those projected under national emission standards alone. However, the size of the reduction is not large when compared to the impact of emissions standards. For example, the total reduction in 2020 from a feebate program is projected to be in the 3-4 $MMTCO_2E$ range, versus the 31.7 $MMTCO_2E$ target for the combined Pavley and LEV-III standards. A major finding is that, because California represents only 10% of the new vehicle market, a California-only feebate policy is likely to have minimal influence on vehicle design decisions. Conversely, our results highlight the critical role that national emissions standards would play in influencing manufacturers' decisions to reduce vehicle emission rates: the increased availability of improved vehicles creates the possibility for more rebate options, contributing to the potential effectiveness of feebate programs. Finally, we emphasize again that these and other findings always depend on the modeling assumptions, which we discuss first before summarizing findings in more detail.

1.3.1. Feebate Model Overview

A Feebate Analysis Model was developed to provide quantitative projections of market behavior and emissions reductions in response to possible feebate policies in California. An important aspect of feebate (and other) policies is their potential to affect future vehicle technology adoption decisions by manufacturers. We assume that when manufacturers make these decisions they take into consideration the overall response of the entire domestic (United States) new vehicle market, and the national policy environment. For this reason the Feebate Analysis Model has a two-tier structure. The top tier is a Manufacturer Decision Model (MDM) that simulates design decisions for new vehicle offerings for the period 2011 to 2025. We also assume that manufacturers are unlikely to produce "California only" vehicle configurations. At the same time, manufacturers would be expected to take into account policy changes unique to the California portion of the market when making their overall design decisions. To include this effect the MDM divides the U.S. market into two sub-markets: California and "Rest of U.S." The bottom tier of the Feebate Analysis Model is a California-specific model (called CARBITS) that supports more detailed examination of policy impacts on the California vehicle fleet (both new and used) for multiple consumer groups. It takes as given the vehicle configuration projections produced by the MDM.

In the MDM, manufacturers can use available conventional and/or hybrid technologies with specified cost curves to make emissions improvements to individual vehicles[6]. They decide on the timing and amount of these improvements. They can also choose to change vehicle *pricing* to shift the new vehicle sales mix. These decisions are made on the basis of anticipated consumer response, the requirement to meet specified emission performance standards, and any feebate program that might be introduced.[7] The MDM provides projections of new vehicle attributes and offerings for the entire U.S., as well as projections on new vehicle sales, average emission rates, etc., for both sub-markets. Overall response to California feebate policies can be evaluated using these results. The bottom-tier California model can be used for more detailed analysis (e.g., the impact on individual consumer groups, or on the used vehicle market).

1.3.2. Feebate Model Assumptions and Reference Policy Scenario

As noted previously, results depend on modeling assumptions. Model development required adoption of base case modeling assumptions, including behavioral assumptions for both manufacturers and consumers, and a reference policy scenario to provide a baseline for policy comparison. Examples of base case assumptions for our model include cost curves for conventional

[6] Cost curves were provided by ICF International.

[7] The model also takes into account allowances for Air Conditioning and Flex Fuel Vehicle credits that can be used to meet emissions standards.

and hybrid vehicle technologies, projections of future economic factors such fuel prices and new vehicle sales levels, and, importantly, behavioral assumptions on consumer preferences for new vehicles. Two key elements in an economics-based market response model are: the value placed on fuel savings by consumers, and their responsiveness to vehicle price changes.

The consumer demand model in the MDM assumes that consumers evaluate only the first three years of fuel savings when deciding what vehicle to purchase. It also assumes the existence of vehicle market segments, where vehicles within the same segment are closer substitutes than those in different segments. This means that consumers responding to a price increase for their prefered vehicle are more likely to switch to another vehicle in the same segment. The MDM consumer demand model uses a pattern of price sensitivities (or, elasticities) based on values taken from the literature.

Finally, the model adopts a reference policy as a baseline for comparison. The definining element is a national emissions standard for 2011-2025. As discussed in section 1.1.3, we adopt the currently proposed national standard for 2011-2016, and assume that from 2017-2025 the emissions target continues to decrease at a rate of 2% per year. This reference policy secario is denoted the *2% National Standard*. Because future standards remain uncertain after 2016, other scenarios can be conveniently specified by changing the post-2016 rate of reduction. One potentially interesting alternative assumes a 0% reduction rate after 2016 (the *0% National Standard*), i.e., the national standard stays flat at the 2016 rate for 2017-2025. This would occur if there are no future national policy changes beyond those currently proposed. The MDM can also model emission standards that apply only to California or the Opt-In states.

Figure 1.6 shows MDM projections of average new vehicle emission rates (in g/mi) in California for the 2% and 0% National Standards. For the 2% National Standard, average emissions from new vehicles in California decline from 303 g/mi in 2011 to 215 g/mi in 2025 (about 30%).[8] New vehicle emission averages (not shown) are higher in the Rest-of-US than in California: they are 5 g/mi higher in 2011, with the gap shrinking to 1 g/mi in 2025. One finding we consider noteworthy is that under the 2% National Standard, manufacturers can be said to "run out" of cost effective technology in 2022. Starting in 2023, manufacturers choose to meet the emission standard by using vehicle pricing to change the sales mix of vehicles. The other option would be to redesign vehicles with additional emissions improvements; however, they chose not to do so for economic reasons.

[8] The 2016 average (254 g/mi) appears to be a bit higher than the national/Pavley targets. However, because the MDM incorporates provisions on air conditioning and flex-fuel vehicle credits, manufacturers are actually in compliance.

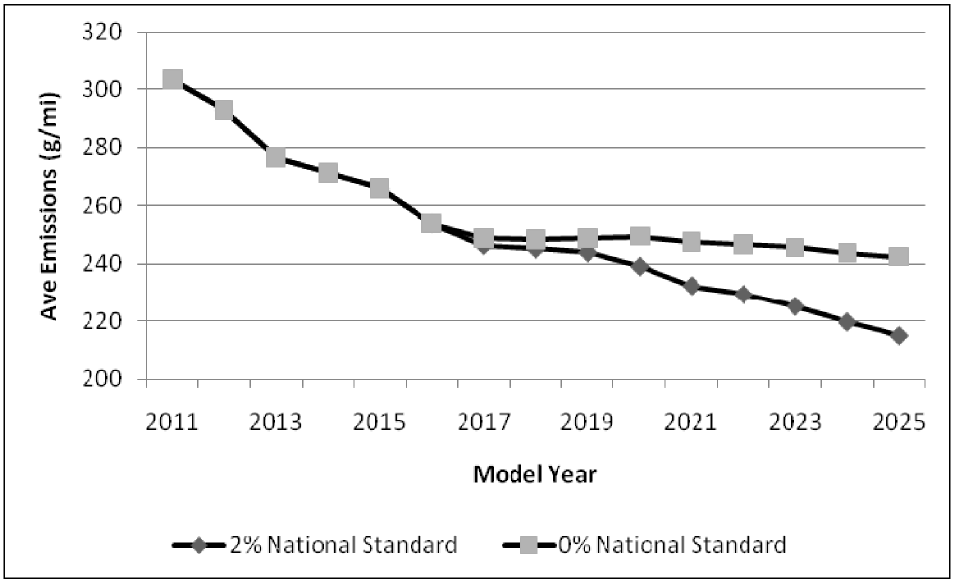

Figure 1.6 Average new vehicle emission rates in California for two national emission standards

The 0% National Standard scenario provides an interesting comparison. It represents the laxest possible post-2016 national standard that does not allow emissions levels to go back up. In later years technology becomes less expensive, and fuel prices are projected to increase. Under these circumstances there is at least the *possibility* that manufacturers might choose to design vehicles that yield emissions levels better than the national standard in response to consumer preferences. However, these results show that, even under a standard that "goes flat" in 2017, manufacturers would still design their vehicles just to meet the standard. It is important to note that this outcome is a consequence of the entire set of base case modeling assumptions. For example, if consumers were to place a higher value on fuel savings, or if fuel prices were much higher, or if vehicle technology were less expensive, manufacturers might choose to design vehicles that would overcomply with the standard.

1.3.3. Evaluation and Comparison of Feebate Policies

Our study compares a large number of feebate policy options by combining various design elements described in the introduction. Two main design elements are: Type of benchmark, and feebate rate. As discussed previously, choosing a benchmark system requires consideration of tradeoffs, whereas the feebate rate primarily effects the strength of the response. In the next sections we evaluate feebate programs for three different benchmark systems using a baseline feebate rate of $20/g/mi, and discuss tradeoffs. Discussion of the sensitivity to higher or lower rates is addressed in section 9.1.3. Outcome measures for evaluating the overall impact of policies include:

- New vehicle emissions averages
- Sales mix and sales levels
- Effect on consumer welfare
- Total reduction of CO_2
- Social costs and benefits associated with CO_2 reduction

Emissions Reductions

A key design issue is the type of benchmark system to use. The literature suggests that different benchmarking systems can differ in overall effectiveness, and on their impact on individual stakeholders. Although the level of the feebate rate is also important, it primarily magnifies (or reduces) the effect of a system if the rate were to be increased (or decreased). Results in this section address both the overall effectiveness of feebates as well as the relative effectiveness of different benchmark systems. Equity-related issues are addressed in other sections.

Figure 1.7 shows the estimated effect on California average new vehicle emission rates of three feebate systems introduced under the 2% National Standard scenario. Results are reported as *changes* from the levels in Figure 1.6 (negative values imply a reduction in the rate). Each system uses the same feebate rate of $20/g/mi, roughly equivalent to a carbon price of $200 per tonne of CO_2.[9] As mentioned earlier, this rate is comparable to those used in similar programs in Europe. The solid lines denote the total change (dashed lines are discussed below). The first is a footprint-based system patterned after the proposed 2011-2016 national emissions standard [diamonds]. Specifically, the system uses two benchmark curves: one for passenger cars, and one for light-duty trucks. The second system uses a single benchmark value for all vehicles [squares], and the third uses two benchmark values (one for passenger cars, and one for light-duty trucks)[triangles]. Note that when simulating these systems the MDM seeks a *revenue neutral* version of each system by allowing benchmark values to vary from year to year.[10]

These results are consistent with what has been found in other studies. The effect is largest for the single benchmark system (an average 14 g/mi reduction for the period 2011 to 2020, the year for which AB 32 targets are specified), and smallest for the footprint system (an average 10 g/mi reduction for 2011-2020). In later years the level of GHG emissions reduction relative to the standard diminishes as the standard becomes more stringent. These emissions *rate* reductions can be used to estimate *total* emission reductions in California (versus the Reference Standard case) for the year 2020 for comparison with AB 32 targets:

- Single benchmark => 4.4 $MMTCO_2E$ reduction
- Car/truck benchmark => 3.9 $MMTCO_2E$ reduction
- Footprint => 3.3 $MMTCO_2E$ reduction

[9] This is a rough estimate that assumes 100,000 lifetime miles for a vehicle (with no discounting). NHTSA estimates a larger value for lifetime miles, but also discounts. One issue is whether or not GHG emissions should be subject to discounting. Whether or not this is a reasonable price for carbon is another discussion in itself. There are arguments regarding economic externalities (e.g., energy security, failure of the market to properly value fuel economy) that arise when discussing what an appropriate price for carbon might be.

[10] The MDM includes an estimate of program administrative costs (discussed in a later section), as well as rebates for ZEV vehicles mandated in California. Benchmarks are found so that these expenditures plus the net fees and rebates for new vehicle sales are revenue neutral over the entire life of the program.

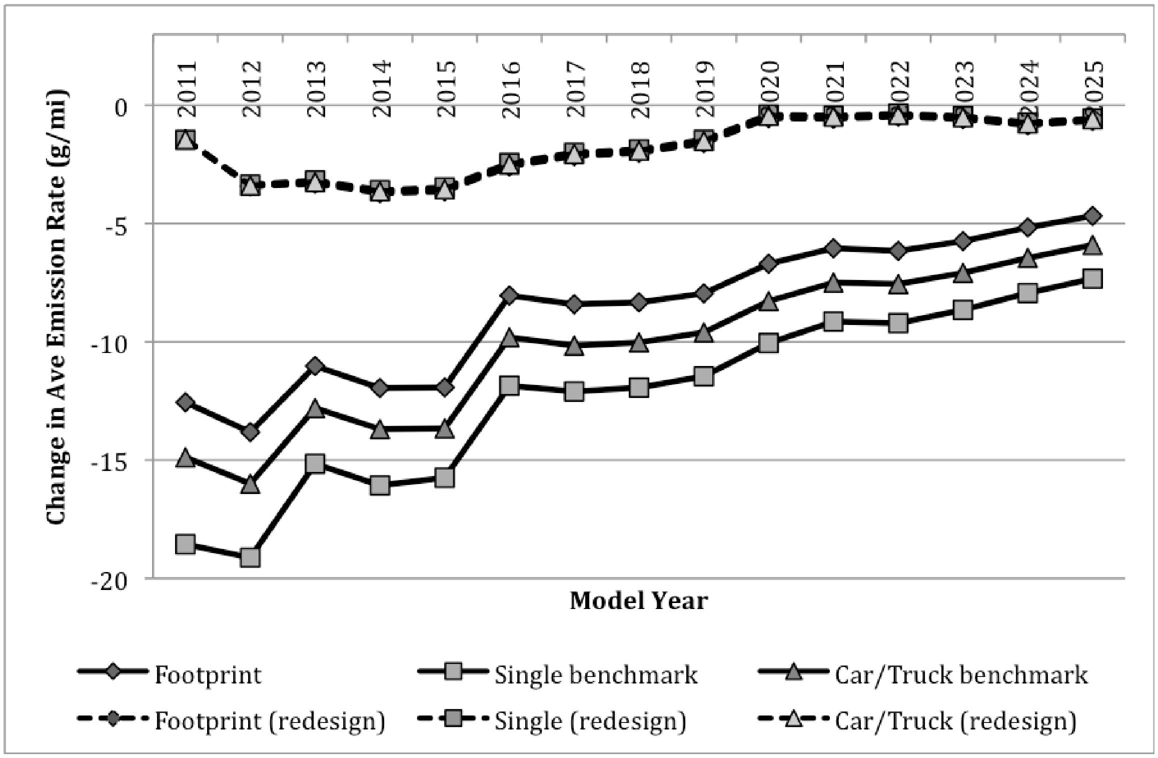

Figure 1.7 Change in California average new vehicle emission rates from feebates for three benchmark systems (total change, and portion of change due to vehicle redesign).

These totals are based on MDM projections of new vehicle sales for 2011 to 2020, the average emissions rates for new vehicles sold in those years, and assumptions on average miles driven in 2020 for new vehicles sold for 2011-2020. These figures are simple approximations that do not take into account other effects such as fleet turnover, etc., and should be viewed accordingly. These estimates suggest that feebate programs could be used to reduce emissions on a scale comparable to the discussions in the AB 32 Scoping Plan.

Another finding is that these feebate systems reduce average emissions *primarily by inducing sales-mix shifts.* The dashed lines in Figure 1.7 are estimates of the amount of change attributed to redesign. Although the feebate systems induce some redesign, the effect is rather small relative to the total. Moreover, the change due to redesign is about the same for all three systems, so that the differences are due to sales mix shifting. The average reduction for 2011 to 2020 model year vehicles due to design change is about 2.4 g/mi for all three benchmark systems, versus a 14 g/mi *total* reduction for the single benchmark (less than 20%). Moreover, *the effect becomes very small starting in 2020* (less than 5%). This is noteworthy because a widely-stated potential benefit of feebates is their potential to incentivize the introduction of new vehicle technology. Our view is that, because California is roughly 10% of the domestic new vehicle market, a California-only feebate would lack the leverage to induce manufacturers to adopt additional emission reduction technologies. Implications for feebate policies that extend beyond California-only are discussed in section 1.3.7.

To summarize, these results provide an evaluation of the three benchmark systems with respect to *emissions reductions*. The single benchmark system yields the greatest reductions, and the footprint-based one yields the least. However, a more complete comparison requires consideration of other factors. These include the overall impact on consumer welfare, other social costs and/or benefits associated with the programs, and questions of implementability and acceptance by the public.

Consumer Surplus

One feature of the MDM is that it uses a consumer surplus (CS) measure in its calculations. CS can be viewed as a monetary measure of total consumer welfare (or utility) associated with the existence of the new vehicle market. It accounts for welfare from purchasing new vehicles (for those who do), as well as the opportunity to purchase (for those who do not). Changes in CS can be used to compare policies that alter market behavior.

Figure 1.8 shows the total change in CS for Californians under each benchmark system (versus the Reference Standard case). In all cases CS decreases, but there are systematic differences: the footprint yields the smallest CS reduction, and the single benchmark the largest. This is consistent with expectations: the footprint system has the most flexibility for producing patterns of fees and rebates that might satistfy the most consumers. The single benchmark is clearly the least flexible, and the car/truck benchmark is in between.

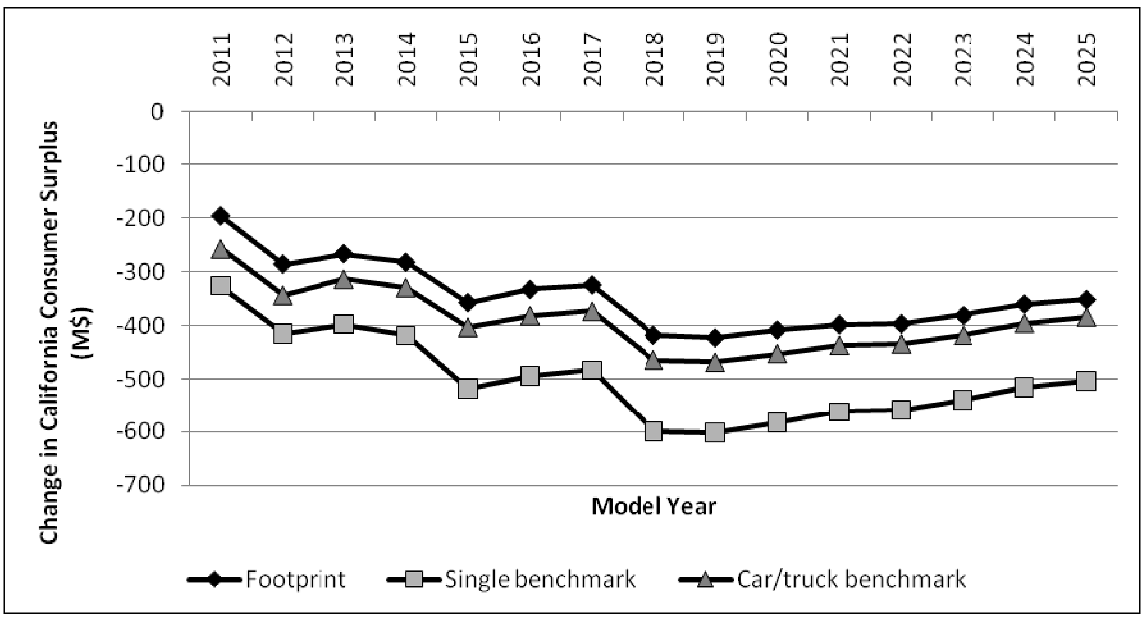

Figure 1.8 Change in California consumer surplus ($M) for three benchmark systems (versus 2% National Standard scenario with no feebate policy)

In addition to emissions reductions and consumer surplus, another impact of feebate policies is the *social benefit associated with increased fuel savings*. Specifically, the MDM assumes that consumers value only the first three years of fuel savings when making vehicle purchase decisions. This value therefore acrues to the consumer and is included in Consumer Surplus as a *personal* benefit. However, the expected lifetime of a vehicle is 14-16 years, and any additional fuel savings that accrue after the first three years will not be accounted for in the CS measure. The monetary value of this additional fuel savings can be considered a *social benefit* for the purpose of making policy decisions, and it can be substantial.

Our analysis indicates that when all costs and benefits are taken into account, the monetary value of fuel savings outweighs other costs (including loss of consumer surplus, adminstrative costs, etc.) so that *all three feebate systems generate a net negative social cost*. In other words, in addition to reducing greenhouse gas emissions, feebates also generate net *postive* social benefits.[11] Because emissions improvements are linked to fuel savings, the single benchmark system yields both the largest emissions reductions and the largest social benefit. Similarly, the footprint system yields the least. It is up to policy makers to evaluate whether this criterion should determine the choice of a benchmark system (if any), or whether other issues (e.g., equity considerations) should also play a role.

1.3.4. Feebates to Replace LEV III-GHG?

To explore the concept of feebates as a replacement for LEV III-GHG we begin with the 0% National Standard scenario described earlier (see Figure 1.6). Specifically, we consider the case where the national standard is assumed to stay at 2016 levels through 2025, but a more stringent LEV III-GHG standard is introduced in California starting in 2017. The key question is: "What could be achieved if feebates were used as an alternative to LEV III-GHG?"

Our earlier findings suggest that manufacturers would be unlikely to respond with major emissions reductions by adopting additoinal fuel economy technologies in their vehicle designs. Figure 1.9 illustrates the effect on average new vehicle emissions of one of our previous feebate programs (a $20/g/mi-footprint feebate in California starting in 2011) under a 0% National Standard. The 2% National Standard averages are included for comparison purposes. The feebate program averages prior to 2017 are the same for the 0% and 2% National Standard scenarios because the standards are the same during the period 2011-2016. For the period 2017-2020 the feebate yields larger emissions reductions than the 2% National Standard, providing an indication of the effectiveness of the feebate. For example, if the LEV III-GHG standard were roughly the same as the 2% National Standard, the feebate would be more than adequate as replacement during this period (particularly when cumulative effects are taken into consideration). However, obtaining emissions reductions that match (or exceed) the 2% standard post-2020 would require higher feebate rates.

This example was provided to clarify the replacement issue. Using separate MDM runs, we also identified the schedule of feebate rates over time that would be required to *exactly match* a 2% emissions standard in California—see Table 1.1.

Table 1.1 Feebate rates to replace a LEV III-GHG standard (2% annual reduction starting in 2017)

Model Year	2017	2018	2019	2020	2021	2022	2023	2024	2025
Feebate rate ($/g/mi)	5	5	5	10	15	20	30	35	40

Note: In MY 2025, a $40/g/mi rate translates to average fees of $1400 and average rebates of $1050.

[11] Given that the usual objective is to find cost-effective policy options, it is noteworthy that these feebate programs yield negative costs.

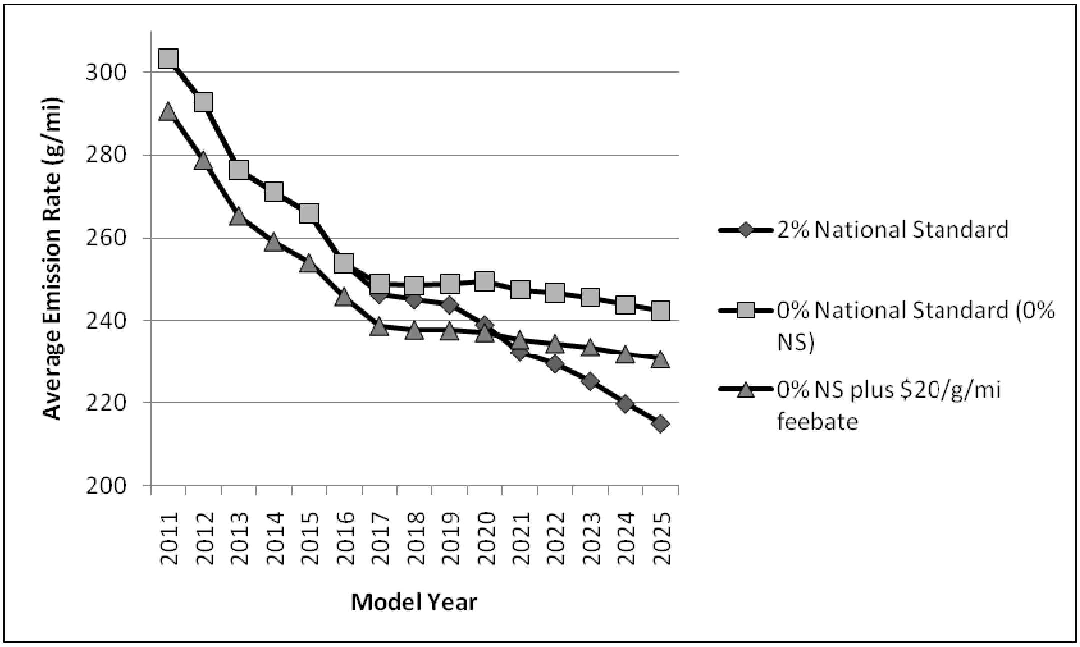

Figure 1.9 Effect of a $20/g/mi footprint feebate program under a 0% National Standard scenario (2% National Standard included for comparison purposes)

1.3.5. Spillover and Leakage

A frequently discussed issue for feebate systems is how they interact with markets outside the feebate region. There is the possibility of *spillover*, i.e., a feebate program within a region affects broader market conditions in ways that yield emissions reductions *outside* the feebate area. There is also the possibility of *leakage*, where emissions reductions inside the feebate region are offset by increased emissions outside the feebate region. One potential source of spillover would be a feebate's effect on manufacturer redesign decisions, which would alter vehicle offerings for the entire market. One possible source of leakage arises from the fact that consumers in different regions have different vehicle preferences. In this case, feebate policies could create a situation where the industry meets its overall *national* emissions requirement through sales mix shifts that balance emission reductions within the region with emissions increases outside the region.

Figure 1.10 shows the change in new vehicle average emissions for the "Rest of the U.S." when feebate programs are offered *in California*. The line for Rest-of-US is obtained for the footprint program; however, the lines for the other two programs are almost identical and are eliminated for readability. Figure 1.10 is a modification of Figure 1.7, so that averages for California are included for comparison purposes. There is evidence of spillover (for all years before 2018 except 2016) but also some leakage (for 2020 to 2025). The pattern suggests that spillover occurs when feebates induce the largest design changes. Note that, although Rest-of-US changes might be considered small compared to California's, these are *per-vehicle changes* for 90% of the domestic market. If the cumulative effects are calculated over the entire period, the spillover and leakage effects approximately cancel out.[12] Having observed this effect, it is important to remember that these results (and others) depend on our baseline assumptions, including those about future technological progress. Slower technological progress could lead to more leakage, and faster progress could lead to more spillover.

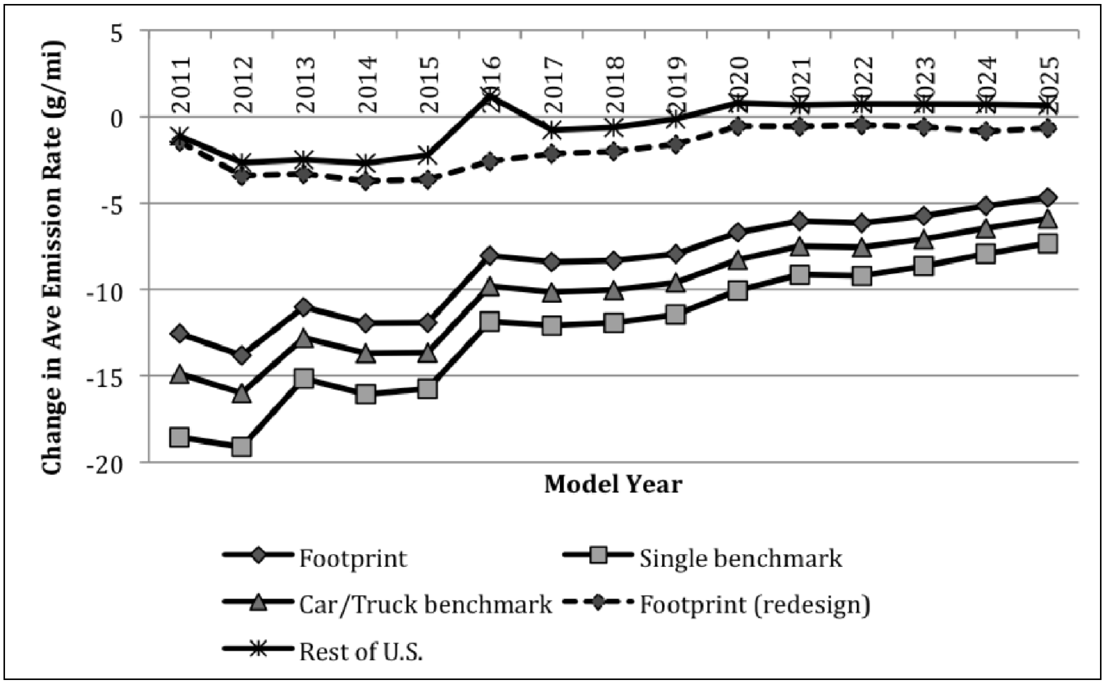

Figure 1.10 Change in new vehicle average emissions due to California feebate programs (includes change in Rest of United States).

1.3.6. Sensitivity to Assumptions

All findings summarized thus far use the same base case modeling assumptions previously described. Our study also includes scenarios to test sensitivity to changes in base case assumptions. Figure 1.11 shows what happens if consumers are assumed to fully value fuel savings over the lifetime of a vehicle when making their vehicle purchases. All three cases use the 2% National Standard, so the profile labeled "Three Years of Fuel Savings" (the base case modeling assumption) corresponds to the previous result for a 2% National Standard (with no feebate). When consumers are assumed to value fuel savings for the full lifetime of the vehicle, the results are dramatically different. Manufacturers *voluntarily* choose to sell vehicles with average emissions that are *much*

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[12] Some readers might notice a small spike that occurs in the year 2016. Although it exists for all results, it is particularly noticeable for the Rest-of-US profile in Figure 1.10. The spike occurs due to the abrupt discontinuation of certain emissions credits. Manufacturers address the loss in credits (at least in part) by re-pricing their vehicles to produce sales-mix shifts that satisfy the emissions standard.

better than the emissions standard because of consumer preferences. In this case an emissions standard would not be required. Adding a $20 footprint feebate yields additional emissions reductions, but these are relatively small compared to the effect of changing the assumption about the value of fuel savings.

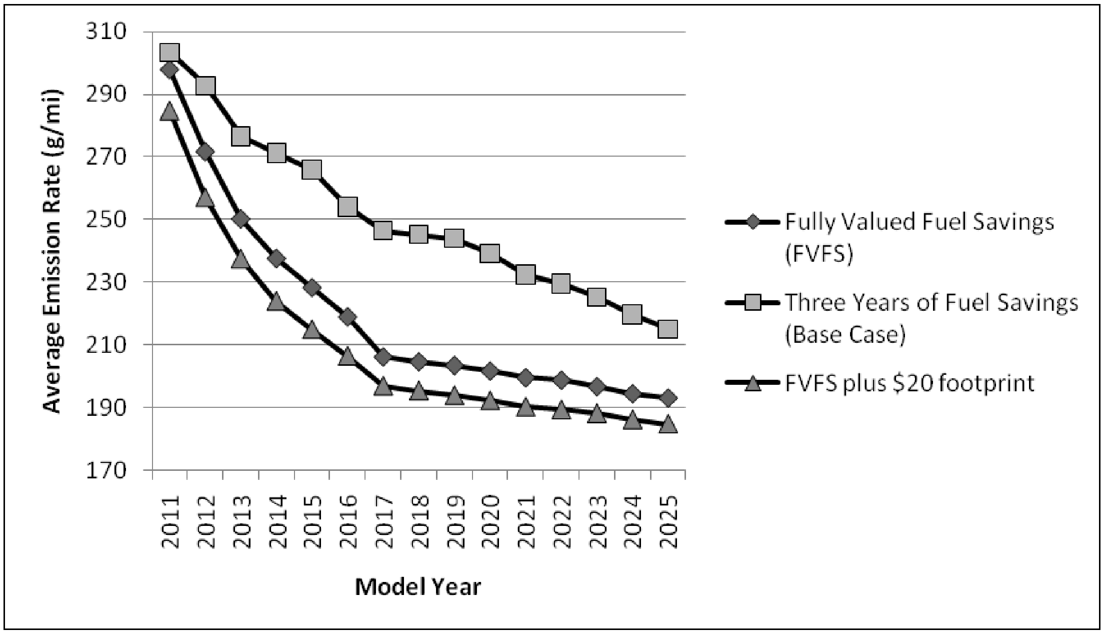

Figure 1.11 Effect of assumptions on consumer value of fuel savings.

Another sensitivity case assumes that consumers are less sensitive to vehicle price—see section 9.1.7. For this case consumers are much less responsive to feebate policies, so the emission reductions are lower than those in the base case. Sensitivity to other base case assumptions are explored in the Chapter 9. For example, the model requires projections on fuel prices, technology costs, etc. However, the two assumptions reviewed here appear to be the most important ones in terms of sensitivity.

Finally, we note that our base case assumptions on the value of fuel savings and price sensitivity are, in a sense, "feebate friendly." If consumers were to place a higher value on fuel savings then feebates would perhaps not even be necessary. If consumers were much less price sensitive, then feebates would not have the desired effects. However, it is important to note that the base case assumptions were developed using our best judgement based on experience with both the literature and industry practices, and were adopted prior to generating the results summarized here.

1.3.7. Effect of Feebate Programs Outside of California

The AB 32 Scoping Plan specifically calls for an evaluation of feebate programs in California. However, California has historically played a leadership role in the area of environmental policy whereby other states might choose to adopt the same or similar policies based on California's example. In the case of the Clean Air Act, states are specifically given the option to adopt either national emission standards or California emission standards. If multiple states were to follow California by adopting its feebate policy, it would have significant implications for policy effectiveness. To explore this possibility, our study includes scenarios that assume other states adopt California's feebate program, effectively increasing its geographic coverage. We consider two scenarios, where market coverge consists of: (1) California plus the thirteen "Opt-In States" (Arizona, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington), and (2) the entire nation (complete market coverage).

Figure 1.12 shows the *change* in new vehicle average emissions in California for a $20/g/mi footprint program under three market coverage scenarios (California only, California plus Opt-in States, and National). The nature of the results is what would be expected, i.e., impact increases with larger geographic coverage. Furthermore, the size of the improvements is substantial. One key finding is that, as geographic coverage increases, a larger portion of the feebate's impact is due to its effect on the redesign decisions of manufacturers. Figure 1.13 includes separate lines for the portion of change attributed to redesign (California-only results were shown in Figure 1.7, and are omitted here for clarity). In the year 2018, the percentage of change due to redesign is 60% and 87% for the California/Opt-in and National coverage scenarios, respectively. The averages for the period 2011-2018 are 54% and 77%, respectively. After 2018 the relative amount of change due to redesign steadily falls (as does the total change).

Effects of increasing the market coverage of a feebate program are summarized in Table 1.2. In addition to the effects within California, there would obviously be important implications for what would occur outside California. In particular, for the California plus Opt-in States scenario, our results indicate that there could be spillover effects in the non-feebate states. These would most likely be due to the increased impact on vehicle redesign decisions induced by the larger market coverage.

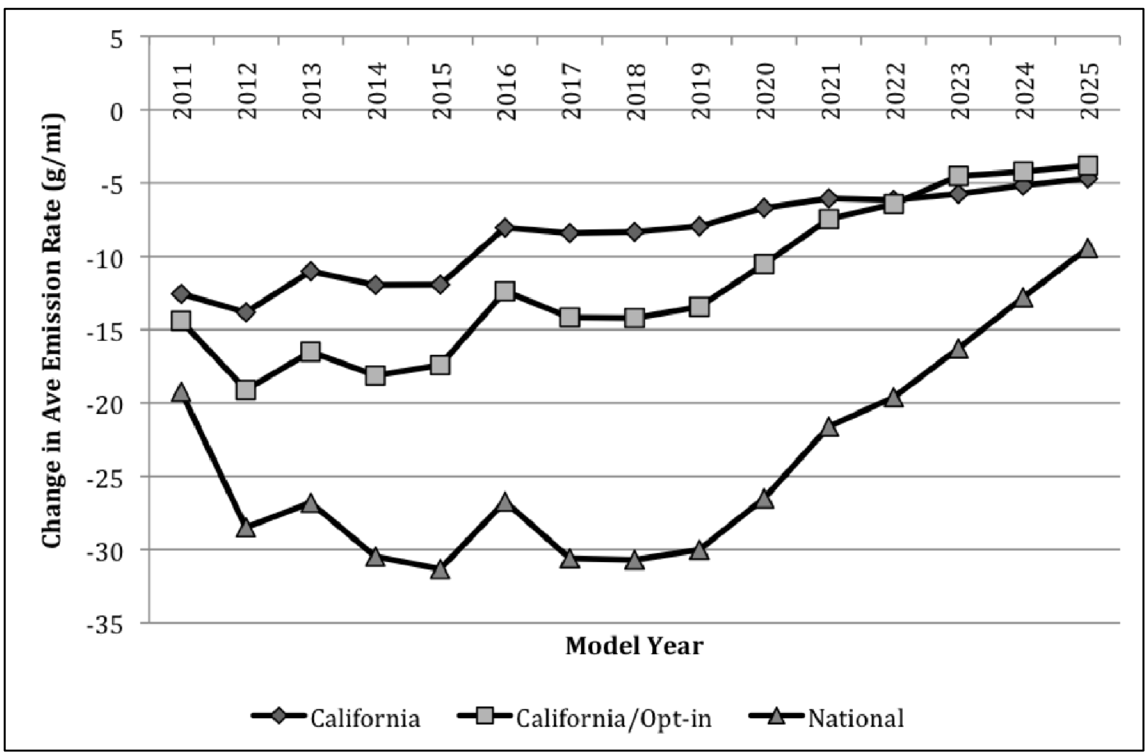

Figure 1.12 Effect of increasing geographic coverage on new vehicle average emissions for a $20/g/mi footprint feebate program.

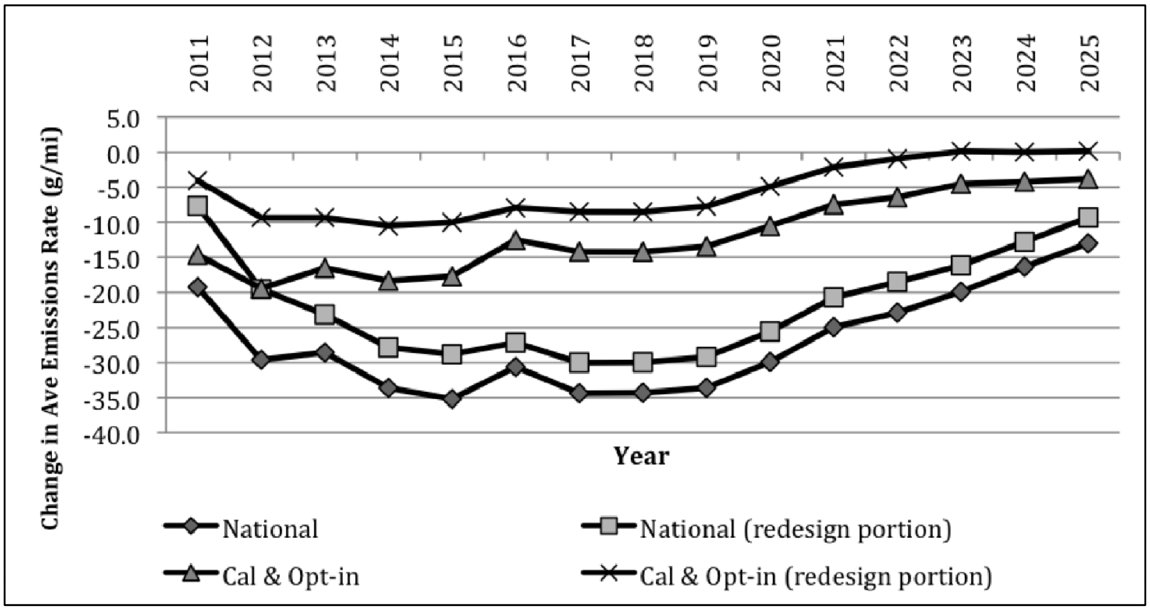

Figure 1.13 Change in new vehicle average emissions for a $20/g/mi footprint program for two geographic coverage scenarios (including portion due to redesign).

Table 1.2 Changes Induced by a Footprint-based Feebate Program ($20/g/mi) for Three Levels of Program Coverage (See text for the list of Opt-in States).

Program Coverage	Reduction of Average New Vehicle Emission Rates in CA (g/mi)	Percent Change in Average New Vehicle Emission Rates in CA	Average Fee per New Vehicle	Average Rebate per New Vehicle	Total Emission Reductions from Feebates in 2020 in CA ($MMTCO_2E$)
California-only	9 g/mi	3% reduction	$700	$600	3 MMT
California + 13 “Opt-In” States	12 g/mi	5% reduction	$675	$550	5 MMT
Entire U.S.	24 g/mi	10% reduction	$600	$500	9 MMT

1.4. What would be the economic and fiscal impacts of a feebate program?

Programs that alter the behavior of the new vehicle market have the potential for a broad range of economic and fiscal impacts. These include effects on industry sales and revenues, dealer revenues, and state and federal tax revenues. Effects on overall consumer surplus in the new vehicle market were mentioned earlier. Ripple effects extending to the used vehicle would affect consumers as well, and also industry-related businesses such as auto parts suppliers and repair garages. These effects would play out in different ways -- some positive and some negative for various stakeholders.

1.4.1. Overall impact on vehicle sales and revenues

Economic analyses derived from MDM results show that feebate programs can generally be expected to depress industry sales and revenues in California to some extent.[13] The overall effect is expected to be small, but the relative effects across manufacturers could vary, depending on the specific program design. This is further addressed in the section on equity issues. Findings related to the overall impact are:

- Feebate programs in California could reduce annual California sales by about 10,000 to 15,000 units per year. There are modest increases in sales in the rest of the country, but they offset no more than 1,000 units per year (on average). These sales declines imply a decrease in total industry revenues in the range of several hundred million to over one billion dollars per year (or about 1%). This translates into a negative impact on California dealers in the form of a *0.5% to 0.75% reduced sales volume*. These sales declines suggest that used vehicles would stay in the market longer, yielding secondary impacts related to the used vehicle market (repair shops, aftermarket sales, etc.). Many of these impacts would yield increased revenues for those businesses. For example, if consumers retain older vehicles for longer periods, they may spend more money at auto garages to maintain them.
- Increases in the feebate rate ($10 to $20 to $30 /g/mi) would yield larger total sales declines, and magnify any disparities among manufacturers (and also dealers).
- Impact of a California feebate program on national employment in automotive manufacturing and related businesses would be very small. Typical industry practice is to measure impact per 100,000 vehicle sales lost, and the reductions projected by the MDM are only on the order of 10-20% of that level.

To provide additional perspective, we also consider scenarios where feebate programs cover larger portions of the market. Under a *nationwide* feebate program:

- Annual new vehicle sales in California would decline by up to 20,000 units. The sales-related effects discussed above for a California-only program would be similarly magnified.
- National new vehicle sales would decline by an average of 135,000 units per year. This could have a measurable impact on national employment in automotive manufacturing and related businesses. Depending on how the sales losses are distributed over manufacturers, the number of displaced workers could vary from 2,000 to 20,000. However, these job losses could be partially offset by changes in the market for used vehicle-related services.
- Total industry revenues would generally decline, up to several billion dollars per year (or about 1%).

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[13] Note that these results are obtained for feebate programs under conditions of increasingly stringent national standards. Previous studies of feebates with no tightening of emissions standards have shown *increases* in revenue even though unit sales *decrease*. This can occur because increased use of fuel economy technologies can raise the price of vehicles at a faster rate than the decrease in sales. See, e.g., Greene, et al. (2005).

1.4.2. Fiscal and Administrative Costs

Costs to the government from feebate programs would fall into two general categories: 1) the cost of administering the feebate program, and 2) other fiscal effects. A feebate program might be expected to cover its own administrative costs from revenue flows associated with the program itself. In this case a "revenue neutral" program would require more fees than rebates in order to offset administrative costs. Because the level of administrative costs could affect the feasibility of a feebate program, our project developed the cost estimates summarized below. Other fiscal effects would include lost vehicle sales taxes and tax revenues from vehicle-related goods and services.

In general, the administrative costs for feebate programs are estimated to be somewhat higher than those for similar previously proposed California programs; however they are still relatively modest in relation to the size of revenue flows in the program. We also note that there is precedent for placing a cap on total administrative costs at some percentage in the authorizing legislation, thus limiting the ability for these costs to creep up over time.

The program administrative cost estimates assume that the majority of the responsibility for designing and administering a California feebate program would be shared among various state agencies (ARB, DMV, Board of Equalization, and Dept. of Finance), rather than residing solely with one of them. The estimates are based partly on analysis done in 2007 for AB 493,[14] but were updated and extended based on additional research and analysis. In general, we estimate that there would be several million dollars per year in ongoing administration costs, depending on the design of the program, and that this would be on the order of 1% (ranging from about 0.5-2.0%) of the total fees collected or rebates paid under the program.

Feebate programs are estimated to have somewhat different costs depending on design:

- If automobile dealers are the collectors of fees and distributors of rebates, administrative costs are estimated as $3.25 million in one-time startup costs followed by $5.5 million in annual program costs.
- If the auto manufacturers (rather than dealers) are the contact point with the state for collection of fees and distribution of rebates (i.e., more "behind the scenes") administrative costs are estimated as $2.75 million in one-time startup costs followed by $4.6 million per year in annual program costs.
- For a "hybrid" type design that involves fees being collected at the dealership but rebates being sent to consumers directly (on a delayed basis based in response to an application for the rebate), administrative costs are estimated as $3.75 million in one-time startup costs followed by $6.5 million per year in annual program costs.

These administrative cost estimates are somewhat higher than previously estimated for AB 493, primarily due to inclusion of estimates of Dept. of Finance cost recovery rates for their administrative functions and the fact that the feebate programs evaluated would include more

[14] The "Clean Car Discount for California Families" bill that narrowly missed passage by the California legislature in 2006-07.

vehicles than were proposed to be included in AB 493. We also note that these cost estimates are small in comparison to the size of the program, as measured by the level of fees collected (or rebates distributed). For example, if the average fee were $700 (as shown in the above table) and about 1 million vehicles were assessed a fee, total fees would be $700M, and administrative costs are still expected to be less than 1 percent of this total.

1.5. What are the equity implications of feebate programs?

1.5.1. Manufacturer Equity

As noted above, total industry revenues would decline by a small percentage under feebate programs. However, because industry revenues in this sector are so large, this still amounts to a large amount of money and one potential concern could be whether feebate programs affect different manufacturers and dealers in disparate ways.

Table 1.3 summarizes the sales mix for seven vehicle segments (Standard Small Car, Standard Midsize/Large Car, Prestige Small Car, Prestige Midsize/Large Car, Pickups, Vans, and SUVs) for the scenarios discussed in section 1.3 (2% National Standard, three benchmark systems using a $20/g/mi feebate rate). The no-feebate results provide a reference case for comparison. Sales mixes are averages over the period 2011-2025; however, the year-to-year variation is extremely small. Raising or lowering the rate would be expected to magnify or shrink the changes that are observed. The Standard versus Prestige distinction is included due to its importance in determining consumer preferences and sales shares. Briefly, each vehicle brand is designated Standard or Prestige based its perceptual position in the market. For example, Standard brands include Chevrolet, Ford, Honda, and Volkswagen, and Prestige brands include Cadillac, Lincoln, Acura, and Audi. Assignment of a vehicle configuration to a category is therefore based on its brand and not, e.g., vehicle price or amenity packages. A detailed listing of Standard versus Prestige brands is included in Table 8.3.

Table 1.3 Estimated Sales Mixes under Different California Feebate Programs

	Small Car	Mid/ Large Car	Prestige Small Car	Prestige Mid/ Large Car	Pickup	Van	SUV
Reference Case	27.6%	19.5%	6.7%	5.8%	10.0%	3.1%	27.2%
Footprint	28.9%	20.0%	6.2%	5.4%	9.9%	3.1%	26.5%
Single Benchmark	30.6%	20.1%	6.4%	5.4%	8.9%	3.0%	25.6%
Two Benchmark	29.6%	19.3%	6.5%	5.5%	9.6%	2.9%	26.6%

Note: Rows may not sum to 100% due to rounding.

As indicated in the table, the main impact of feebate systems is to increase the demand for non-prestige cars and decrease the demand for all other vehicle types, primarily SUVs. The differences among the systems are what would be expected based on theory. The footprint yields the smallest increase in small car demand, single benchmark yields the largest, and the two benchmark (car/truck) system lies in between. The single benchmark yields the largest increase in non-prestige midsize/large cars, and the largest decreases for Pickups and SUVs. At the same time, none of these changes is particularly large. The single largest increase is for small cars with the single benchmark, a change from 27.6 to 30.6% (a 3 percentage point increase).

Manufacturers' product portfolios will determine how they are affected by these sales shifts. Portfolio mixes tend to be correlated not only with the prestige versus standard distinction, but also with country of origin. To provide a high-level comparison, we have added a regional dimension and assigned each manufacturer to one of six groups. The effect of feebate programs on sales revenue share is summarized in Table 1.4.

Table 1.4 Estimated Revenue Shares for Six Manufacturer Groups Under Different California Feebate Programs

	Domestic-Standard	Europe-Standard	Asia-Standard	Domestic-Prestige	Europe-Prestige	Asia-Prestige
Reference Case	27.9%	1.4%	39.2%	2.6%	17.6%	11.3%
Footprint	27.5%	1.2%	41.6%	2.5%	16.2%	11.0%
Single Benchmark	26.9%	1.3%	42.2%	2.4%	16.3%	11.0%
Two Benchmark	27.1%	1.3%	42.1%	2.4%	16.2%	11.0%

Note: Rows may not sum to 100% due to rounding.

The changes in share are relatively small, as might have been expected from the results shown in Table 1.3. Under all benchmark systems, revenue shares increase for Asia-Standard, and decrease for all other groups. The increase for Asia-Standard is smallest for footprint, and largest for single benchmark. Conversely, Domestic-Standard loses the least share for footprint, and the most for single benchmark. This is consistent with Table 1.3, in that Asia-Standard dominates both the Small and Midsize/Large car markets. Again, although these effects are consistent with what would be expected, they are still quite small.

1.5.2. Consumer Equity

It is often the case with significant policy measures that there will be subtle and/or explicit "social equity" impacts of various types. These can be in various forms, from direct economic effects through taxation or other direct welfare loss to more subtle effects such as health impacts from exposure to increased levels of pollution. In many cases it is desirable to have policies that are not "regressive" from a social equity perspective. Other policies may be explicitly "progressive," but many others seek to be neither progressive nor regressive and to accomplish some other policy goal (e.g., GHG emission reduction) without major impacts on social equity.

The CARBITS model includes a variety of assessment measures that can be broken down by household demographic groups to explore issues related to social equity. For example, in the case of income there are five income categories. CARBITS modeling results capture effects due to shifts in vehicle-purchasing decisions by income group, allowing an examination of the social "incidence" of feebate programs from the least well off to the most well off of the income quintiles. Section 9.2.4 provides CARBITS results for the impact on various metrics by income category. We summarize the main findings here. With regard to payment of fees and rebates:

• The average rebate per vehicle is similar across income categories.

• The average fee per vehicle varies by income category. The average fee is smallest for the lowest income group, and average fees increase with increasing income.

• Overall net feebates are actually *positive* for the lowest income group. For the single benchmark, they are also positive for the second-lowest income group. Net feebates are negative for all other groups, and become increasingly negative with increasing income.

Based on these findings, feebate programs could be characterized as "non-regressive" with regard to the payment of fees and rebates. It is also important to recall that feebate programs apply only to the purchase of *new* vehicles, and that the incidence of new vehicle purchases increases dramatically with increasing income.

Of potentially greater interest is an evaluation of the "ripple effects" that can be expected to occur over time through the used vehicle market. This can be examined using an overall measure of consumer surplus (CS) that captures household utility for the entire vehicle market. The basic measure is the change in CS for a feebate system versus the Reference Standard case. CARBITS CS results differ from the MDM in certain ways, for reasons discussed in section 9.2. However, for purposes of comparing feebate systems they behave similarly, and CARBITS measures are specifically useful for assessing the differential impacts across income categories. One main caveat regarding the CARBITS results: The changes in consumer surplus are rather small in virtually all cases.

Before discussing dynamic effects, we consider the *average* change in CS by income group taken over the entire period 2011-2025. The change in CS is *positive* for the two lowest income groups, and *negative* for the three highest income groups—see Figure 9.28. This is true under all three feebate systems (footprint, single benchmark, and car/truck benchmark), although the patterns vary. This is another piece of evidence to suggest that the types of feebate programs assessed here are not likely to be regressive.

Looking at the *yearly* change in CS, the average change in CS per household (across all households) is generally positive for the early years. The change in CS initially increases, but then falls so as to become negative, and then becomes increasingly negative in the later years. The crossover from positive to negative occurs in 2018 for the single benchmark case, and in 2020 for the footprint and car/truck cases—see Figure 9.27. The interesting thing to observe is what happens when these yearly changes are broken down by household income category. In all years, for all feebate systems, *the lowest income group has a positive change in consumer surplus*—see Figures 9.30 to 9.32. For many years the second lowest income group also has a positive change in consumer surplus. The higher income groups are the ones that experience *negative* changes in CS, and it is these households that drive the average CS results over all households.

Our interpretation of this finding is that there are two effects. First, if lower income households purchase new vehicles, the vehicles they choose lead to positive net feebates and therefore increased consumer surplus. Second, as higher fuel economy vehicles continue to diffuse into the used vehicle market over time, lower income households benefit from the availability of used vehicles with higher fuel economy. These plus other results suggest that the effect of feebate programs is non-regressive with respect to their impact on lower income households.

1.6. How do stakeholders view feebate programs?

The Feebate Analysis Model results in Section 1.3 give some idea of how feebates might impact average emissions rates of vehicles sold in the new vehicle market. However, there are other practical issues to consider that fall outside the scope of quantitative modeling. The attitudes and views of various stakeholders affected by feebate programs could be important when making certain program design decisions. In the case studies from Europe (Section 1.2), attitudes of average consumers and the government's interaction with vehicle providers at times played important roles in policy makers' decision-making. To explore consumer-related issues, focus groups and a statewide survey of the general car-buying public were conducted. In addition, members of the team interviewed representatives from vehicle manufacturers and auto dealerships. The following sections summarize key findings from this stakeholder opinion research.

1.6.1. Consumer Research

Consumer research was conducted in two phases. Exploratory research using focus groups was performed first to gain fundamental understanding of knowledge, perceptions, and issues of most concern to consumers regarding feebate program designs. A total of twelve focus groups were conducted in the Bay Area, the Central Valley, Los Angeles area, Sacramento, and San Diego; two of the focus groups were conducted in Spanish. Although focus group results cannot be used to establish specific statistically valid conclusions, they yield key qualitative understandings that provide a sound basis for developing questions for quantitative research using a large statewide survey. Administered by telephone, survey interviews were conducted with over 3,000 households through California, yielding an adequate sample of responses for valid statistical analysis.

Key Focus Group Findings

- When designing the focus group protocol, a major concern was how hard it might be for respondents to understand feebates. However, participants seemed to *quickly understand the concept of a feebate program*.
- In most cases, after discussion over the course of the focus groups, the overall response to feebate programs was *negative*.
- Many participants generally had a negative view of both manufacturers/dealers and government programs, and viewed feebate programs with suspicion. There was concern that manufacturers/dealers would find a way to manipulate feebate-related transactions to their benefit.
- Participants suggested alternative policy approaches to address vehicle fuel efficiency, including gas taxes and direct regulation of manufacturers. In addition, many proposed that fees and rebates should be targeted directly to manufacturers rather than consumers.
- Participants generally felt that a feebate program would be ineffective in influencing vehicle purchase decisions.
- When pressed to estimate the level at which feebates might be effective, they indicated that the fee or rebate would need to be 10-25% of the sticker price, or alternatively, in a range from $1,000-$5,000.

- Participant responses to the various feebate program design elements reflect, and were consistent with, trade-offs relating to issues of fairness and complexity that are well-known in the literature.
  - Respondents generally preferred a continuous feebate function to a step-based function, believing that the continuous was more "fair" (even if a step based function might be "easier to understand").
  - Although there was substantial disagreement, the majority of respondents preferred a class-based system for (at least) cars and light-duty trucks for reasons of fairness to families and small businesses. Others found class or size based systems too complex and thought that consumers would find them confusing.
  - At the same time, there was an understanding that higher emitting vehicles could receive rebates while lower emitting vehicles could be charged fees under a class-based system. This also seemed "unfair" and, moreover called into question the purpose and effectiveness of the program.
  - The possibility of special exemptions or other breaks for large families or businesses was recognized as a way to address the fairness issue, but with concerns that it be administered fairly.
- There was considerable skepticism that a feebate program could be managed so as to meet the goal of revenue neutrality.

Key Statewide Survey Findings

The statistics below summarize key findings from the 3,000-household statewide survey administered between October and December 2009. The numbers shown are the raw survey results as well as a "weighted" sample that adjusts responses to make them more representative of the true demographic composition of the state.

- In contrast to the focus group results (which are not statistically valid), survey respondents were generally *positive and supportive of feebate programs*. Seventy-six percent of respondents either agreed (46%) or strongly agreed (30%) that they "would generally be supportive of this type of program to help slow the rate of climate change". (See Figure 1.14) With the weighted results, the percentages were agree (50%) and strongly agree (26%), retaining a total percentage of 76% but with fewer in the strongly agree category.
- Support for feebate programs is highly correlated with perceptions and opinions on issues related to climate change and energy dependence. The large majority of all respondents:
  - Are aware of the terms:
    - "climate change" (92% / weighted 87%),
    - "greenhouse gases" (80% / weighted 71%).
  - Believe that:
    - The earth is experiencing climate change (41% strongly agree / 38% weighted; 45% agree / 47% weighted)
    - Human activity is a contributing factor (36% strongly agree / 35% weighted; 46% agree / 50% weighted)
    - Dependence on foreign oil is a serious problem (37% strongly agree, 43% weighted; 44% agree / 45% weighted)
- Consumers were asked what they would do "if a new vehicle that you were planning to purchase increased in price by $2,000 due to an emission fee."

- 16% said they would buy the vehicle anyway,
- 39% said they would buy a different vehicle,
- 20% said they would buy a used vehicle,
- 14% said they would save money to buy the same vehicle later,
- 5% said they would not consider a vehicle with an emissions fee, and
- 6% did not know how they would respond.

- The respondent's self-described positioning on political issues was well-balanced among conservatives, moderates, and liberals:
  - 31% Liberal/Very Liberal
    - 7% very liberal
    - 24% liberal
  - 32% Moderate
  - 29% Conservative/Very Conservative
    - 23% conservative
    - 6% very conservative
  - 4% Other / 3% Not sure / 2% Refused

As shown above, the weighted sample results differ from the raw survey results, but only by a relatively small amount of a few percentage points between categories. The overall conclusions remain unchanged.

Question: I would generally be supportive of this kind of program to help slow the rate of climate change

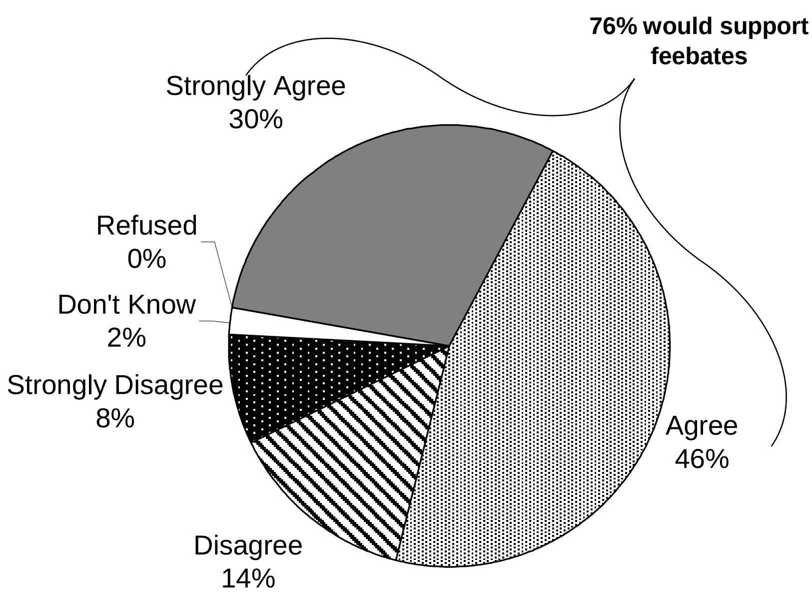

Figure 1.14 Breakdown of responses from telephone survey administered to 3,072 households in California in late 2009 (unweighted)

1.6.2. Dealer Interviews

In addition to consumers, auto dealers and automakers were interviewed to gain insights into their perceptions of feebate programs and their support or opposition to them. Key findings from the dealer interviews include:

- Dealers expressed both practical opposition to a feebate program related to potential loss of sales and increased administrative burden as well as more of an ideological opposition related to perceived restriction of consumer choice.
- When asked about preferred alternatives to the feebate program, three of the eight dealers expressed a preference for an increase in fuel taxes, arguing that higher fuel taxes are more likely to have a significant impact by influencing driving habits and reducing vehicle miles traveled.
- Regarding program administration, three of the eight dealers strongly opposed dealership-level administration, mostly because of the administrative burden.
  - One interviewee described his dealership as already "inundated as a business in handling the State's business."
  - Two dealers also described past problems with other programs administered at the dealership—like the tire fee—which has resulted in steep fines when dealers make mistakes when reporting and making payments to the State.
  - Two of the eight dealerships, however, indicated that given the synergies with current reporting requirements, if set up correctly they may be able to undertake the administrative aspects without much trouble.
- When asked about compensation from the State for administration, four of the eight dealers provided estimates for acceptable reimbursement. Two dealers indicated that $50-$100 per transaction would be adequate, one dealer preferred a monthly compensation of ~$1000 per month, and one dealer argued for a percentage reimbursement rather than a fixed per transaction or per month repayment.
- Six of the eight dealers interviewed expressed willingness to set aside time to train salespeople about the program, if implemented. Five dealers stated that this training would not be a problem, since salespeople already undergo training on a regular basis, and one dealer indicated that they would comply if compelled by the State.

1.6.3. Vehicle Manufacturer Interviews

The team conducted six interviews with experts from five automobile manufacturers in the US and abroad during the period July to December 2009 (one company was interviewed twice, with two different perspectives). Also one additional automobile manufacturer provided a response to the interview questions in written form. Larger automakers were the primary focus but a few of the smaller ones were also interviewed. Overall, the six manufacturers queried represented about 72% of the US market based on 2009 sales.[15]

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[15] Note that the automaker interviews were conducted on a confidential basis, where the specific individuals interviewed are not identified.

Automakers were generally opposed or "lukewarm" to potential feebate programs, particularly at the individual state level. The automakers interviewed clearly had various amounts of internal thinking and debate about potential feebate policies, but generally were very aware of them due to their previous application in other countries. They generally expressed that their potential support or opposition would hinge on the design of the programs, and were more supportive of federal programs than those instituted by individual or groups of states. Key points of opposition included restriction of consumer choice, and preference for fuel tax based policies that would more directly address consumers' use of fuels rather than programs such as feebates that would be applied to the initial purchase of lower versus higher emitting vehicles but not directly tied to the ongoing production of greenhouse gas emissions based on vehicle use.

Key findings from the automaker interviews were that:

- Three of the six automakers interviewed were generally supportive of a feebate program, though all of the automakers indicated that their potential for support depends on the structure and design of the program.
    - For two automakers, support stems from the belief that a feebate program sends a signal to the market and car buyers that the government supports a fleet-wide shift toward more fuel-efficient vehicles.
    - One automaker supports feebates as part of the company's overall shift toward greater environmental stewardship.
- Two interviewees expressed general opposition to a feebate program. For one automaker, this sentiment stems from the belief that the program would be biased against consumers with large families or needs that require larger vehicles and trucks. Another automaker described feebates as "unnecessary and duplicative" and an "inefficient, expensive and complicated way to get small environmental benefits."
- Four automakers indicated a preference for a linear feebate structure as opposed to a step-based structure or a structure with a zero-band, and three of these indicated a preference for a single benchmark system that places all vehicles on the same scale.
    - Two automakers prefer a multiple-class system that would "compare vehicles that are really comparable;" for example, a class-based system that would compare SUVs to SUVs, and compact cars to compact cars.
    - One automaker that is generally opposed to feebates prefers class-based as the "lesser of two evils."
    - None of the automakers indicated a preference for a step-based function (one strongly opposed it), and two pointed out that the step-based structure could lead to market distortions, "gaming," and border issues.
- When presented with the concept of a footprint-based function, one automaker indicated that this kind of system would be too complicated for consumers to understand and another expressed dislike for footprint-based systems in general.
    - Two of the six automakers preferred footprint-based: one likened the footprint-based system to the shadow area-based program in the Netherlands (which this automaker favored), and another prefers a feebate system that aligns with CAFE (so thus also prefers footprint-based).
- Four of the six automakers indicated that a feebate program in California would likely impact product design and product planning.

- Three of these indicated that the program would primarily result in product adjustments at the manufacturer level, while one indicated that feebates would result in a mixture of product design changes and shifts in production allocation.
- One of the four argues that this impact on product planning will be largely negative and that the program will cause "planning mistakes" and "wasted resources."

• When asked about previous experience with similar incentive/disincentive programs, three of the five automakers indicated that they had had relatively *positive* experiences in the past.
  - One automaker felt that the Canadian feebate program—though relatively short-lived—was generally good and motivated the company to improve one model in order to make it eligible for the incentive.
  - Another automaker felt that Cash for Clunkers was successful at influencing consumer decision-making and also attracting new car buyers to the new car market.
  - A third automaker described the Netherlands feebate program—which they described as a "multiple-class, vehicle shadow area-based program"—as a model for future feebate programs.[16]

• Four of the six automakers also described *negative* experiences with past programs.
  - Cash for Clunkers, according to two automakers, disrupted dealership cash flows and provided little lead-time for dealers and manufacturers to prepare for program implementation.
  - Two automakers used the Canadian program as an example of what "not to do" with a California feebate program, since they argue that the program was too short-lived and resulted in a lot of gaming and little technological change and environmental benefit.

• Three of the six automakers responded that the feebate program should be administered by the dealership, where they believe it would more effectively influence consumer decision-making. One automaker pointed out that administration by any entity other than the government (i.e. via vehicle registration) would dilute the signal from the government and incorrectly associate the feebate to the dealer or manufacturer.

• All automakers that were asked about national versus state-by-state feebates programs much preferred a national program. If a national program could not be developed and if state programs were adopted, manufacturers would prefer similarly designed and aligned state programs.

1.7. How might a feebate program best be coordinated with other state measures and goals?

The primary focus of this project was determined by the AB 32 Scoping Plan, which explicitly called for an evaluation of feebates as a substitute for (or complement to) emissions standards for new passenger vehicles. However, there are other policies in the transportation section of the Scoping Plan that, because they also impinge on emissions from passenger vehicles could require coordination with feebate policies. These include: 1) the Zero-Emission Vehicle (ZEV) program; 2)

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[16] After the interview was conducted, the Netherlands made the decision to drop a class-based program in favor of one with a single standard—see section 2.

the Low Carbon Fuel Standard (LCFS); and 3) SB 375 – the "sustainable communities strategy" program. In addition, there are non-transportation AB 32 programs that could interact with the transportation sector, such as a proposed statewide GHG "cap and trade" program. The most important of these interactions are briefly discussed below, with a larger discussion in the final report.

1.7.1. California Zero Emission Vehicle (ZEV) Program

This program requires increasing numbers of zero emission vehicles (ZEVs) and very low-emission "partial zero emission vehicles" (PZEVs) to be sold in California in the coming years. The rules of the program have become quite complex, as the program has evolved extensively since first introduced in 1990. The regulations now lay out multiple pathways by which automakers of various sizes may meet the regulation, to provide an element of flexibility. The gist of the current regulation is that major manufacturers must meet percentage requirements for advanced vehicle introduction that increase over time. They can do so with various combination of ZEVs, "enhanced advanced technology-PZEVs," "advanced technology-PZEVs," and "PZEVs." These ZEV rules are currently under revision but are expected to provide an ongoing stimulus for automakers to produce initially small but growing numbers of near zero-emission vehicles.

However, these vehicles would also be subject to any feebate policy introduced in California. Their emissions characteristics virtually ensure that these efficient and low-fuel cycle GHG vehicles would receive rebates, providing additional incentives for consumers and making compliance with the ZEV mandate easier. Under the feebate scenarios examined in this project, ZEVs could get up to a few thousand dollars in incentives. In this regard, it should be recognized that any feebate program should be coordinated with other ZEV-related incentive programs.

1.7.2. Low Carbon Fuel Standard (LCFS)

This is one of the "early-action" GHG emission reduction measures required for identification and implementation by AB 32. The LCFS limits the average carbon intensity of transportation fuels supplied by regulated parties for use in California. The LCFS requires a 10% average reduction in carbon intensity by 2020 relative to 2010 levels. This represents a 15 MMT reduction in GHGs or about 10% of the reductions needed to achieve the total AB 32 target.

Since the LCFS applies solely to fuels, and feebates apply only to the sale of vehicles, the potential interaction effects between the two programs are somewhat subtle. There are potential synergies between the two, to the extent that the two programs do reinforce the introduction of lower carbon fuels into the market (i.e., feebates also encourage the adoption of advanced technology vehicles using lower carbon fuels, such as plug-in hybrid and potentially biofuel-powered vehicles). Hence, the addition of a feebate program in California could help some fuel producers meet the LCFS requirements by making it easier for them to sell the required amount of low carbon fuels. However, we note that many of the feebate scenarios we have analyzed mainly result in incremental improvements to conventional vehicles that would use reformulated gasoline. The scenarios involve somewhat lower usage of gasoline overall, which would slightly reduce the amounts of lower-carbon fuels needed to meet the LCFS carbon fuel intensity targets, but otherwise have little implications for the LCFS program.

Other key but less direct policy interaction areas include those with other AB 32 related programs, such as SB 375 – related to smart growth and land use changes – and potential GHG cap and trade programs. These and some other potential policy interactions are discussed in Section 10.5.

1.8. Key Conclusions

Based on the collection of results, we provide an overall summary of some conclusions along with brief discussion. These reflect the outcomes of individual project tasks as well as interactions among the tasks. They represent the key take-away messages from the project efforts.

1. There is evidence from case studies in four European countries to suggest that feebate programs *can* be effective in lowering the average emissions rates of new vehicles.

- This finding is based on average vehicle emissions data from both before and after the introduction of feebate systems.
- At the same time, this finding should be viewed with some caution for a number of reasons.
  - There are important differences between the policy and cultural environment of Europe versus California.
  - Introduction of these systems overlapped with fuel price increases in most cases. At the same time, even taking into account fuel price volatility, the data seem to indicate that feebates did have a measureable effect.

2. Quantitative models suggest that, under the right conditions, feebates can be used to reduce greenhouse gas emissions from new vehicles in California below national emissions standard levels. In addition, results indicate that feebates yield net positive social benefits aside from greenhouse gas reductions.

- A California feebate program could reduce average emissions from new vehicles by 3 to 5 percent, producing 3 to 5 $MMTCO_2E$ of reductions in California in 2020, depending on the design of the policy.
- Results are subject to base case modeling assumptions on consumers' value for fuel savings, their responsiveness to price changes, fuel prices, and vehicle technology costs.
- If consumers were to value fuel savings over the full lifetime of the vehicle, the market would yield emissions levels below currently discussed targets without policy intervention.

3. The ability to affect vehicle design decisions is one of the frequently stated benefits of feebate programs. However, because California is about 10% of the domestic market, feebate policies based in California alone would only have a limited effect on vehicle design decisions.

- For scenarios involving California-only feebate programs, manufacturers' technology decisions are largely determined by national emissions standards.
- Because California-only feebates have limited impact on vehicle design decisions, they are also limited as a source of "spillover" and produce minimal co-benefits for non-feebate regions.
- *If feebates were implemented over a larger geographical area, the potential for spillover would increase*. If other states or the entire country adopted California's feebate policies, the impact could significantly increase.
- A nationwide feebate system could have a very large impact on emissions reductions from passenger vehicles due to its much greater impact on vehicle design decisions. Average emissions from new vehicles would be lowered by about 10 percent, and roughly three-fourths of these reductions would result from vehicle redesign as opposed to changes in purchasing behavior.

4. Quantitative models suggest that a single benchmark system (i.e. one that is not indexed to vehicle size or class) would yield the largest reduction in greenhouse gas emissions, but also the largest reduction in consumer welfare (measured by Consumer Surplus). However, when future fuel savings are taken into account, a single benchmark system would yield the largest net social benefit.

5. Quantitative models suggest that, under the right conditions, feebates could be used to reduce greenhouse gas emissions in lieu of more stringent performance-based standards beyond 2016. A properly designed feebate program could be used as a substitute for increasingly stringent GHG standards for new vehicles beyond 2016 (i.e. LEV III-GHG). This would require raising the feebate rate over time, from $5/g/mi up to $40/g/mi by 2025.

6. Although a single benchmark system would yield the largest net social benefit, issues of equity and fairness among stakeholders could require consideration of alternatives.

- In the project focus groups, there was sensitivity to the issue of "fairness" and a belief that a class-based (or footprint) system would be "fairer" than a single benchmark for people who "need big vehicles."
- This concern is consistent with experience with France's single benchmark system. The system was recently modified to provide subsidies to large families who "need" larger vehicles.
- Some focus group participants understood that, under a class-based (or footprint) system, there would be instances where some large, higher emission vehicles would receive rebates while other lower emission vehicles would receive fees. This is confusing, and seems inconsistent with the stated purpose of feebate systems.
- This view is consistent with recent experience in the Netherlands, who introduced a footprint-based system. Consumer sentiment about the complexity of the system, and the possibility of higher emitting vehicles receiving rebates, caused the Netherlands to *abandon* its footprint system in favor of a *single benchmark* system.

7. Model results suggest that there would be a decline in new vehicle sales under all feebate programs, with an associated 1% drop in industry revenue for the California market. Although this is small in percentage terms, it is significant in terms of dollar amounts.

8. Feebate systems have an impact on sales patterns. All systems increase the demand for non-prestige cars (particularly small ones) and decrease the demand for all other vehicle types, particularly SUVs. However, there are differences across systems. A footprint-based system yields the smallest increase in small car demand, the single benchmark yields the largest, and a two-benchmark (car/truck) system lies in between.

9. Because product portfolios vary across manufacturers, they are affected differently by sales-mix shifts.

- Although evaluating impacts on individual manufacturers would be unreliable, grouping manufacturers using two dimensions (prestige versus non-prestige, domestic versus Asian versus European) reveals shifts in revenue shares due to feebate systems.
- Revenue shares for non-prestige vehicles with Asian nameplates ("Asia-Standard") increase for all feebate systems, and decrease for all other groups. The increase for Asia-Standard is smallest for a footprint-based system, and largest for a single benchmark system.

- These results assume that vehicle portfolio offerings across manufacturers remain unchanged from those projected for the period 2008-2013.

10. Analyses of the impact of feebate policies on different income groups suggest that these policies are not regressive.

- In the new vehicle market, the majority of fees and rebates are applied to higher income groups because they purchase the majority of new vehicles.
- For households that purchase a new vehicle, the average feebate is negative for all households except for those in the lowest income groups. For those income groups with a negative average feebate, the average gets more negative as income increases.
- Analysis of consumer surplus changes indicates that that lower-income households experience an *increase* in consumer surplus due to feebates, whereas higher income households experience a decrease. This is consistent with the pattern of feebates for new vehicle purchases, but also reflects a "ripple effect" from the diffusion of more fuel-efficient vehicles into the used vehicle fleet over time.

11. Results from a large statewide survey (sample size of 3,000) indicate that consumers in California are generally concerned with anthropogenic climate change and energy independence, and would be supportive of a feebate system.

- In the survey, a total of 76% of survey respondents either strongly agreed (26%) or agreed (50%) that they "would generally be supportive of this type of program to help slow the rate of climate change."
- Exploratory research using focus groups (total of about 100 participants) was conducted prior to the survey. The issue of program fairness was a major theme; for example, a household that really needs a large vehicle might be forced to pay a fee. We found that overall response to feebate programs was weakly or strongly negative in most groups. Although focus groups cannot yield statistically significant conclusions, this outcome is qualitatively different from the survey results and should not be summarily dismissed. One possible explanation is that, in the dynamic and interactive setting of focus groups, the presence of individuals with concerns about fairness or a dislike of government programs could influence the overall tenor and direction of discussions.
- With regard to program fairness, survey results generally indicate that the idea of providing feebate-like incentives is *not generally considered unfair* – although some respondents would rather see government programs targeted more directly at the automakers themselves.

12. Automobile dealers are generally opposed to feebate programs due to concerns about administrative burdens, lost revenues, and broader "ideological" opposition to government policies that are perceived to reduce consumer choice.

- Dealers have had mixed and often negative experiences with other types of grant and incentive programs (e.g., Cash for Clunkers) that come with state reporting requirements.
- Some (but not all) dealers are concerned with potential revenue losses under a feebate program. (This concern is generally confirmed by quantitative modeling results.)

13. Automobile manufacturers are mixed in their support or opposition to feebate programs, some citing it as being in line with their corporate stance for "environmental

stewardship" but others being concerned about potential negative effects on sales revenues that also could impact dealers.

- The automakers are generally knowledgeable about feebate programs and have a preference for linear as opposed to "step based" programs.
- The automakers had a mixed response to footprint and class-based programs, some suggesting that a footprint-based system would be well harmonized with CAFE and others suggesting that either type would be too complicated for consumers to easily understand and thus not "transparent" enough.
- The automakers expressed a clear preference for a national rather than individual state programs, and worst of all a "patchwork" of differing state programs – some suggested that individual state programs should be at a minimum, harmonized with each other in the absence of a federal program.

14. Administrative costs for feebate programs are estimated to range from $4.6 to $6.5 million annually (plus $2-$4 million in startup costs). This cost is relatively small when compared to the volume of revenue flow in a feebate program, is on the order of 1% of total fees collected, and is consistent with the level of administrative burden that is typical of state programs of this sort.

15. The potential effectiveness of feebate programs is affected by future events that in some cases can be unpredictable, such as gasoline price changes, cost evolutions for new technologies, or changes in automobile market structure. The future stringency of fuel economy or greenhouse gas emission standards is also found to be a key factor in the incremental benefits of a California-level feebate program. Policymakers should be aware of the potential for these events to interact with feebate program implementation and potentially affect overall effectiveness.

2. INTRODUCTION

The California Global Warming Solutions Act of 2006 (AB 32) calls for the state's greenhouse gas (GHG) emissions to return to 1990 levels by 2020. The California Air Resources Board (ARB, or Board) is the lead agency for implementing AB 32, and on December 12, 2008 the Board approved a Scoping Plan (Plan) that provides policy recommendations and estimates of emission reductions for individual sectors of the California economy. Passenger vehicles are a large contributor of GHG emissions, and the primary policy option specified by the Plan is the direct regulation of GHG emissions via a declining fleet average standard for new vehicle sales. The Board has already approved one such a standard under AB 1493 (Pavley) in September 2004. It applies to passenger cars and light-duty trucks and is phased in beginning with the 2009 model year, achieving maximum stringency for the 2016 model year. The Plan identifies this standard (referred to as Pavley I) as one policy for helping to meet the requirements of AB 32. The Plan also identifies another policy option (Pavely II, or LEV-III) that would further strengthen the standards beginning with the 2017 model year.

However, at the time the Plan was drafted the U. S. Environmental Protection Agency (EPA) had denied the necessary waiver for implementing Pavley, placing these policy options in doubt. Moreover, according to the Plan "AB 32 specifically states (section 38590) that if the Pavley (AB 1493) regulations do not stay in effect, that the State shall implement alternative regulations to control mobile sources to *achieve equivalent or greater GHG reductions*" (emphasis added). The Plan goes on to identify a type of economic incentive policy known as a *feebate* as the possible backstop to the Pavley regulations. Although there are many possible types of feebate policies, for this document they all share the following basic definition:

> A **feebate** is a market-based policy for encouraging greenhouse gas (GHG) emission reductions from new passenger vehicles by levying fees on relatively high-emitting vehicles and providing rebates to lower-emitting vehicles.

The Plan envisions designing a feebate program that would obtain "cumulative emission reductions equivalent to those that would have been achieved under the Pavley regulations." However, the Plan also recognizes that, in the event that Pavley regulations *are* implemented, feebates could be used as a complementary policy to achieve even greater GHG reductions.

To address issues related to the practical design and implementation of a feebate program for California, the Plan specifies that a comprehensive study of feebates be conducted. To meet this requirement ARB commissioned a research project on feebates. A request for proposals was issued in fall 2008. Proposals from two University of California research teams (Davis and Berkeley) were combined into a single research project, and work began in February 2009. The team produced an interim statement of findings in April 2010.

This document is the project's Final Report, and the sections that follow comprise the Research Report portion. Section 3 provides background to support the material presented in the remainder of the report. Sections 4 and 5 provide an overview of research project tasks and methodologies employed, respectively. Section 6 discusses "lessons learned" from ten case studies of feebate and feebate-like policies. Section 7 discusses how policy options were developed and describes those that were adopted for detailed analysis. Section 8 provides details on the Feebate Analysis Model developed for the project. Section 9 compiles the results of policy analysis from the methodologies discussed in sections 5 and 8. Finally, sections 10 and 11 present policy implications, and recommendations and conclusions, respectively.

3. BACKGROUND

Implementing policies to reach the AB 32 goal of reducing the state's greenhouse gas (GHG) emissions to 1990 levels by 2020 requires detailed estimates of the state's past emissions, business-as-usual estimates for 2020, and specific targets and estimates for reductions from specified policies. Although AB 32 is based on a return to 1990 levels, emissions levels in the Scoping Plan are expressed as a "2002-2004 average." The emissions total for this average is 469 $MMTCO_2E$, and the business-as-usual (BAU) projection for 2020 in the Scoping Plan[17] is 596 $MMTCO_2E$. Based on extensive technical work and consultation with stakeholders, ARB developed a 2020 target of 427 $MMTCO_2E$. This implies a reduction of 169 $MMTCO_2E$ (or approximately 30%) from the state's 2020 projected emissions, and the reduction of 42 $MMTCO_2E$ (almost 10%) from 2002-2004 average emission levels.

In this section details from the AB 32 Scoping Plan on emissions targets and policy options (including the role of feebates) are reviewed. Because emission standards play a fundamental role in policy analysis, relevant details on these are reviewed. Past efforts in California to implement feebate systems that provide interesting and useful background on this subject are also reviewed. Finally, the fundamental design elements providing the "building blocks" for developing alternative feebate policies are described, as these will be referenced in the remainder of the report.

3.1. AB 32 emissions targets for passenger vehicles

The AB 32 Scoping Plan reports that the transportation sector had a 2002-2004 average emissions level of 179.3 $MMTCO_2E$, and has a BAU projection of 225.4 $MMTCO_2E$ out of the total 596 $MMTCO_2E$ (or 38%), making it by far the largest sector in terms of GHG emissions. By this accounting the transportation sector's share of reductions would be 64 $MMTCO_2E$. Because passenger vehicles produce 74% of the sector's emissions, their share of BAU emissions and targeted reductions would be 167 $MMTCO_2E$ and 47.4 $MMTCO_2E$, respectively.

With regard to reduction policies, the transportation sector is included under California's Cap and Trade program, which complicates the discussion. However, the Plan identifies specific reduction measures that are directly or indirectly related to passenger vehicles—see Table 3.1. These include vehicle efficiency measures (e.g., to reduce rolling resistance, encourage more efficient auxiliary systems, etc.) and the Low Carbon Fuel Standard (LCFS). The total of these targets is 51.2 $MMTCO_2E$; however, only a portion of the vehicle efficiency measures and the LCSF would apply to passenger vehicles. At the same time, there are undetermined savings due to the effects of the Cap and Trade program that would presumably have an impact on fuel prices and vehicle miles traveled.

[17] These figures come from the original version of the Scoping Plan. Because ARB issues periodic revisions of the Scoping Plan, these figures may not agree with the most recent version.

Table 3.1 Summary of Passenger Vehicle Related Reduction Measures

Reduction Measure	Potential 2020 Reductions $MMTCO_2E$
Pavley (AB 1493)	27.7
LEV III-GHG Standards	4
Vehicle Efficiency Measures	4.5
Low Carbon Fuel Standard (Discrete Early Action)	15

The total reduction assigned to the GHG standards (both Pavley and LEV III) is 31.7 $MMTCO_2E$. Appendix C of the Scoping Plan (pages C-61 to C-63) describes ARB's plans with regard to feebates, which include the following:

- A general description of feebates similar to those in this report
- A statement that ARB has commissioned this research project
- A 31.7 $MMTCO_2E$ emission reduction target for feebates in lieu of Pavley regulations
- A statement that ARB will evaluate feebates as a complementary measure if EPA grants a waiver

On June 30, 2009 the EPA granted a waiver for Pavley, rendering moot the subject of using feebates as a replacement for Pavley (with its target of 27.7 $MMTCO_2E$). This is discussed in more detail in the next section.

3.2. The role of emissions standards

The likely impact of feebate programs on greenhouse gas emissions for the study's planning horizon (2011-2025) depends critically on a wide range of factors that will affect the future new vehicle market. In particular, future emissions performance standards play a major role; however, the form and stringency of these standards through 2025 are far from certain at this time. In fact, current and expected near-term policy conditions have already changed multiple times during the course of this project. As noted previously, in June 2009 the EPA granted a waiver for the Pavley regulation. Moreover, in May 2009 the Obama administration had announced it would develop a new national emissions standard to be harmonized with Pavley. We provide additional background on these here. Other factors and assumptions expected to impact feebate program evaluation are addressed in later sections.

Emissions standards can be summarized in terms of the average emissions rate of new vehicles sold for a given model year. The timing and amount of actual emissions reductions depend on how the vehicles are driven over their lifetimes. Evaluating feebate programs on the basis of these same measures requires a baseline (or reference) policy for comparison. The following facts on emissions standards are relevant for establishing a reference policy scenario:

- The Pavley standard uses two benchmarks. It requires that new passenger cars and trucks up to 3750 lbs on average emit less than 205 gCO2E per mile by MY2016. For light-duty trucks 3750-8500 lb the limit for the average is 332 gCO2E/mi. ARB anticipates the fleet-wide average under this regulation to be 243 gCO2E/mi. The emissions reductions from this policy are estimated to be 27.7 MMTCO2E.

- The proposed new national standard starts in MY2012 and also goes through MY2016. It is based on two footprint curves (one for passenger cars, and one for light-duty trucks), and is expected to yield a new vehicle fleet-wide average of 250 gCO2E/mi in MY2016. Details on these footprint curves can be found in section 7.2.

- California will enforce the Pavley standard for MY2009-2011, and then accept compliance with the national standard for MY2012-2016. Although the national standard is less stringent (250 versus 243 gCO2E/mi in 2016), it is expected to yield greater GHG reductions because it applies nationwide.

- There is nothing in currently proposed policy to indicate what national emissions standards would be after 2016. However, the Obama administration recently signaled its intention to develop a policy that pursues more stringent standards beginning in 2017 (EPA/NHTSA, 2010b).

- A LEV III-GHG standard in California (called Pavley II in the Plan), if implemented, would start in MY2017 and go through MY2025. Although there is a rough projection of emission reductions in the Scoping Plan for this standard (4 MMTCO2E in 2020, growing to 27 MMTCO2E by 2030) these figures are highly speculative and there is currently little information on what the form and new vehicle emissions averages might be.

To address the need for a reference policy scenario over the entire period (through 2025), our research makes the following assumptions:

- The current policy is used through MY2011, and the currently proposed national standards are used for MY2012-2016. Because the national standards were designed to harmonize with the California program, we consider them to be a reasonable substitute for Pavley.

- The period MY2017-2025 requires an assumption for national emissions standards. In consultation with ARB staff, our study adopts a Reference Policy that assumes a 2% reduction per year starting in 2017.

This reference policy scenario, denoted the 2% National Standard scenario, is used to make baseline projections. Projections for the 2% National Standard plus a feebate program are then compared to the baseline to evaluate how the feebate program might complement emissions standards. There is also an interest in the feasibility of using feebates as a substitute for future emissions standards. To examine this, we examine alternative scenarios that assume national standards stay at 2016 levels for 2017-2025. Because this corresponds to a 0% reduction starting in 2017, this is denoted the 0% National Standard scenario. Additional details on the reference policy scenario are provided in section 7.2 on policy formulation.

3.3. Past efforts in California to implement feebates

The idea of using feebates in California is not new. A number of attempts to implement feebate programs have been made by legislators. Two such cases are: DRIVE+(SB 1905), and the Clean Vehicle Incentive Program (AB 493). The following descriptions of these two programs provide useful illustration of the range of issues that must be addressed when implementing a feebate program.

3.3.1. DRIVE+ (SB 1905)

State Senator Gary Hart initially introduced this legislation in 1990 as SB 1905: "Demand-Based Reductions in Vehicle Emissions Plus Reductions in Carbon Dioxide" or the "DRIVE+" bill. It was re-introduced in similar forms in 1991 (SB 431), 1992 (SB 1843) and 1993 (SB 378). The initial SB 1905 passed easily in the legislature in but was then vetoed by then-Governor George Deukmejian on his last day in office. Each of the subsequent versions failed to garner enough support to pass the legislature (NCSL, 1996).

Under the DRIVE+ plan, automobile dealers would have sent fees collected from the purchase of higher emitting vehicles to the California Department of Motor Vehicles (DMV). Consumers were to receive rebates directly from the DMV, for lower emitting vehicles. Fees and rebates were calculated based on a combination of smog-forming emissions and carbon dioxide emissions. For example, in SB 378 the initial values were $1,925 per g/mi for hydrocarbons, $2,200 per g/mi for oxides of nitrogen, $220 per g/mi for carbon monoxide, $586 per g/mi for particulates (PM10), and $2.50 per g/mi for carbon dioxide. The DRIVE+ proposal was designed to be revenue neutral, including accounting for DMV administrative costs. In order to accomplish this, a "DRIVE+ fund" was to be established to collect fees and distribute rebates, with a reserve account to ensure revenue-neutrality even in cases of sales fluctuations (NCSL, 1996).

The initial DRIVE+ program included a feebates plan based on six separate vehicle classes. In the 1992 version of the bill, this was simplified to a single vehicle class, but again that bill also failed to pass in the legislature (Schuster et al., 2004). The bill also at one point included a provision that a special vehicle license plate be issued and the funds used to help pay for the initial startup of the program.

3.3.2. Clean Vehicle Incentive Program (AB 493)

Introduced in 2006 by State Assemblyman Ira Ruskin and narrowly defeated in the legislature in its third reading in 2007, AB 493—the Clean Vehicle Incentive Program (CVIP)—was designed to encourage manufacturers to offer more low-emitting vehicles to CA car-buyers, and to encourage consumers to purchase the cleaner vehicles. Like DRIVE+, the program consisted of one-time rebates and surcharges of up to $2,500 (surcharges also could not exceed the vehicle sales tax), with some "average" emission vehicles excluded (i.e., the program included a significant "zero-band"), on the purchase of new vehicles. Unlike DRIVE+, the CVIP focused entirely on GHGs and not smog-forming pollutants as well. The "zero-band" or "doughnut hole" consisted of approximately 25% of vehicles that were assessed as average or close to average in terms of their GHG emissions. Also like DRIVE+, the program was designed to be "self-financing" (i.e., revenue neutral) and market-based. The program applied to light- and medium-duty passenger vehicles with a gross vehicle weight rating of 10,000 pounds or less.

The CVIP plan as proposed divided up responsibilities for developing, administering, and enforcing the program between the ARB, the DMV, and the Board of Equalization (BOE). BOE was to bear the largest ongoing costs for managing the program fund (estimated at $1 million per year in the bill's legislative analysis) but both ARB and BOE would require significant startup funds to get the program going, on the order of $850,000 (ARB) to $1.5 million (BOE) for the period leading up to the start of the program.

3.4. Elements of Feebate Policies

To provide additional background on feebates, we review the structural elements that, when combined, comprise a feebate policy. The first requirement is an efficiency criterion for defining a feebate. Our study uses the CO2-equivalent emission rate of a vehicle, measured as grams of CO2 per mile (or simply g/mi). Generally, a feebate policy requires the following:

- A benchmark that defines which vehicles receive fees and which receive rebates.
- A functional form and a rate parameter (or parameters) that determine payment amounts.
- A locus of monetary transactions to determine how and when rebates and fees are actually transferred at the time a new vehicle is purchased.

In addition, practical details of how a program is introduced and implemented are important. The following discussion provides a review of these design elements in more detail.

3.4.1. Structure of benchmarks

Perhaps the simplest possible feebate policy is to use a single benchmark for all vehicles, combined with a single rate parameter, so that a feebate amount is given by the simple equation:

Feebate = rate*(emissions_rate – benchmark),

where rate is in units of dollars per gram per mile ($/g/mi), and the emissions_rate and benchmark are measured in grams per mile (g/mi). For example, consider a policy with a rate of $20/g/mi and a benchmark of 300 g/mi (~ 30 mpg). A new vehicle emitting at a rate of 350 g/mi (~25 mpg) emits more than the benchmark, and would be assessed a fee of 20*(350-300) = $1,000. A vehicle emitting 250 g/mi (~36 mpg) would be assessed a fee of -$1,000, i.e., it would receive a $1,000 rebate (a negative fee is the same as a rebate).

Simple movement of the benchmark changes the net flow of fees and rebates, and in many cases it would be politically attractive to set the benchmark so that revenue neutrality is attained. Options for benchmarks considered during the course of this study include:

- Single benchmark
- Two benchmarks (one for passenger cars, one for light duty trucks)
- Class-based benchmarks (e.g., subcompact car, minivan, small pickup, midsize SUV)
- Footprint-based benchmark(s)

For a footprint-based benchmark, the benchmark is assigned on the basis of a vehicle's size as measured by its footprint, defined to be: wheelbase x track-width. The MY2012-2016 national GHG emissions standard is based on two footprint curves (one for passenger cars, and one for light-duty trucks) that assign a benchmark for each footprint value (yielding literally hundreds of benchmarks). As discussed in Chapter 7, the emphasis of our research shifted during the course of the project to footprint-based benchmarks due to their emergence to prominence in the new national emissions standard.

There are arguments for/against the benchmark options. A single benchmark is "fair" in that it represents an absolute standard that is the same for all vehicles. In addition, theory suggests that this approach could yield larger improvements than the others. However, some consider it "unfair" because some consumers (e.g., large families, self-employed service providers) are forced to pay a fee because they "need" a larger vehicle. Moreover, there is a concern that a single benchmark could impact manufacturers in different ways, depending on the types of vehicles they sell. The footprint approach (or possibly an approach using size-based classes) addresses both of these issues by establishing benchmarks as a function of size, although it increases the complexity of the program. The two-benchmark system can be viewed as lying between these two approaches. An objective of this study is to examining the tradeoffs among these systems in more detail.

3.4.2. Functional form and rate

A second design element is how fees/rebates vary as a function of distance away from the benchmark. In the previous simple example, the functional form is a straight line and the rate represents the marginal value of reducing a vehicle's GHG emissions by one unit. A straight-line functional form values every gram of CO_2 equally. Options for functional forms include:

- Straight line (linear)
- Piecewise linear (segments that change rate)
- Step function

These are illustrated in Figure 3.1 below. These forms can be combined to include specified maximum and/or minimum values, and also a "donut hole" where there are no feebates over a specified range. Some consider step functions to be easier for consumers to understand, and this has been a matter of some discussion. However, a drawback is that the feebate changes abruptly at certain specific values of the emissions rate, so that two vehicles that are almost identical could have very different feebate levels. The Chapter 6 on Lessons Learned gives examples of all three of these functional forms, and discusses tradeoffs among alternative functional forms.

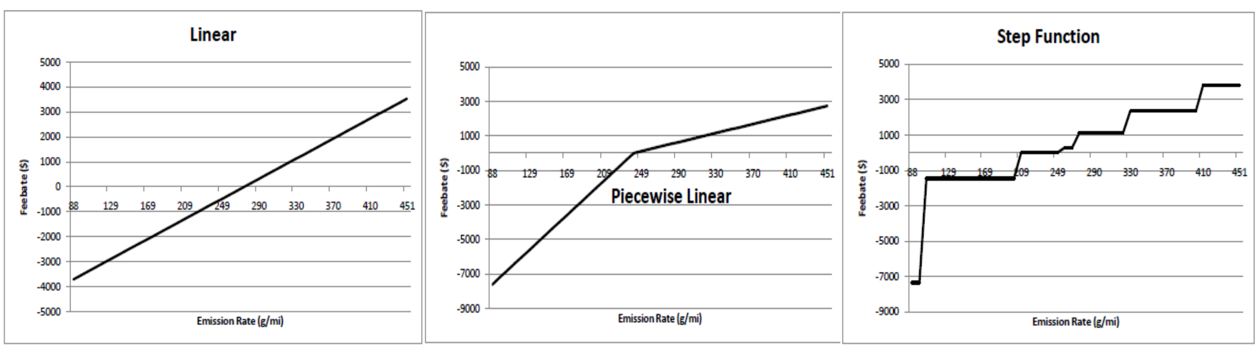

Figure 3. 1 Three Feebate Functional Forms

When considering the effect of the feebate rate, the simplest case is the earlier example of a linear function with a single benchmark. The rate represents the change in vehicle purchase price per unit of improvement in the emissions rate (in g/mi). Vehicles emitting more emissions than the benchmark will be assessed a fee that will cause sales to decline, and vehicles emitting fewer emissions than the benchmark will receive a rebate that will cause sales to increase. All other things equal, increasing the rate will magnify the effect on sales shifts.

3.4.3. Point of regulation/locus of transaction

Another essential design question is the manner in which feebates will be transacted. Feebates may be enforced at the level of the vehicle manufacturer, in which case there will be a small number of parties involved and most "transactions" will be internal to the firm. However, this does not mean that the feebate is being applied to the manufacturer rather than the consumer. Any feebate could appear as an additional line item on the vehicle label, and would effectively represent a change to the vehicle's purchase price.

Alternatively, feebates could be made a part of the transaction between dealers and customers. This would greatly increase both the number of transactions and the volume of revenue flows but could possibly have a greater impact on consumer decision-making. Finally, there could be systems where consumers are required to process their feebate transactions directly with a government agency.

3.4.4. Implementation strategies

Another element potentially affecting the success of a feebate policy is the way that it is introduced. A feebate policy could be implemented either abruptly, or with prior notice given to manufacturers and consumers. A delay between the announcement and implementation of the policy gives manufacturers time to adapt, but could also have the initial perverse effect (in the short term) of causing consumers to buy higher emission vehicles that would soon be charged a fee. Similarly, they could delay the purchase of lower emission vehicles until the rebates become available.

Other considerations include whether to phase in different elements of the system at different times, e.g., beginning with rebates and adding fees later (or vice-versa), gradually increasing the number of vehicles subject to the program, etc. Finally, there are practical issues on how to manage revenue flows, especially if conditions in the market change dramatically due to, e.g., volatility of energy prices, technology breakthroughs, etc.

4. RESEARCH STUDY TASKS

The main objective of this project is to provide the ARB with a California-specific assessment of feebate programs for new vehicles as a replacement for the Pavley standards or as a complement to the Pavley standards. A research plan was developed to address this objective from multiple perspectives, applying a variety of methodologies. The research was carried out in seven tasks. These are: Task 1: Lessons Learned; Task 2: Focus Groups and Interviews; Task 3: Policy Formulation; Task 4: Feebate Analysis Model; Task 5: Policy Analysis; Task 6: Policy Implications; Task 7: Statewide Survey. Figure 4.1, below, shows how tasks are interrelated in the context of the overall project.

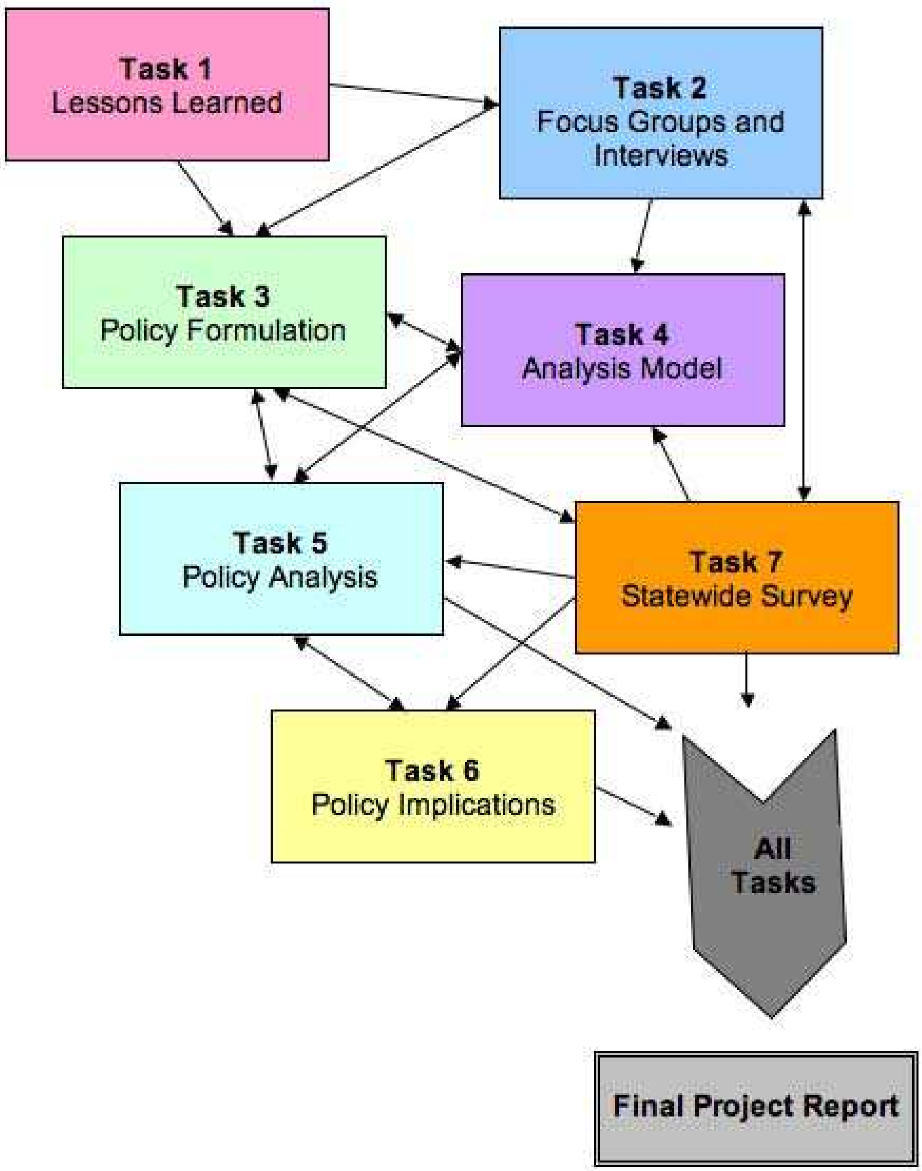

Figure 4.1 Research Task Influence Diagram

The following is a brief overview of the research tasks performed in this project. An overview of the methodologies employed appears in the next section.

Task 1. Compile case studies on real-world policies to identify any lessons learned. The team compiled ten case studies on a range of feebate-related policies (i.e., economic incentive-based policies related to vehicle purchase and use).

Tasks 2 and 7. Determine possible responses of key stakeholders to feebate programs. Focus groups and a statewide survey of consumers were conducted. Personal interviews were conducted with new vehicle dealers, vehicle manufacturers, and feebate program experts, and additional stakeholder feedback was obtained through public workshops early in the project.

Task 3. Develop specific feebate policy options to be evaluated. Feebate policy design elements are combined in different ways to generate specific policy options. There are virtually an infinite numbers of combinations that could be considered. The team developed and prioritized options based on input from a public forum, and consultation with ARB staff.

Task 4. Develop a model for producing quantitative projections of future outcomes under alternative policy scenarios. A Feebate Analysis Model was developed specifically for this project. Vehicle redesign and pricing choices by manufacturers as well as consumer response in the new vehicle market are simulated under alternative policy options, yielding estimates of relative impact on average emissions rates of new vehicles, total emission reductions, and social costs and benefits.

Tasks 5 and 6. Analyze alternative policy options and assess findings with regard to policy implications. Using methodologies and results from other tasks, policy options are analyzed from multiple perspectives and implications are developed. Other specific tasks include the estimation of administrative costs, economic and fiscal impacts, an exploration of equity implications, and potential interactions between feebates and other AB 32-related policy initiatives.

5. METHODOLOGY OVERVIEW

The tasks described in the previous section draw on a number of research methodologies. This section provides an overview of these, divided under the general headings of "modeling" and "Stakeholder Attitude and Opinion Research."

5.1. Modeling

A Feebate Analysis Model was developed to provide quantitative projections of market behavior and emissions reductions in response to possible feebate policies in California. An important aspect of feebate (and other) policies is their potential to affect future vehicle technology adoption decisions by manufacturers. We assume that when manufacturers make these decisions they take into consideration the overall response of the entire domestic (United States) new vehicle market, and the national policy environment. For these reasons, the Feebate Analysis Model has a two-tier structure. The top tier is a Manufacturer Decision Model (MDM) that simulates design decisions for new vehicle offerings for the period 2007 to 2025. The bottom tier of the Feebate Analysis Model is a California-specific model that supports more detailed examination of policy impacts on the California vehicle fleet (both new and used) for multiple consumer groups. It takes as given the vehicle configuration projections produced by the MDM. The following sections give overviews of three main features of the Feebate Analysis Model: Vehicle configurations, the MDM, and the

California vehicle market simulation model. More details on the MDM and California models appear in sections 8.1 and 8.2, respectively.

5.1.1. Vehicle configurations in the Feebate Analysis Model

The Feebate Analysis Model employs vehicle configurations that are defined at a relatively high level of detail compared with most previous studies. Vehicle configurations are defined at roughly the same level of detail as the vehicle data reported by manufacturers to the EPA and NHTSA. Generally speaking, this level of detail would include the following:

Model Year

Manufacturer

Division (Make)

Model Name

Engine Characteristics (e.g., type, size)

Transmission

Drivetrain

Body type and size

Curbweight

At this level of detail, changes in the physical configuration of a vehicle could yield changes in both fuel economy and performance in ways that would affect, e.g., a manufacturer's compliance with emissions standards. Combined with vehicle prices, such changes would also affect vehicle demand, which must be estimated using consumer response models. The MDM and the California models each have their own consumer response models, as will be described.

The vehicle attribute database used in the study is for the base model year 2007. For an interim period (2008-2013) a dynamic database that incorporates near-term forecasts of vehicle configuration changes for the industry is used. These include aspects of the recent dramatic restructuring of the vehicle manufacturing industry. Once changes from the dynamic database have been incorporated, the basic structure of the vehicle market is assumed to remain the same for the rest of the scenario analysis period (through 2025). Additional details on vehicle configurations, including a discussion of body type and size classes, are discussed in section 8.

5.1.2. Manufacturer Decision Model (MDM)

The MDM is a dynamic multi-period optimization model that simulates automobile manufacturers' behavior in response to feebates and regulatory standards. Manufacturers are assumed to have two options: 1) adopting emission reduction (fuel economy improvement) technologies; and 2) implementing pricing strategies that adjust vehicle prices in order to shift sales toward lower emission vehicles and thus reduce fleet average emissions. Vehicle emissions rate (or fuel economy) is assumed to be the only design factor and other characteristics (e.g. vehicle weight, size and horsepower) are assumed to be constant over the planning horizon. Vehicle emissions improvements and manufacturers' pricing strategies will induce changes (relative to the base year) in vehicle price, operating cost, and feebate value. The impact of these changes on consumer demand and surplus is estimated using a representative consumer choice model. The objective of manufacturers is to maximize consumer surplus (equivalent to maximizing profit under the assumption of a competitive automobile market) while simultaneously considering consumer response and meeting fuel economy and emissions standards. The primary output of the MDM is a prediction about the amount of vehicle technology adoption at the level of vehicle configuration, which in turn is input to the California Vehicle Market Simulation model for conducting detailed analysis on consumer markets. The MDM can also output projections on consumer choices (e.g. new vehicle sales and market shares of each vehicle configuration) and consumer surplus under various feebate programs.

The MDM incorporates a high degree of technological detail on manufacturers' current product lines, future product plans, redesign schedules, and the costs and potential effectiveness of mitigation technologies. The technological potential to reduce emissions is represented by technology cost curves that estimate retail price equivalent (RPE) per vehicle as a function of the relative increase in fuel economy or reductions in GHG emission rates. Separate technology cost curves are provided by vehicle class (20 vehicle classes as discussed later), engine technology (gasoline, diesel, and hybrid vehicles), and time period (short, medium and long term). The technology cost curves are adjusted for each manufacturer based on a statistical analysis of each manufacturer's realized fuel efficiency technologies. The MDM also recognizes the inherent time constraints of product redesign in automotive manufacturing. Each vehicle has its own redesign schedule and the redesign cycle is typically five years, at which point new technologies to reduce greenhouse gas emissions and improve fuel economy may be adopted.

The automobile market is highly heterogeneous, reflecting the different tastes of the car-buying public. This fact is recognized by including twenty different vehicle class segments in the MDM. Within each segment, consumers' responses to price and operating cost changes are different. To reflect the impact of regional GHG policies (e.g. a California-only feebate program), the national automobile market is divided into two regions (either California and Rest of US, or, Opt-in States and Rest of US). Consumer choices in these two regions are modeled separately. Different regions may have different sales mixes due to the existence of regional feebate programs or emissions-related policies. However, manufacturers are assumed to offer for sale the same vehicle designs in all regions. The vehicles designed will therefore be a compromise between the demands of the two different markets.

The planning horizon is from MY2007 to MY2025 and it is divided into two periods: 2007-2010 without feebate policies and 2011-2025 with feebate policies. The MDM is solved first for the period of 2007-2010. The fuel economy ratings of vehicles in 2010 are updated and saved as output. Then starting with the new fuel economy ratings of 2010, it is solved for the period 2011 to 2025. The 2007-2010 fuel economy standards are very different from 2011-2025 standards in terms of stringency and definition of compliance categories (passenger cars/light trucks). Formulating and solving the MDM in two time stages eases the modeling effort. Moreover, the limited scope of the period 2007-2010 is compatible to the limited foresight of manufacturers who could not foresee the tough 2012-2016 national standards when they were designing vehicles for the years of 2007 or 2008. Solving the model in one single period from 2007 to 2025 assumes that manufacturers have the ability to predict future standards with perfect foresight and would potentially overestimate fuel economy improvement. The first stage problem only needs to be solved once and the second stage problem is solved for various policy cases. Thus the division of the planning horizon into two periods also reduces computational time.

5.1.3. California Vehicle Market Simulation Model (aka, CARBITS)

The vehicle market simulation model developed for this project is an extension of an earlier model developed for ARB known as "CARBITS." CARBITS is a response model for the light-duty vehicle (LDV) market in the State of California. The original version was developed to support policy analysis related to California's AB 1493 legislation on motor vehicle greenhouse gas emissions. Since then it has been extensively revised; the current version developed for this project is denoted CARBITS 3.0. The primary revision was to expand its capability to use the highly detailed vehicle configurations described above.

CARBITS integrates market response and demographic sub-models to simulate the behavior of the California light-duty vehicle market over a multi-year period. Yearly results are based on simulation of household-level behavior in the personal vehicle market, which comprises the vast majority of the light-duty vehicle market in California. The basic high-level structure of the CARBITS platform requires that the analyst provide a forecast scenario. There are two major inputs that define a forecast scenario: a Vehicle Technology Forecast, and a Fuel Forecast.

Results are obtained by aggregating estimates of expected household-level vehicle holdings to represent the California market. CARBITS incorporates a database of households with weights that are constructed to "scale up" the database so that it represents all households in California. CARBITS includes a module that simulates demographic changes over time. The consumer response model was developed in accordance with discrete choice theory, in which households (with varying characteristics, e.g., household size and income) are assumed to make choices so as to maximize the utility they derive from various types of vehicles based on their features ("attributes"). This requires that all vehicles (for both the new and used vehicle markets) be characterized by an appropriate set of variables associated with consumer preferences for competing vehicle types (e.g., a 1994 gasoline-powered subcompact car). For example, consumers base their vehicle holding decisions on attributes such as market value/purchase price, fuel economy, and performance that will vary both within and across the different vehicle types. CARBITS is initialized with a historical database for used vehicles; the Vehicle Technology Forecast used by this version of CARBITS is the *output* of the MDM, i.e., the forecasted vehicle configurations.

CARBITS has two main features that address issues of interest for analyzing feebate policies. First, as noted, CARBITS addresses both the used and new vehicle markets. CARBITS can therefore be used to assess the impact of feebates on the future evolution of the used vehicle fleet. Second, because CARBITS models the response of various household types, it is possible to examine issues related to equity. For example, it is possible to examine the impact of feebates on different income categories. CARBITS is used to perform this type of analysis in section 9.2.

5.2. Stakeholder Attitude and Opinion Research

Several methodologies were employed for the "Stakeholder Attitude and Opinion Research" aspects of the project, revolving around the use of expert and stakeholder interviews, focus groups with the general public, and a statewide telephone survey. The key stakeholder groups that were contacted included "original equipment manufacturer" (OEM) automakers, automobile dealers in California and the California New Car Dealers Association, environmental groups, and the general public. The general methods used for these aspects of the project are discussed below, with a particular emphasis on the statewide survey that involved a relatively intricate methodology to develop and implement. Summaries of results are included later in the report, and key project instruments such as the focus group protocols are included in the attached appendices.

Interviews with Experts and Stakeholders

The interviews with experts and stakeholders consisted of in person or telephone interviews that referred to a set of questions developed prior to the interview, to help guide the process and to make sure that key questions are asked. Several interviews were conducted with past feebate program experts in the U.S. and abroad, with major automobile company representatives, and with managers of automobile dealerships in various regions of California.

Each interview lasted for 25 to 60 minutes and was recorded for purposes of the later development of a complete summary of each interview. The interviews were conducted according to procedures required by the UC Berkeley Office for the Protection of Human Subjects where consent to record the interview was obtained prior to recording, and the participants were informed that their interviews were only to be reported on an anonymous basis where they would not be personally identified.

Focus Groups

In order to assess potential public perceptions and opinions about a potential feebate program in California, a series of focus groups was conducted in different regions of the state. A total of twelve focus groups were conducted, in two rounds of six focus groups each, with a total of 110-120 participants. In each round, two focus groups were held in the Bay/Sacramento area, two or three were held in the Los Angeles/San Diego area, and one or two were held in the Central Valley area of the state. In each round, one focus group was conducted in Spanish and the remaining five were conducted in English. The consulting firm of Ewald & Wasserman Research Consultants, LLC in Sacramento, California, was engaged to recruit participants for the focus groups, based on their low bid for the service.

The focus groups took place over two hours in the early evening, at a public library or other convenient location for participants. The focus groups were moderated by research staff with UC Berkeley's TSRC. A carefully developed "focus group protocol" was used in each group to guide the discussion. However, care was made to allow the focus group participants freedom to discuss issues of importance to them, so the nature of each focus group was somewhat variable. Each of the twelve focus groups had eight to ten participants.

Statewide Survey

Also to help assess potential public response to a vehicle feebates program, a statewide telephone-based survey was conduced in Fall 2009. The survey instrument was designed and initially pre-tested by the UC Berkeley project team. The telephone data collection was then conducted by Ewald & Wasserman Research Consultants, LLC (hereafter E&W) in their office in San Francisco, CA, in combination with a second laboratory located in San Diego, CA. The target sample size for the survey was 3,000 completed surveys (i.e., "n=3000") and the survey was conducted by telephone using random-digit dialing and that therefore included cell phones as well as land lines. Efforts were taken to make the survey sample representative by ensuring that key ethnic and other demographic groups were adequately sampled, rather than simply accepting the first 3,000 completed surveys based on who would complete them (see below).

The telephone survey length was designed to average about 15 minutes to complete, and respondents did not receive any monetary incentive for partaking in the survey. The final survey length was between 13 and 16 minutes, depending on the language, with Spanish interviews taking about 2 minutes longer than the English surveys. Multiple revisions of the survey were produced collectively by the research team prior to administering the survey, based on prioritization of key issues to probe given the survey length constraint, and final versions of the survey were informally pre-tested to help improve question wording and respondent comprehension of the questions.

The goal of the telephone survey was to collect survey data from a representative sample of California residents, who fulfilled the Feebate survey criteria (living in California for nine months or more out of the year and planning on leasing or purchasing a vehicle within the next 10 or 15 years) and spoke either English or Spanish. These criteria were designed to: 1) ensure that the respondent was living in California for most of the year and not temporarily residing in state and 2) ensure that the respondent would answer questions as someone who potentially could be directly affected by the proposed policy. In establishing these two screening criteria, the survey sought respondents representative of Californians who would likely be impacted by the policy and thus have a vested interest in its implementation.

The first draft of the survey instrument was programmed by E&W and the data collection was started with a goal of n=50 completed surveys for a "pilot" of the survey instrument. For the pilot E&W delivered n=58 completed surveys. After the pilot, the survey instrument was modified to include the pilot findings and interviewer observations and the final version was programmed for CATI.

Survey Analysis Methods

The survey collected a total of 3,072 completed surveys from the population of California. While a concerted effort was made during the data collection process to produce a demographic distribution that closely matched that of the state, there was some departure within the sample from the general population along certain demographic attributes. That is, the distribution of age, income and education are somewhat different from that of the general population within the state. Such departures can often occur in CATI surveys, due to the fact that populations with certain demographics have a higher propensity to respond to telephone surveys than others. Typically, people with higher age, education, and income have a greater propensity to respond to telephone surveys and this propensity will skew the sample towards a wealthier, more educated cohort.

However, the impact of this departure on the overall results can be corrected through a "re-weighting" of the sample. For this analysis, the sample is re-weighted using post-stratification weights, which adjust the demographics of the sample to closely match that of the state population. This adjustment scales the opinions of respondents of under-represented demographics to have a greater weight (>1) on the distribution of opinion. Similarly, respondents of over-represented demographics are adjusted to have a reduced weight (<1) on the distribution of opinion.

As discussed in more detail in the later section on Survey Analysis and Results, the post-stratification weights applied to this analysis were developed to rebalance the sample along the demographics of income, education, age, and race. The post-stratification weights were developed using the Public Use Microdata Sample (PUMS) databased from the annual American Community Survey (ACS) (US Census, 2009). For each state in the nation, the PUMS dataset offers the complete de-identified data of a 1% sub-sample of the ACS for each year. The sample itself is provided with weights such that the representation of each observation within the PUMS sub-sample scales appropriately such that the sum of all weights matches the California population. For the analysis in this study, the sample was re-weighted using post-stratification weights built off of a 3-dimensional joint-distribution of income, education and age using the 2006-2008 PUMS dataset for California. Some re-weighting along the distribution of the “race” variable also resulted as discussed in the detailed survey results section later in the report.

Ultimately, the weighting of the sample along the selected demographics produce distributions of opinions to key questions pertaining to the feebates policy. That is, the weighting does not alter any general conclusions that would be drawn from the raw sample. But to maintain analytical transparency, both the weighted and un-weighted distributions are presented for key results to show the relative impact of the sample re-weighting on the overall results. To begin, Table 5.1 shows the distribution of key demographics of the original sample, the population, and the re-weighted sample for comparative purposes.

Table 5.1 Distribution of Key Demographic Attributes

(a) Household Income	Raw Sample	California Population	Reweighted Sample
Less than $10,000	4%	5%	6%
$10,000 to $25,000	9%	14%	12%
$25,000 to $35,000	8%	9%	8%
$35,000 to $50,000	11%	13%	13%
$50,000 to $75,000	17%	18%	18%
$75,000 to $100,000	16%	13%	14%
$100,000 to $150,000	18%	15%	16%
More than $150,000	16%	13%	12%

(b) Age	Raw Sample	California Population	Reweighted Sample
18 - 24	4%	14%	12%
25 - 34	11%	19%	20%
35 - 44	17%	20%	21%
45 - 54	25%	19%	20%
55 - 64	24%	13%	14%
65 - 74	14%	8%	8%
75 or over	6%	7%	6%

(c) Education	Raw Sample	California Population	Reweighted Sample
Did not complete high school	6%	20%	17%
High school graduate	10%	24%	23%
Some college	18%	23%	25%
2-year college degree	12%	7%	7%
4-year college degree	28%	17%	18%
Graduate degree	25%	9%	10%

(d) Race	Raw Sample	California Population	Reweighted Sample
Caucasian or White	55.8%	42.6%	44.5%
Hispanic	24.5%	36.1%	36.9%
African American	5.2%	6.0%	5.5%
Asian	8.2%	12.1%	6.1%
Native American or Alaskan Native	2.4%	0.5%	2.7%
Hawaiian or Pacific Islander	1.0%	0.3%	1.3%
Other	2.7%	2.4%	3.0%

Table 5.1 illustrates the general demographic attributes of the sample, population and the re-weighted sample for income, age, education and race. Table 5.1(a) presents the distributions for household income, which show that the raw sample is skewed slightly towards higher incomes in comparison to the population. The weighted sample is adjusted to match ACS income more accurately. The raw sample distributions in Table 5.1 (b), (c) and (d) are skewed a bit more significantly away from the population distribution. The raw sample was older, more educated and more Caucasian than the California population. The re-weighting of the sample adjusted the demographic distribution to more closely match the demographic distribution of the population within California. The same weight that adjusts the relative influence of sample respondents to produce the new demographic distribution is applied to the respondent opinions to produce weighted response distributions. The gender split of the raw sample was 47% male, 53% female, the weighted sample shifted the share to 48/52, while the population is estimated to be 50/50.

Please see Section 9.3, later in this report, for a discussion of key findings related to the stakeholder opinion research. Also see the report appendices for further details of the methods and results for the interviews, focus groups, and California statewide survey.

6. LESSONS LEARNED

Although there is an academic literature on feebates, for purposes of this research project it was considered important to collect information about any *real-world* experiences with actual policies that have been implemented, and to identify "lessons learned." In recent years several governments have put in place either complete feebate systems or vehicle incentive systems with some of the characteristics of feebates. A detailed set of ten case studies has been compiled that cover a range of systems: These appear in Appendix D. Two of the ten cases are from North America (Canada and U.S.), but the remaining eight are from Europe (Denmark, France, Germany, the Netherlands, Norway, Spain, Sweden, and the United Kingdom). Because the complex policy landscape in Europe can make a direct comparison to California a bit difficult, we spend some time reviewing the European context for GHG emissions policies.

During the course of this study, four of the countries (Denmark, France, the Netherlands, and Norway) had in place a completely "pure" feebate system that exactly fits the basic definition. Canada had a short-lived feebate system that started in March 2007, with the rebate portion dropped in 2009. The other countries provide examples of CO_2-related vehicle incentives that are formulated as part of more traditional tax policy. Two specific types are the registration tax, and the circulation tax, which will be defined and discussed. Although the circumstances and policy environments in the various cases can be quite complex, the goal here is to summarize to the degree possible some "lessons learned" that can be applied when considering policy options for California.

6.1. European Context

Eight of the ten cases in our study involve European countries. Seven of the eight countries (all but Norway) belong to the European Union (EU), which has its own independent policy-making activities related to greenhouse gas emissions. Policymakers must contend with conditions in their own countries as well as the implications of belonging to the EU. More generally, both the EU and European countries acting individually have been much more aggressive in this arena than the United States with regard to GHG-related policies.

In April 2009, the European Commission enacted *mandatory* CO_2 emissions standards for passenger vehicles of 130 g/km [209 g/mi, or 42.5 mpg] by 2012 after automakers failed to achieve their voluntary reduction targets earlier in the decade. These standards apply to 65% of each manufacturer's new passenger cars in 2012 and will increase to 100% of passenger cars in 2015. From 2020 onward, the emissions target is 95 g/km [153 g/mi, or 58.1 mpg], though the details of the path to this target have not yet been defined. As a point of comparison, the Pavley standard is 233 g/mi [38.1 mpg] in 2012 for passenger cars and 361 g/mi [24.6 mpg] for light-duty trucks (3751-8500 lbs).[18]

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[18] Because emissions measurements in Europe use different test cycles than those in the U.S., these comparisons are only approximate.

Vehicles and fuels are both heavily taxed in most European countries. In the case of vehicles, they are typically taxed very heavily when purchased new in the form of ad valorem taxes such as a sales tax or value added tax (VAT). Used vehicle transactions can also be heavily taxed. However, for our purposes there are two additional kinds of taxes that are based at least in part on a vehicle's attributes. They are:

Registration Tax. A one-time only tax specifically applied to vehicle purchases.
Circulation Tax. A recurring tax on vehicle ownership that is typically paid annually.

Because our feebate definition specifies that the transaction is a one-time only event at the time a vehicle is purchased new, a registration tax (assuming that it is limited to new vehicles) can be considered "half of a feebate system". Given these definitions, one obvious pathway to a feebate system is to extend or modify an existing registration tax so that the tax amount varies as a function of GHG or CO_2 emissions levels. For example, in the cases of Denmark and Norway, registration taxes that were based in part on engine size were modified to use emissions rather than engine size to determine the tax amount, and then the system was subsequently turned into a feebate. As noted previously, Canada had a feebate system but canceled the rebate portion, effectively leaving a registration tax based on emissions levels. Spain has a registration tax that applies to both new and used vehicle sales, where emission levels are used to determine the sales tax rates (the higher the emissions, the higher the tax rate).

Circulation taxes can also be based on emissions levels. Four of the countries (Denmark, Germany, Sweden, and the UK) have circulation taxes that are based at least in part on emissions levels. These illustrate the complexity of comparing policies and their impact on vehicle sales: Denmark has *both* a feebate system (see above) and a circulation tax. In the case of the UK the tax (called vehicle excise duty or "VED") has a different rate function for new versus used vehicles so that it behaves at least in part like a registration tax. Rates are typically different for gasoline and diesel vehicles. Finally, most countries have additional vehicle incentive programs for high-efficiency vehicles (e.g., hybrids) or alternative fuels (e.g., flex-fuel vehicles) that would apply in addition to the registration/circulation tax systems, further complicating policy comparisons.

6.2. Comparison of Policy Features

Individual cases are documented in Appendix D, as noted previously. The purpose of this section is to provide a high-level comparison of policy features in ways that contribute to the research project goal of increased understanding relevant to feebates. For a summary of basic policy features see Table 6.1, which identifies policies based on the categories feebate, registration, and circulation. The date indicates when the policy was put into place (if known). In the case of registration and circulation taxes, the date typically indicates when the policy was modified to include CO_2 or GHG emissions. For countries with two entries, the second policy represents a replacement of the first policy. Note that for historical reasons Denmark expresses its policies in terms of fuel economy and not emissions levels, as does Canada and the US.

First note that, although just a few years ago examples of feebates and feebate-like policies were rare, the policy frameworks based on emissions/fuel consumption are now quite common in the EU. This is interesting because these countries have had high fuel prices (due to fuel taxes) for quite some time, yet recently these European governments apparently came to believe that feebate-like policies fill a gap that others did not. The timing of this would seem to coincide with the move to mandatory emissions standards.

Table 6.1 Comparison of Feebate and Feebate-like Policies

Country	Start Date	Policy Type	Benchmark Type	Benchmark Value(s)	Functional Form
Canada	March 20, 2007	Feebate [ecoAuto rebate + Green Levy]	Rebate: Two (PC and LDT) Fee: Single	Rebates 245 g/mi cars 314 g/mi LDT Fee 491 g/mi	Step function
Canada	March 30, 2009	Registration [Green Levy]	Single	See above	See above
Denmark	1997	Circulation	Single	189 g/mi	Step
Denmark	June 2007	Feebate	Single	241 g/mi	Linear [2 segments]
France		Feebate	Single	Rebate 209 g/mi Fee 257 g/mi	Nine Steps
Germany	July 1, 2009	Circulation	Single	193 g/mi	Linear
Netherlands	July 2006; Revised Feb 2008	Feebate	Footprint/ Class	Based on Class average	Class value + % from benchmark
Netherlands	January 1, 2010	Registration	Single	177 g/mi	Linear [3 segments]
Norway	Jan 2007	Registration	Single	193 g/mi	Linear
Norway	2009	Feebate	Single	193 g/mi	Linear [4 segments]
Spain	--	Registration	Single	193 g/mi	Four Steps
Sweden	2006	Circulation	Single	161 g/mi	Linear
United States (Gas Guzzler Tax)	1980 Updated 1991	Registration	Single		Large number of steps (approx. linear)
United Kingdon	March 1, 2001	Circulation	Single	193 g/mi new 161 g/mi used	Step

Benchmarks

In most cases policies are framed in terms of a *single benchmark* system. All eight of the registration and circulation taxes use a single benchmark. Three of the four existing feebate systems use a single benchmark. Canada's short-lived system had two benchmarks (one for passenger cars, and one for minivans and SUVs) but these applied only to rebates and not fees. The Netherlands started out with a footprint-based system, but has since abandoned it for a registration system with single benchmark. It is interesting to note that this was done due to consumer sentiment. Their research indicated that consumers thought the footprint system was too confusing and complicated. In addition, they did not like the fact that a larger, higher emitting vehicle could receive a rebate, while a smaller, lower emitting vehicle would be charged a fee. In contrast, France's single benchmark system created concerns about fairness to large families that "need a larger vehicle," and the system has since been modified to include subsidies to address this issue.

With regard to the benchmarks themselves, one frequently seen value is 193 g/mi (120 g/km), which corresponds to the EU's original voluntary 2012 target. In the case of Norway's feebate system, this value was chosen for precisely this reason. The circulation tax benchmarks for Denmark, Sweden, and used vehicles in the UK are more aggressive. Recall that these values apply to *all* vehicles in the fleet, and set an expectation for any vehicles purchased (or produced) in the future. The value 161 g/mi (for Sweden and the UK) corresponds to a figure of 100 g/km, which is close to the 95 g/km EU target in 2020. Benchmark figures for feebates tend to be higher (with the exception of Norway, as noted).

Functional Forms

There is a mixture of functional forms involving straight lines, lines with multiple segments of different slopes (piecewise linear), and step functions. Three of the four circulation taxes are based on straight lines (the exception being the UK). For registration taxes and feebates there is a mixture of step functions and straight lines. Canada used a step function for its feebate system, as does France. This choice was based on the belief that step functions are "easier for consumers to understand." In addition, both countries included "donut holes" over a range of emissions values where vehicles receive neither fees nor rebates. France has a donut hole for the range 209-257 g/mi (130-160 g/km; note that 130 g/km is the EU's mandatory target for 2012). One argument in the literature is that consumers might be more accepting of a feebate system if there is a range of vehicles that is unaffected by the feebate policy. A donut hole fits naturally within a step-function-based system (although it is not precluded by other functional forms). Spain and the US Gas Guzzler Tax both use step functions, although the large number of steps in the Gas Guzzler Tax makes it appear nearly linear. In contrast, Denmark and Norway use straight lines for their feebate systems. However, rather than use a single slope (feebate rate) both have opted for more complicated systems with multiple line segments with varying slopes.

Feebate Rates

One parameter of interest in designing feebate systems is the feebate rate, measured in, e.g., $/g/mi or $/g/km. In the simplest case of a straight-line functional form, this rate is just the slope of the line. However, as described in the previous section there is also the possibility of step functions and piecewise linear functions. So, comparing feebate rates across systems can be difficult. Table 6.2 summarizes rates (in the case of step functions these are approximate) for some feebate policies[19]. The base case feebate rate used in the policy options developed in Chapter 7 is $20/g/mi. For a graphical comparison of feebate functions that use these rates, see Figure 6.1.

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[19] The Netherlands was excluded because its design precludes representation of this type. The $20/g/mi rate corresponds to the Canadian rate, as well as the base case rate in our quantitative analysis.

Table 6.2 Approximate Rates for Feebate Systems

Country	Feebate Rate
Canada	$20/g/mi [Slope for segment on each side of a large donut hole.]
Denmark	Rebate rate = $50/g/mi Fee rate = $13/g/mi
France	Approximate rate of $16.5/g/mi
Netherlands	Complexity precludes estimation
Norway	Rebate rate = $52/g/mi Initial fee rate = $55/g/mi Fee rate increases to $259/g/mi

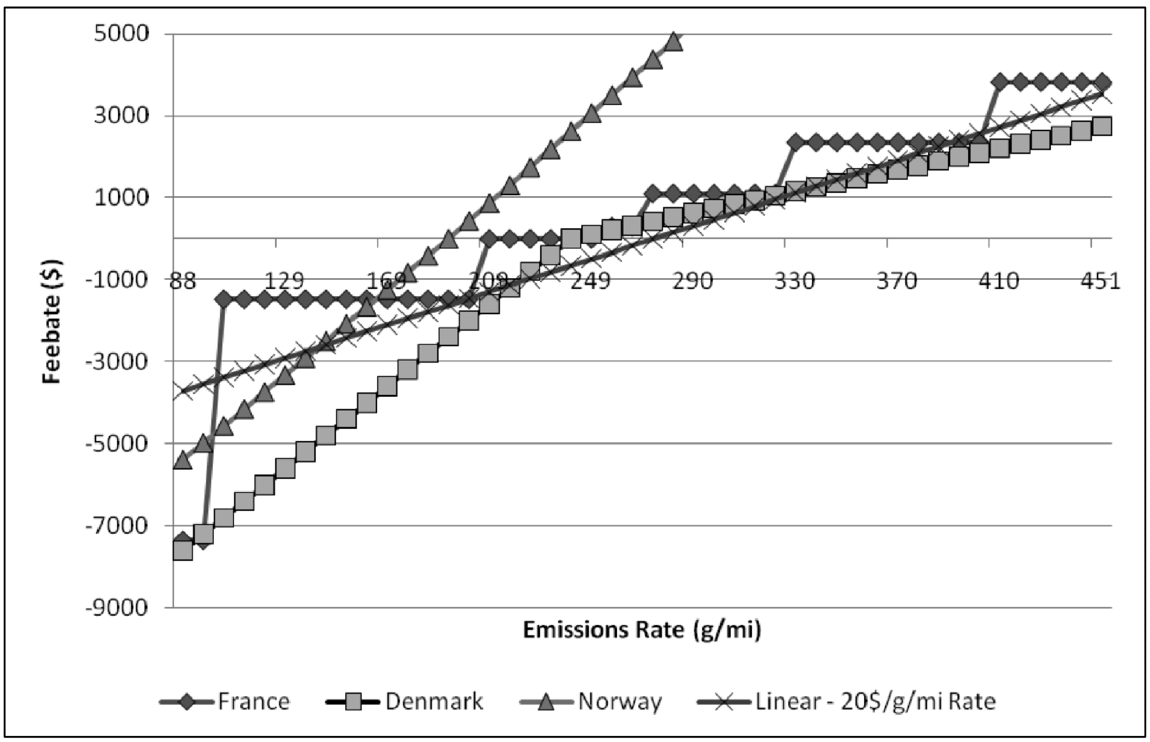

Figure 6.1 Comparison of Feebate Functions

6.3. *Summary of Findings from Feebate Case Studies*

In the remainder of this section we focus on what can be learned from the feebate case studies. In the cases of Denmark, France, and Norway, the policies were introduced in such a way as to provide an opportunity for a "before and after" comparison in terms of new vehicle average emissions rates. More generally, the studies provide some insights on issues such as public reaction, revenue neutrality, and methods of administration and management of programs.

Assessment of Effectiveness

Given the availability of appropriate data, the most practical approach to assessing feebate program effectiveness uses average new vehicle emission rates. For the time frames considered here, a successful feebate program would yield a decrease in average new vehicle emissions by causing a shift in consumer purchases. The following figures show average new vehicle emissions before and after the introduction of feebate programs in Denmark, France, and Norway, respectively. One complication is that there were also sizeable changes in fuel prices during this period. Even so, the basic shapes of the curves suggest clear shifts associated with the introduction of feebate programs.

Emissions averages for Denmark are provided in Figure 6.2 for gasoline and diesel separately, and also combined. The shift is smaller for diesel than for gasoline, with the latter taking on a value of roughly 18 g/km (26 g/mi). Figures 6.3 and 6.4 for France and Norways suggest shifts of 7 g/km (~11 g/mi) and 10 gm/km (~16 g/mi) respectively. Note: The data for Norway correspond to the the conversion of the vehicle registration tax in January 2007 to include CO_2, followed by the offer of rebates beginning in January 2009. The case of the Netherlands is a bit more complicated, and we refer the reader to Appendix D. However, those results also suggest that their feebate policy helped to reduce greenhouse gas emissions by inducing sales-mix shifts to lower-emitting vehicles.

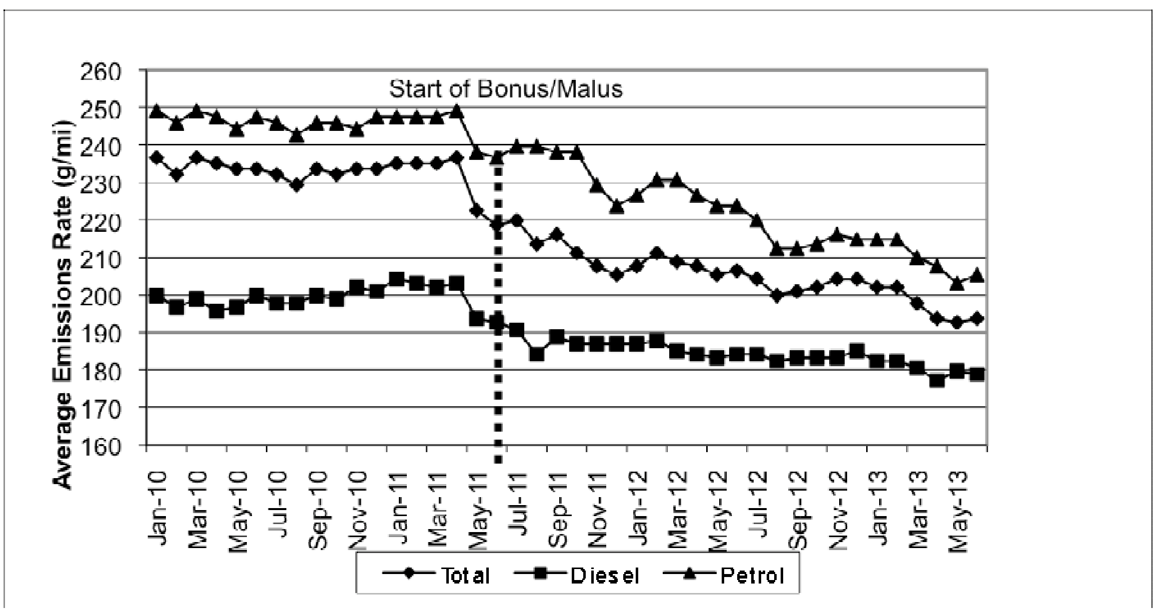

Figure 6.2 Effect of Bonus/Malus in Denmark on New Vehicle Average Emissions Rates

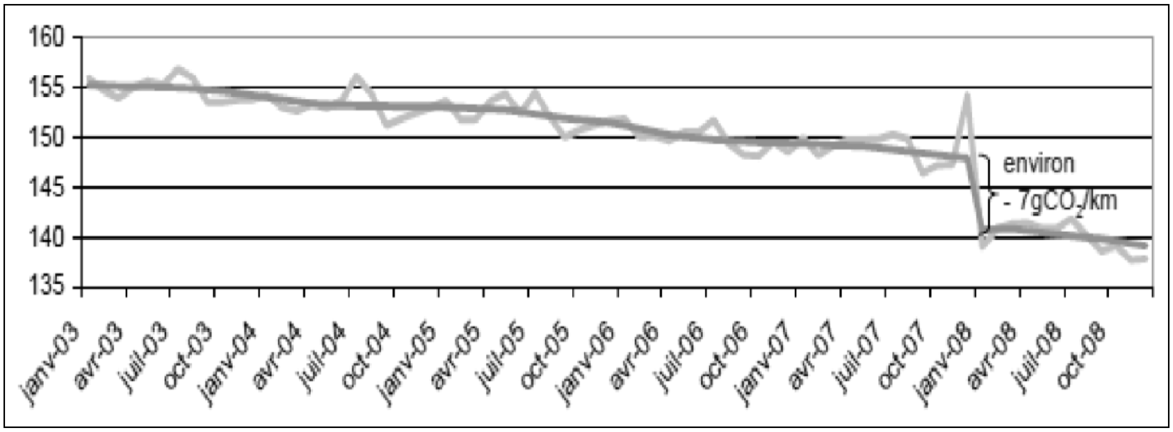

Figure 6.3 Effect of Bonus/Malus in France on New Vehicle Average Emissions Rates (grams CO2 per km)

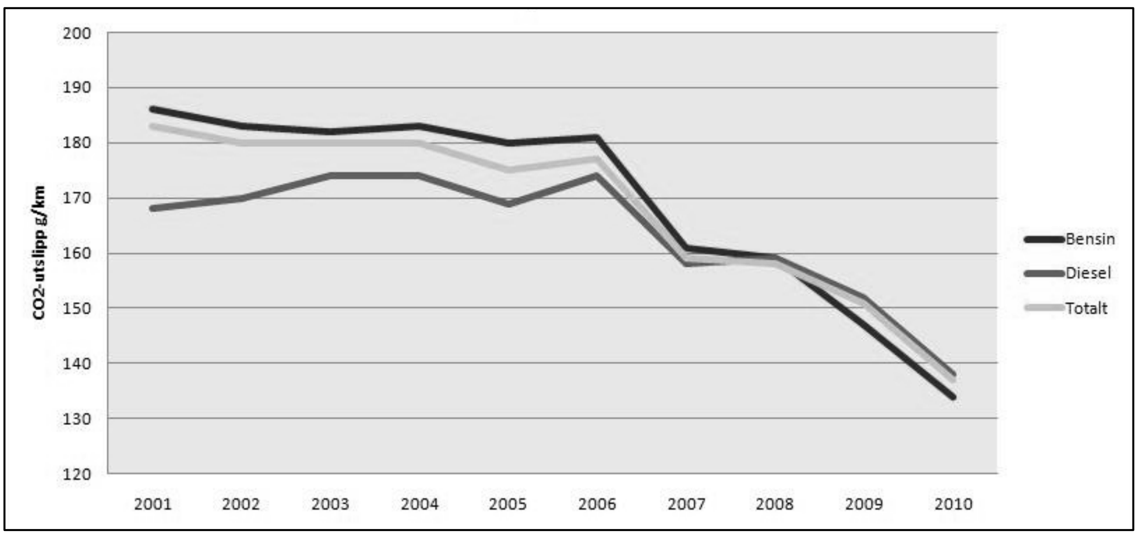

Figure 6.4 Effect of Conversion to CO2 Registration Tax and Feebate Program on Average New Vehicle Emissions in Norway through January 2010 (Bensin = Gasoline)

Revenue Neutrality

One of the ideas behind a feebate system is that, because the policy collects fees and distributes rebates, it can be designed to be revenue neutral. Three of the feebate policies (Canada, France, the Netherlands) had revenue neutrality as a stated or intended goal. In all three cases the policies failed in this regard, i.e., the rebates exceeded the fees, sometimes by a wide margin. This illustrates the inherent difficulty in achieving the goal of revenue neutrality.

The responses of the governments were all different. In the case of Canada, the rebate part of the program was discontinued. Although this decision may not have been exclusively due to the revenue neutrality issue, it undoubtedly played a role. The Netherlands compensated by simply raising the general car registration tax rate. Moreover, as noted previously, the program has now been changed so that it is effectively a registration tax system. France made a strong commitment to a consistent policy when the bonus/malus was introduced, announcing that it would be in place for at least five years. During this period, the threshold values were to be moved 5 g/km every two years. It remains to be seen what the impact of these adjustments will be on revenue neutrality.

In contrast to the above three cases, Denmark and Norway represent a different set of policy circumstances. In both cases, although they have technically implemented feebate systems, the feebates are embedded within a more comprehensive taxation system with a primary purpose of generating general revenue. The policies are not stand-alone policies and revenues feed into their general fund, so the issue of revenue neutrality is less relevant.

In any case, taken together, the evidence suggests that managing a feebate system to be revenue neutral could be challenging without a clear way to make frequent adjustments. At the same time, a feebate system that is subject to frequent adjustments could be less effective as a policy because it would not send a clear, certain signal of what to expect in the future. For this reason, a government wishing to use a feebate system may need to be prepared to take a longer-term view on this issue, similar to France.

Public Reaction

Generally speaking, the reaction of the public to the introduction of feebate systems has generally been positive in these cases. In Canada, there was an indication based on survey research that the public generally supports gas-guzzler taxes and rebates, and there were no complaints registered in response to their program. France claims a high level of public support for their feebate system. In the Netherlands, the public found the system based on classes and footprints to be too complex, as discussed earlier. The decision to move to a registration tax based on an absolute CO2 emissions rate was due in part to the public's reaction. In the case of Norway, the public (including the auto sector) generally supported both the initial and revised CO2 emissions-based taxes. There were public hearings at the time, with minimal fanfare. In the case of Denmark, the number and complexity of auto-related taxes ensures that the average consumer is generally unaware of the various details of all the taxes (or rebates) being applied to a vehicle. The price displayed on a new vehicle is given as a single number. At the same time, the EU requires energy labeling on all vehicles.

Administration of Transactions

With the exception of Canada, the feebate transactions were generally consolidated into an existing tax system so that they occurred at the time of purchase. As already noted, in Denmark everything is taken into account in the sales price of the new vehicle. The auto dealers handle all transactions. This is also the case in France. In the Netherlands the car importers handle all transactions, and pass taxes (or rebates) directly on to the consumers. In Norway the Ministry of Finance handles all taxes, which are included in the price of the vehicle. Similar to Denmark, the taxes are not broken out separately.

As noted, Canada is the exception. Canada had two different agencies handling fees and rebates. Consumers were required to apply for rebates on line, and a check was received some time later. Dealers handled the fees. It is entirely possible that this approach to handling transactions contributed to the fate of Canada's feebate program, where rebates were dropped. Having said this, a similar outcome occurred in the Netherlands, even though a unified approach was used to handle the transactions.

7. POLICY FORMULATION

One simple description of the project's main research objective is: (i) formulate alternative feebate policy options, and (ii) evaluate and compare the options. Section 3.4 describes the basic design elements of feebate programs that, when combined, yield specific policies. Based on that framework, this section gives an overview of the process by which policy alternatives were developed. An important part of the processes was a public consultation meeting held in February 2009. The outcome of this meeting, and subsequent and ongoing consultation with ARB staff, comprised an evolving process that culminated in the final set of policies analyzed for this project. Given the informative nature of the discussions in this meeting, these will be reviewed in some detail. As discussed in section 3.2, key events that occurred during this process were the granting of the Pavley waiver and proposed new near-term national emissions standards by the Obama administration. These standards played a critical role in our selection of a reference policy for this project. In addition, the emergence of a dual footprint-based system of national standards led us to adopt a footprint-based feebate system as the base case for policy analysis and evaluation. This section reviews the development process, the reference and base cases, and the final set of policy scenarios.

7.1. Overview of development process

7.1.1. Public Consultation Meeting of February 26, 2009

As part of the development of the research proposal, the research team developed a preliminary set of policy scenarios using the framework described previously in section 3.4. The ARB sponsored a public consultation meeting on February 26, 2009 at the Cal/EPA Headquarters Building in Sacramento to review and discuss the policy scenarios initially proposed for analysis by the University of California research team. The presentation included a discussion of how policy scenarios would be analyzed using the Feebate Analysis Model being developed by UC Davis, and through information obtained via interviews, focus groups, a statewide survey and additional analyses to be carried out by UC Berkeley (see Figure 4.1). A review of feebate policy design elements was provided, and the team discussed the goal of developing policy scenarios intended to address a wide range of alternative feebate design issues, including fee and rebate levels, point of regulation, implementation strategy, consumer response, and interaction with other AB32 programs. Participants were apprised that the main purpose of the research is to provide the ARB with sufficient information to support decision making about whether to implement a feebate system for California and how best to design and implement such a system. The feebate policy options presented at this meeting are shown in Table 7.1.

At this time, the team had already anticipated that the base case benchmark for the study would be based on a two-footprint system (passenger cars versus light-duty trucks). Other benchmark types include a single benchmark, two benchmarks (cars versus light-duty trucks), and a system involving benchmarks for N different vehicle classes (to be determined). The base case feebate rate was proposed to be $15 per gram per mile, and examination of five different rates was anticipated. The agenda for the meeting ensured that there was ample discussion on issues related to transaction locus and phase-in strategies, as these were anticipated to be potentially important issues based on the literature and the initial development of information for case studies discussed in section 6 (particularly Canada and France). All of these discussions are reviewed in more detail here.

Table 7.1 Feebate Policies Discussed in February 2009 Public Meeting

No.	Functional Form	Rate $/g/mi	Benchmarks	Transaction Locus	Phase-in Strategy
1	Linear	$5	Pcar v. Lt. Trk FP	State-Manufacturer	2-Year Delay
2	Linear	$10	Pcar v. Lt. Trk FP	State-Manufacturer	2-Year Delay
3	Linear	$15	Pcar v. Lt. Trk FP	State-Manufacturer	2-Year Delay
4	Linear	$20	Pcar v. Lt. Trk FP	State-Manufacturer	2-Year Delay
5	Linear	$25	Pcar v. Lt. Trk FP	State-Manufacturer	2-Year Delay
6	Linear	$15	Single Benchmk.	State-Manufacturer	2-Year Delay
7	Linear	$15	N Vehicle Classes	State-Manufacturer	2-Year Delay
8	Linear	$15	Pcar v. Lt. Trk.	State-Manufacturer	2-Year Delay
9	*Linear*	*$15*	*Single*	*State-Manufacturer*	*Immediate*
10	*Linear*	*$15*	*Pcar v. Lt. Trk*	*State-Manufacturer*	*Immediate*
11	*Linear*	*$15*	*N Vehicle Classes*	*State-Manufacturer*	*Immediate*
12	*Linear*	*$15*	*Footprint*	*State-Manufacturer*	*Immediate*
13	Step Function	$15	Single Benchmark	State-Manufacturer	2-Year Delay
14	Step Function	$15	Pcar v. Lt. Trk	State-Manufacturer	2-Year Delay
15	*Step Function*	*$15*	*N Vehicle Classes*	*State-Manufacturer*	*2-Year Delay*
16	*Step Function*	*$15*	*Single*	*State-Manufacturer*	*Immediate*
17	*Step Function*	*$15*	*Pcar v. Lt. Trk*	*State-Manufacturer*	*Immediate*
18	*Step Function*	*$15*	*N Vehicle Classes*	*State-Manufacturer*	*Immediate*
19	*Linear*	*$15*	*Pcar v. Lt. Trk*	*State-Customer*	*2-Year Delay*
20	*Linear*	*$15*	*Pcar v. Lt. Trk*	*Dealer-Customer*	*2-Year Delay*
21	*Linear*	*$15*	*Pcar v. Lt. Trk*	*Dealer-Customer*	*2-Year Delay*
22	*Linear*	*$15*	*Single*	*Dealer-Customer*	*Immediate*
23	*Step Function*	*$15*	*Single*	*Dealer-Customer*	*Immediate*
24	Linear	$15	Pcar v. Lt. Trk	State-Manufacturer	Phase in Rate
25	Linear	$15	Pcar v. Lt. Trk	State-Manufacturer	Initial Subsidy to Neutrality

Italicized scenarios are later eliminated – see text for discussion.

Dr. Greene explained how the feebate rate could be related to carbon prices, and the size of other externalities and market imperfections. For example, a feebate charge can be linked to the discounted present value of future carbon permit prices or carbon taxes. Let C be the price of carbon, E be the emissions rate of a vehicle and E_0 the benchmark emissions rate, M_0 be the miles the vehicle will be driven when new, δ be the rate of decline in vehicle use with age, and ρ be the discount rate for future carbon prices, and L the expected vehicle lifetime. PV in equation 1 is the present value of future carbon charges.

(7.1)

$$PV = \int_{t=0}^{L} C(E_0 - E)M_o e^{-\delta t} e^{-\rho t} dt$$

If M_0 = 14,000 miles/year, δ = -0.04 (4% decrease per year), ρ = -0.07 (7%/year), then PV equals approximately 100,000C(E_0 - E). For a carbon price of $100/t$CO_2$ the feebate rate would be $10/g$CO_2$/mile. The U.S. gas-guzzler tax is a step function but on average is equivalent to a rate of $1800/0.01gallon per mile or $20/g$CO_2$/mile. The French Bonus/Malus feebate system equates to approximately $16.50/g$CO_2$/mile.

The equivalencies of various feebate rates are shown in Table 7.2 in terms of present value per lifetime gallon, per gram of CO_2 per mile, and dollars per ton of carbon.[20] The calculations assume that the full value of the feebate is assigned to either fuel consumption or carbon emissions. However, the feebate rate can be viewed as accomplishing several purposes. There is strong evidence that consumers undervalue future fuel savings relative to their expected value (e.g., see Greene, German and Delucchi, 2009). One view is that consumers, on average, require a simple 3-year payback for improvements in fuel economy that increase the purchase price of a vehicle. A charge of $1,285/0.01gal./mi ($1.20/gal.) would be needed just to correct for that undervaluation. If, in addition, $50/t$CO_2$ ($470/0.01gal./mi) is added to represent the external costs of greenhouse gas emissions, plus an oil import premium of $14/bbl ($0.33/gallon or $350/0.01gal./mi.), a total feebate rate of $2100/0.01gal./mi. or $23.90 per g$CO_2$/mi. would be justified. To reflect this range of potential justifications for alternative feebate rates, the research team proposed to investigate the impacts of rates ranging from $5 to $25 per g$CO_2$ per mile.

Table 7.2 Alternative Feebate Rates and Their Equivalencies in Terms of Externality Costs, Oil Consumption Premiums and Correcting the Uncertainty Loss-Aversion Problem

Feebate Rate $/0.01gal/mi	Equivalent $ per Lifetime PV Gal. $/gal	Feebate Rate $/g$CO_2$/mi	Equivalent Carbon Price $/t$CO_2$	Gasoline Tax of Equal Impact $/gallon
$500	$0.47	$5.69	$53	$1.18
$1,000	$0.93	$11.38	$106	$2.36
$1,500	$1.40	$17.07	$159	$3.54
$2,000	$1.87	$22.76	$212	$4.72
$2,500	$2.33	$28.45	$266	$5.90

Assumes vehicle is driven 15,000 miles per year when new, declining at 4% per year, over a lifetime of 14 years. Future dollars are discounted at 7%/year. Source: Greene, 2009.

The final column of Table 7.2 is intended to illustrate the leverage of feebates relative to a gasoline tax as a policy for incentivizing improvement in new vehicle fuel economy. If consumers require a simple three-year payback for an upfront investment to achieve higher fuel economy, then they are undervaluing fuel savings relative to full lifetime expected present value by a factor of 2.5. Thus, a

[20] The discounting in this case is not discounting of carbon emissions or climate damage. It is discounting of future payments of carbon taxes or carbon permit prices.

gasoline tax of $3.50 would be required to achieve the same impact on new car fuel economy as a feebate rate of $1,500.

The feebate rate determines the marginal value of increasing fuel economy or reducing greenhouse gas emissions. The benchmark determines which vehicles pay a fee and which receive a rebate. It is the research team's understanding that a California feebate system would need to be revenue neutral. Nevertheless, benchmarks can be defined in many ways. The research team originally proposed to test the four types shown in Table 7.1.

Feebate functions relating GHG emissions to fees and rebates per vehicle can take many different forms. The research team proposed considering a simple linear function with a constant feebate rate per gram of CO_2 equivalent per mile, as well as step functions similar to the French Bonus/Malus function or the U.S gas-guzzler tax (see Section 6).

The research team discussed its belief that it would be easier to predict and manage revenues with a linear feebate function. In contrast, a step function has the undesirable features of allowing a large increase in the rebate value for a small change in emissions, and may be more difficult to adjust over time as vehicle emissions are reduced. However, French authorities had expressed a belief that consumers find step functions easier to understand. Because the choice of linear versus step function has many potential implications for policy outcomes, one goal of the research project is to better understand and quantify their differences. Issues of consumer perception will be explored via focus groups and surveys.

The locus of the feebate transaction and how the system is communicated to consumers are interrelated issues. Key options for the locus of the transaction are:

1. Between state and manufacturer
2. Between dealer and customer
3. Between state and customer

Hybrid systems are also possible in which fees and rebates are transacted between different parties. Option 1 would greatly reduce the number of transactions and could permit more frequent adjustment of benchmarks to achieve revenue neutrality.

How consumers are made aware of the feebate system is yet another issue. Public service announcements are one option, as are requirements to label vehicles, or for dealers to show fees and rebates on the bill of sale. The research team felt that these issues would be best explored via focus groups and the statewide survey, with additional analysis of the administrative impacts and compliance costs of different strategies.

Feebate systems can also be phased-in in a variety of ways. The French and Canadian systems were implemented immediately, with no delay. Indeed, in the Bonus/Malus system rebates were made retroactive for approximately one month. This, however, gives manufacturers no time to adjust product designs to the new system. A lead time of two years would be required to allow even a fraction of the new vehicles sold in the year the feebate system began to be redesigned by manufacturers in response to the policy. On the other hand, delaying the onset of the system would likely encourage consumers intending to purchase low emission vehicles to delay their purchases until they could be rewarded by rebates, and consumers intending to purchase higher emission vehicles to accelerate their purchases to avoid fees.

Other implementation options include gradually increasing the feebate rate over time, or creating a zero-zone of moderate-emission vehicles that would initially have neither fees nor rebates (a "donut hole") and gradually closing the hole in the feebate system over time. A feebate system could be designed to be net subsidizing initially, transitioning to revenue neutrality over time, but such a system would violate the requirement of revenue neutrality in its early years. This approach would be more likely for a national-level feebate, where there is greater flexibility for subsidizing policy initiatives.

A complete feebate system requires decisions on all of the design elements discussed here, as shown in Table 7.1.

Comments and Discussion

A key issue not explicitly addressed in the presentation was the testing of feebates as a replacement for or complement to Pavley standards. There would be 48 cases to run if all 24 cases were tested both as a replacement and a complement. Given that the Feebate Analysis Model had not yet been built and therefore its run time was not known, it was unclear whether or not this would be too ambitious. One participant noted that, when the feebate system is intended as a replacement for Pavley, the feebate rate would be determined by the requirement to achieve the same GHG reductions as the Pavley law. Estimates made by the Union of Concerned Scientists (UCS) suggest this would be approximately \$36/gCO_2/mile, higher than the rates suggested in Table 7.1. Also, it would be unlikely that the locus of the transaction or the phase-in strategy would have a significant effect on the replacement/complement issue. This suggested testing the replacement/complement issue using a linear feebate function, at the necessary feebate rate, using single-point, passenger-car/light truck, and footprint-based benchmark systems. (However, as discussed previously, this issue has become largely moot.)

The research team was asked whether it would consider the impacts on the used vehicle market. Our model is able to do this within the state of California but not for the remainder of the U.S. The potential for leakage in other states was also raised: that is, increases in GHG emissions in other states when manufacturers find it easier to meet federal CAFE standards due to the more stringent Pavley standards in California and opt-in states. At the time, the team viewed this as outside the scope of our study as we understood it. The subsequent announcement harmonizing California and federal standards also makes this question moot with respect to emissions standards through MY2016, at least. It remains a possible issue for feebates, however, unless a national system is implemented. In a study issued subsequent to the consultation meeting, Goulder et al. (2009) indicate that leakage could be a problem if manufacturers market different vehicles in California and other opt-in states than in the rest of the U.S. However, the same study indicates that if the same vehicle designs were sold throughout the country, more stringent GHG emissions standards in California and other opt-in states would generate significant spillover benefits to the rest of the U.S. in the form of additional reductions in GHG emissions. Investigation of how manufacturers would implement design changes (nationwide or in subsets of states) therefore becomes an important issue to resolve for a feebate analysis.

How the fees would be collected and rebates disbursed received considerable attention. Some were concerned that if the feebates were transacted at the dealership, the consumer might not see or receive full rebates. Others were concerned that fees might come out of salespersons' commissions. If the feebate were transacted at the point of sale, it would presumably become a part of the overall process of price negotiation. There was concern that it might become submerged in the complexity of the multi-attribute vehicle purchase process. While economic theory provides some useful guidance in this area, the answers ultimately depend on the nature of supply and demand for each vehicle and on the actual versus theoretical operation of the car market. Some also expressed concern that transacting feebates at the point of sale would be much harder to administer. A variety of different formulations were discussed, including hybrid systems in which fees and rebates are transacted between different parties—see Table 7.1.

Others raised questions about the determination and announcement of benchmarks. How would they be announced and when? How would revenue neutrality be achieved? If feebates were transacted at the point of sale (as in the French Bonus/Malus system), for consumers to understand what feebates will apply, benchmarks would have to be determined prior to the model year and could not be changed. If feebates were transacted between the state and the manufacturer there might be greater flexibility.

Some concern was expressed about insuring that new vehicles not subject to feebates could be purchased in other states and brought into California. However, the state has considerable experience with such enforcement issues and confidence that they can be addressed satisfactorily.

Questions were raised about the size of administrative costs, how they would be paid, and what the source of the working capital would be. Would they be paid out of fees (making the system slightly revenue enhancing) or out of general revenues? Some suggested that administrative costs were likely to be in the range of $1.5 million per year, or less than $2 per new vehicle sold.

Several participants were interested in the potential impacts of "surprises" on the effectiveness and costs of a feebate system. Surprises mentioned included the following:

1. Changes in consumers' attitudes and preferences (esp. for fuel economy)
2. Oil price shocks
3. Changes in the structure of the automobile industry
4. Increase in federal gas tax or creation of federal feebate system

Interest was expressed in what elasticities would be used in the model to reflect consumers' responses to fuel prices and to feebates. Some believed that these responses had shifted fundamentally in recent years and that there was a falling willingness to pay for fuel economy improvement. There was a request to vet the elasticities that would be used in the modeling.

A question was raised about how the California feebates model would represent manufacturers' ability to charge customers for the costs they would incur in reducing the emissions rates of vehicles. The questioner claimed that there was a fundamental flaw in the analysis done by Walter McManus for UCS, and that McManus' analysis did not appear to allow manufacturers to fully pass through costs to customers.

Other questions concerned how other policies like the ZEV mandates and low carbon fuel standards would be represented. The modeling team explained that they intended to represent the ZEV standards using a fixed scenario developed by ARB for the market penetration of ZEVs rather than attempting to predict such. The question of the impact of the LCFS and whether and how it should be represented was later taken up with the ARB. The LCFS was not directly represented in our quantitative modeling because it has no direct impact on market behavior of manufacturers or consumers. Interaction between feebates and the LCFS was considered separately in a qualitative analysis—see section 10.5.

Finally, the research team was asked how purchases by public entities (e.g., police, fire, emergency services, etc.) would be handled. It seems likely these vehicles will receive special treatment, such as exemption. Be that as it may, these vehicles were considered to be beyond the scope of our analysis, which focused on the personal vehicle market.

Summary and Conclusions

Subsequent to the consultation meeting, the federal and California state governments reached an agreement that, to a reasonable approximation, establishes the Pavley standards as the national standard through 2016. This made the question of feebates as a replacement for the Pavley standards moot but left open the question of complementing LEV-III GHG (Pavley II) standards. As a result, the major emphasis of the study shifted towards understanding the role of feebates as a *complement* to GHG emission standards, though this important development does not completely eliminate the need to test feebates as a possible replacement for LEV-III standards,.

The question of whether vehicle manufacturers would implement engineering design changes in California and other opt-in states versus the rest of the U.S. emerged as a potentially significant issue. After some deliberation, the team adopted the assumption that manufacturers would not design "California-only" vehicles, but, rather, would taken into account the behavior of the market as a whole when deciding what vehicles to design and offer, and that all vehicles would be offered to the entire market.

Too review, significant policy design issues raised by participants were:

1. Timing and method of announcing benchmarks
2. Size of administrative costs and source of revenue to finance them
3. Effects of "surprises" on feebate system impacts
4. Vetting of feebate model elasticities
5. Treatment of ZEV mandates and LCFS standards (tested in which policy cases?)
6. Exclusion of public vehicles

7.1.2. Moving Forward

Subsequent to the February 2009 meeting the team pursued its research agenda in a mode that was heavily influenced by the discussion described above. The UC Davis modeling team continued its development of the Feebate Analysis Model to maximize its ability to address the issues raised by this discussion. The background and documentation on the model are provided in the next section, with more details related to programming and implementation included in the appendices. In the succeeding months, an ongoing process of policy formulation and scenario development took place in consultation with ARB staff.

As has been noted repeatedly, the main changes that occurred after the February meeting were in response to the granting of the waiver and the harmonizing of the California and national emissions standards. The exploration of feebates as a replacement for Pavley was deemed lower priority, and the emphasis shifted to how feebate policies would complement emissions standards. How this has influenced our final reference and base cases is described in more detail in the next section. With reference to Table 7.1, the policy option of using N vehicle classes has been dropped. It is considered unlikely, and in any case would exhibit properties similar to footprint-based systems.

Another change from Table 7.1 was to move the analysis of the locus of feebate transactions and the timing of implementation out of the quantitative modeling analysis. In the judgment of the research team these issues would be best handled by qualitative analysis informed by interviews, focus groups, survey research, and the literature. Specifically, potential consumer response to the timing and method of benchmark announcements, as well as any other changes to the feebate system, are analyzed by UC Berkeley in section 9.3, drawing on its focus group and survey research. Levels of administrative costs and sources of revenue to finance a feebate program are also analyzed by UC Berkeley in section 10.5.

The impact of surprises was addressed by developing specific scenarios to be analyzed by the Feebate Analysis Model. In general, public vehicles, such as police, fire and emergency vehicles, were excluded from the analysis on the assumption that they would be exempt from the feebate program. ZEV mandates and the California LCFS will be represented by scenario assumptions and included in every analysis case. The UC research team has consulted with ARB staff and obtained guidance from them on how best to represent these programs.

7.2. Reference and Base Cases for Quantitative Modeling

Quantitative modeling methodology described in Section 5.1 is used to simulate vehicle market behavior over the period 2007-2025. Before discussing specific policy scenarios for feebates, we must first establish reference and base cases to provide a framework for evaluation and comparison.

Our methodology uses two reference scenarios, as will be described. The first reference scenario for the period 2009-2030 adopts fundamental quantities from the EIA Annual Energy Outlook Projections. These projections reflect a detailed methodology that takes into account general macroeconomic forecasts including income per capita, penetration of vehicle technology, fuel prices (costs) as well as a set of reference assumptions on relevant energy policies and regulations. The main projections used in calibrating our models are baseline vehicle sales forecasts and fuel price forecasts. The EIA-reference policy scenario assumes the values from the projections described below.

EIA sales projections are calculated based on the light-duty vehicle Manufacturers Technology Choice Model (MTCM). “The MTCM includes 63 fuel saving technologies with data specific to cars and light trucks including incremental fuel efficiency improvement, incremental cost, first year of introduction, and fractional horsepower change” (EIA Annual Energy Outlook 2009a). In the vehicle sales share module, EPA size class sales shares are projected as a function of income per capita, fuel prices, and average predicted vehicle prices.

In order to determine the technology penetration, the discounted stream of fuel savings is compared to the marginal cost of each technology. The EIA model assumes that all fuel-saving technologies have a 3-year payback period and the real discount rate is 15 percent. Expected future fuel prices are calculated based on an average of fuel prices 3 and 4 years prior to the present year. Degradation factors are used to adjust new vehicle tested fuel economy values to "on-road" fuel economy values to reflect normal driving conditions. The model assumes current fuel economy standards through 2011, NHTSA's proposed standards for 2012 through 2016, an annual increase from 2017 to 2020 to reach the 35 MPG level, and a constant standard after 2020.

Finally, the Consumer Vehicle Choice Module (CVCM) utilizes a nested multinomial logit (NMNL) model that predicts sales shares based on relevant vehicle and fuel attributes such as price, maintenance cost, range, multi-fuel capability, fuel economy, acceleration and luggage space. Most vehicle attributes are determined endogenously in the EIA model. The fuel attributes used in market share estimation include availability and price. Figure 7.1 shows the resulting EIA total light-duty vehicle sales projections (nationally) from 2007 through 2030.

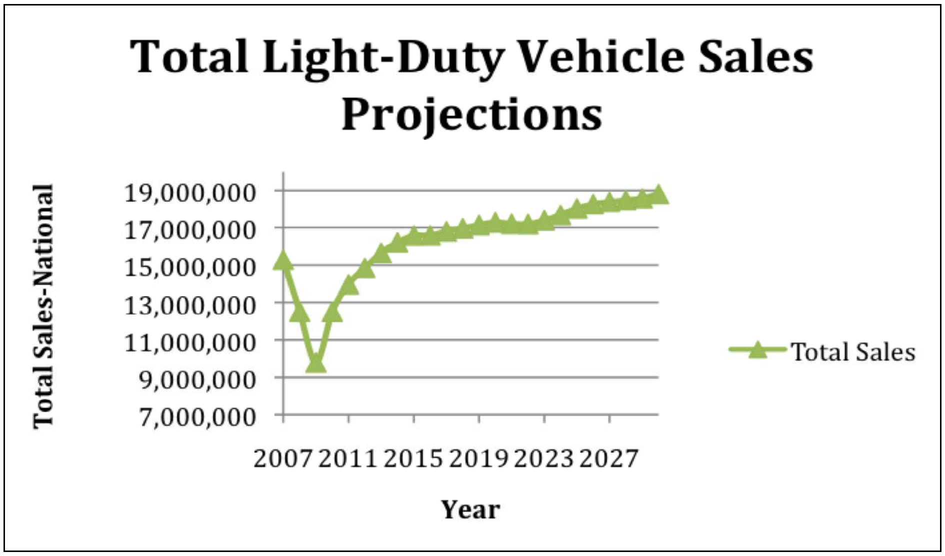

Figure 7.1 EIA sales projections (EIA Annual Energy Outlook 2009b)

End-use petroleum product prices are also derived from EIA's energy outlook projections. EIA fuel prices are estimated based on the summation of marginal costs of production, production-related fixed costs and distribution costs and taxes (EIA Annual Energy Outlook 2009c). Figure 7.2 shows the estimated fuel prices from 2007 to 2030 (in 2007 dollars).

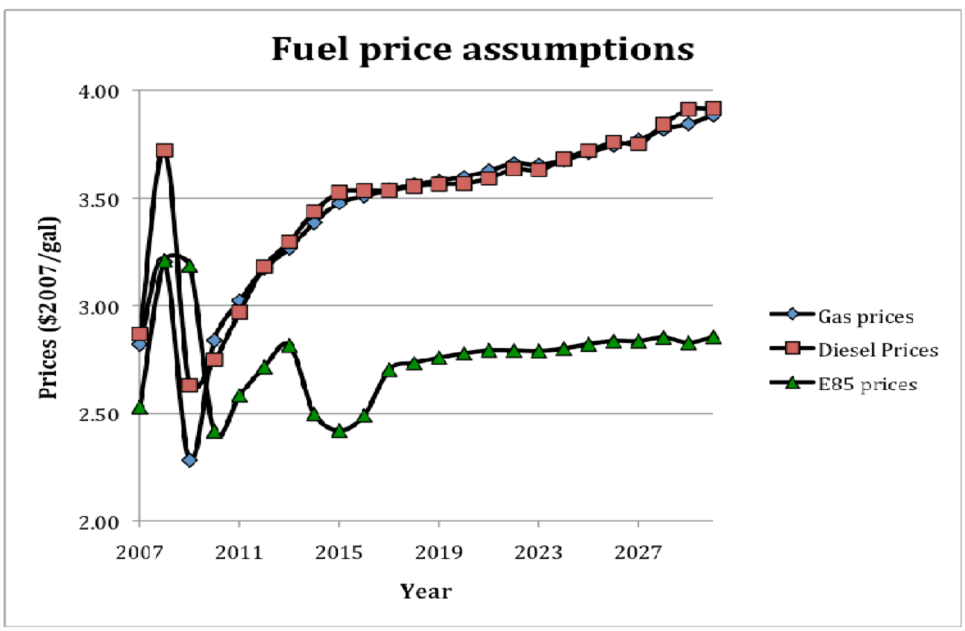

Figure 7.2 EIA fuel price projections (EIA Annual Energy Outlook 2009d)

Because we used EIA assumptions and projections about fuel prices, fuel economy standards, and total vehicle sales, it represents a reference case for an initial calibration of the MDM. Implementing the EIA fuel price projections and assumed fuel economy standards, we matched total light-duty vehicle sales in our model with the EIA total sales projections. We did that by calibrating alternative specific coefficients of our nested logit vehicle choice model so that the MDM output replicates the EIA's total sales projections.

Reference Scenario for Policy Analysis

Assumptions for the reference scenario to be used for policy analysis were discussed in Section 3.2. Implementing this required three sets of emissions standards over three different time periods. During the first time period (2007-2010), current CAFE standards were applied. For 2011-2016, NHTSA's reformed standard was used in 2011, and the newly established EPA/NHTSA CO_2 emission targets were used for 2012-2016. As described in Section 3.2, there is no current policy beyond 2016, and we adopted an assumption that emissions targets decrease by 2% per year until 2025 for our Reference Case. This section provides technical details on the CAFE and GHG emissions standards.

The CAFE fuel economy standards are listed in Table 7.3. Two distinct sets of standards have been implemented for passenger cars and for light trucks. For each year, a single fuel economy standard (in MPG) has been established for each of the two fleets. In our model, we convert these to their equivalent in terms of CO_2 emissions, and implement them for model years 2007 through 2010.

Table 7.3 CAFE fuel economy standard MY2007-2010 (miles per gallon)

Model Year	Cars	Light trucks
2007	27.5	22.2
2008	27.5	22.5
2009	27.5	23.1
2010	27.5	23.5

Effective in 2011, a reformed CAFE program was adopted. Under the reformed CAFE, each vehicle's required mpg is based on target levels set according to a vehicle's "footprint"—the product of its width and its wheelbase. For model year 2011, the target values are determined from the following equation:

$$T_i(t) = [\frac{1}{a} + (\frac{1}{b} - \frac{1}{a})\frac{e^{\frac{fp_i - c}{d}}}{1 + e^{\frac{fp_i - c}{d}}}]$$

where:
T = fuel economy target, mpg
a = maximum fuel economy target, mpg
b = minimum fuel economy target, mpg
c = footprint value at which the fuel economy target is midway between a and b, ft^2
d = parameter defining the rate at which the value of targets decline from the largest to smallest values, ft^2

e = 2.718
fp = footprint of the vehicle model, ft^2

Table 7.4 Footprint function parameters (MY2011)

	Parameters			
Model year	*a*	*b*	*c*	*d*
2011 passenger car	31.20	24.00	51.41	1.91
2011 light truck	27.10	21.10	56.41	4.28

For model years 2012 to 2016, we adopted the new EPA/ NHTSA CO_2 emissions standard. The targets are described mathematically by a family of piecewise linear functions as follows:

$$\text{TARGET } CO_2 = \begin{cases} \mathbf{a}, & \text{if } \mathbf{x} <= l \\ \mathbf{cx} + \mathbf{d}, & \text{if } \mathbf{l} < x <= h \\ \mathbf{b}, & \text{if } \mathbf{x} > h \end{cases}$$

Where,

TARGET CO_2 = the CO_2 target value applicable to vehicles of a given footprint (in g CO_2/mi)
a = the minimum CO_2 target value (in g/mi)
b = the maximum CO_2 target value (in g/mi)
c = the slope of the linear function (in g/mi per sq ft)
d = is the zero-offset for the line (in g/mi CO_2)
x = footprint of the vehicle model (in square feet)
l & h are the lower and higher footprint limits,

Table 7.5 Footprint function parameters (2012-2016)

a) Passenger cars

Model Year	a	b	c	d	l (lower limit)	h (upper limit)
2012	242	313	4.72	48.8	41	56
2013	234	305	4.72	40.8	41	56
2014	227	297	4.72	33.2	41	56
2015	215	286	4.72	22	41	56
2016 and later	204	275	4.72	10.9	41	56

b) Light trucks

Year	a	b	c	d	l (lower limit)	h (upper limit)
2012	298	399	4.04	132.6	41	66
2013	287	388	4.04	121.6	41	66
2014	276	377	4.04	110.3	41	66
2015	261	362	4.04	95.2	41	66
2016 and later	246	347	4.04	80.4	41	66

Figure 7.3 shows the standards graphically for both passenger cars and light trucks. It should be noted for year 2011, the emission target is calculated based on the reformed CAFE standard (in mpg) and the conversion coefficient (8788 g CO2/gal) for gasoline-fueled vehicles.

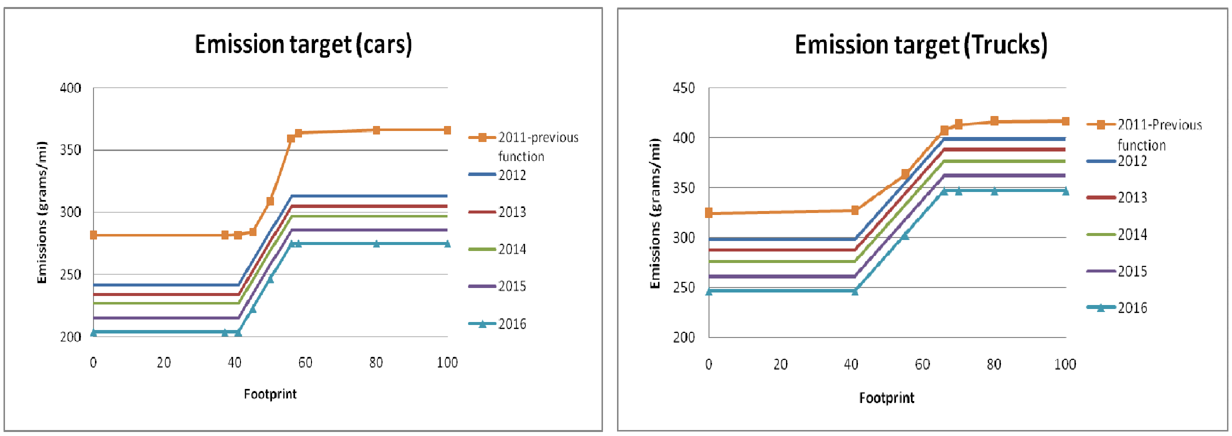

Figure 7.3 Footprint based emission targets adopted in all scenarios (MY2011-2016)

For modeling, we used the above standards from MY2007 through MY2016. But after 2016, there is no general agreement on what the national standards would be. So, we assumed different constant percentage decreases in allowable emission levels in our scenarios. As noted previously, the Reference scenario for policy analysis assumes a 2% reduction per year. We also considered the case of a 0% reduction per year, i.e., a flat standard after 2016, as well as more aggressive reductions up to 4% per year.

The Base Case feebate policy in our study assumes the Reference scenario, and then applies a footprint-based feebate benchmark using the same equations as those used for the 2011-2016 national emissions standard. Other feebate policy outcomes can be compared either to the Reference case, or to the Base Case. Additional policy scenarios can be developed using the fact that our model divides the market into two regions (according to where the feebate system applies). So, in addition to studying scenarios for a California-only feebate policy, the market can be divided according by Opt-in versus Non-opt-in states. In addition, the model allows the application of a separate emission standard within California (or within all Opt-in states). For example, this means that we can have 2% annual decrease in emission standards for California only (as a representation of LEV III-GHG) while the remaining states' emission targets remain the same after 2016. Similarly, an Opt-in-state-specific emission standard could be applied. A detailed description of the various policy scenarios adopted for the study appears in the next section.

7.3. Final Policy Scenarios

Based upon the comments and suggestions received in the consultation meeting, as well as subsequent discussions with ARB staff and among the members of the UC research team, we revised and shortened the list of scenarios to be analyzed. To develop scenarios, we first enumerated the options available for each design component of a system, and then formed policies using combinations of these options (for more background information on the elements of a feebate system and their potential impacts on a feebate system see Section 3.4).

As discussed in Section 7.1.2, we removed the analysis of the locus of transactions and the timing of implementation from the quantitative model and consequently from our modeling scenarios. Also, levels of transaction costs and sources of revenue to finance a feebate program will be analyzed in the policy implication section and not as scenarios for the quantitative model. So, the possible options in our scenarios are as follows:

- Markets to adopt feebate system:
  - CA
  - Opt-in (s177) states
  - US
- Benchmarks for feebate system:
  - Footprint based by car/truck
  - Single
  - Car/Truck
- Functional forms of feebates:
  - Linear / constant rate over time
  - Linear / increasing rate over time
  - Step
- Feebate rates:
  - $10/g CO2/mi
  - $20
  - $30
- Annual Decline in National and/or Regional Emission Standards after 2016:
  - 0%
  - 1%
  - 2%
  - 3%
  - 4%
- Market divisions for regional standards:
  - s177 / Rest of US
  - CA / Rest of US

Each scenario consists of an option chosen from each of these components. The feebate design cases (cases 1 to 12) examine the effect of varying options from the various components (markets, benchmarks, feebate rate, and market divisions) while the emission standard cases (cases 26 to 32) only look at the impact of various rates of decrease in emission standards after 2016 (annual decline in standards).

Table 7.6 Summary of model scenarios

Scenario description	Main category	Scenario NO.
Various feebate markets	Feebate design	1,2,3,4
Various feebate rates	Feebate design	5,6,9
Late start	Feebate design	7
Various functional forms	Feebate design	8,12
Various benchmarks	Feebate design	10,11
Various fuel prices	Sensitivity analysis	13,14
Various technology costs	Sensitivity analysis	15,16,17
Alternative fuel valuation	Sensitivity analysis	18
Various price elasticities	Sensitivity analysis	19,20
Various ZEV scenarios	Sensitivity analysis	21,22
Various administration costs	Sensitivity analysis	23,24,25
Various post-2016 standards and on different markets	post-2016 emission standards	26,27,28,29,30,31,32
LEVIII replacement	Additional cases	33
Max redesigns in CA	Additional cases	34
Only banking, no pricing	Additional cases	35

In addition to the combinations of available options (cases 1 to 12, 26 to 32), cases 13 to 25 are used to examine the sensitivity of the feebate system to changes in various base case assumptions. In some cases, these could represent "surprises." Specifically, we consider the effect of different fuel prices from the base case (13, 14), changes in the base technology cost curves (15, 16, 17), an alternative fuel saving valuation (18), changes in price elasticities (19, 20), higher emissions for ZEV vehicles based on upstream emission calculations (21), higher ZEV vehicle sales (22), and various administration costs (23, 24, 25). Table 7.6 summarizes the final scenarios.

A list of all the scenarios and their related attributes are shown in Table 7.7. Each scenario consists of a set of options chosen for the above-mentioned components. Cases that alter base-case assumptions consist of more than one run: one without the feebate, and one with the feebate.

7.3.1. Feebate design cases

After reviewing initial outputs from the model and having discussions with ARB staff, we chose the following case (case2) as our Base Case: Feebate system in California based on a footprint-based benchmark, constant linear function, $20 rate, and 2% annual decline in the post-2016 national emission standard without a separate California standard. Case 1 (Reference Case), is the same as the Base Case but without a feebate system.

Table 7.7 Complete list of scenarios

No.	Scenario Description	Emission standard decline after 2016			Feebate system					Notes
		US standard	Regional standard	Region	Feebate market	Starting year	Feebate rate	Functional form	Benchmark	
Feebate Design										
1	Reference Case 1	2%	-	-	-	-	$0	-	-	2% natl std
2	CA Base Feebate Case	2%	-	-	CA	2011	$20	Linear	Footprint	
3a	Opt-In Reference Case	2%	-	-	-	-	-	-	-	
3b	Opt-In Base Feebate Case	2%	-	-	Opt-In	2011	$20	Linear	Footprint	Feebate in Opt-In States
4	Natl Base Feebate Case	2%	-	-	US	2011	$20	Linear	Footprint	Feebate for Entire US
5	$10 rate	2%	-	-	CA	2011	$10	Linear	Footprint	
6	$30 rate	2%	-	-	CA	2011	$30	Linear	Footprint	
7	Late Start	2%	-	-	CA	2017	$20	Linear	Footprint	"Simulate" program delay
8	Increasing Linear Function	2%	-	-	CA	2011	$20	Increase Linear	Footprint	1% increase of feebate rate over time
9	$30 US Feebate	2%	-	-	US	2011	$30	Linear	Footprint	
10	Single Benchmark	2%	-	-	CA	2011	$20	Linear	Single	Single benchmark for all vehs
11	Car/Truck Benchmark	2%	-	-	CA	2011	$20	Linear	C/T	Separate benchmarks for car and truck
12	Step Function	2%	-	-	CA	2011	$20	Step	Single	Single benchmark; Feebate schedule is a step function
Sensitivity Analysis										
13a	High Fuel Price Reference Case	2%	-	-	-	-	-	-	-	Use AEO High Fuel Price Case
13b	High Fuel Price with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Use AEO High Fuel Price Case
14a	Low Fuel Price Reference Case	2%	-	-	-	-	-	-	-	Use AEO Low Fuel Price Case
14b	Low Fuel Price with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Use AEO Low Fuel Price Case
15a	High Tech Costs Reference Case	2%	-	-	-	-	-	-	-	Use 1/3 Higher Cost for Conventional Tech
15b	High Tech Costs with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Use 1/3 Higher Cost for Conventional Tech
16a	Low Tech Costs Reference Case	2%	-	-	-	-	-	-	-	Use 1/3 Lower Cost for Conventional Tech
16b	Low Tech Costs with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Use 1/3 Lower Cost for Conventional Tech
17a	Low Hybrid Cost Reference Case	2%	-	-	-	-	-	-	-	Use Lower Hybrid Conversion Costs from MIT study
17b	Low Hybrid Tech Costs with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Use Lower Hybrid Conversion Costs from MIT study
17c	Low Hybrid Tech Costs with Natl Feebate	2%	-	-	US	2011	$20	Linear	Footprint	Use Lower Hybrid Conversion Costs from MIT study
18a	Alt Fuel Valuation Reference Case	2%	-	-	-	-	-	-	-	Change Payback to Lifetime
18b	Alt Fuel Valuation with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Change Payback to Lifetime
19a	High Price Elasticity Reference Case	2%	-	-	-	-	-	-	-	Higher price elasticity
19b	High Price Elasticity with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Higher price elasticity
20a	Low Price Elasticity Reference Case	2%	-	-	-	-	-	-	-	Lower price elasticity
20b	Low Price Elasticity with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Higher price elasticity
21	Upstream Emissions	2%	-	-	CA	2011	$20	Linear	Footprint	Change ZEV emissions to 130 g/mi
22	Aggressive ZEV	2%	-	-	CA	2011	$20	Linear	Footprint	Boost MY2018-2025 ZEV sales x4
23	High Admin Costs	2%	-	-	CA	2011	$20	Linear	Footprint	Transaction Cost $10/veh
24	No Admin Costs	2%	-	-	CA	2011	$20	Linear	Footprint	Equilibrate to $0m
25	Low Admin Costs	2%	-	-	CA	2011	$20	Linear	Footprint	Transaction Cost $1/veh
Assumptions on post-2016 emission standard										
26a	Reference Case 0	0%	-	-	-	-	-	-	-	%0 natl std
26b	Feebate with 0% standard	0%	-	-	CA	2011	$20	Linear	Footprint	
27a	Lenient Standard Reference Case	1%	-	-	-	-	-	-	-	
27b	Lenient Standard with Base Feebate	1%	-	-	CA	2011	$20	Linear	Footprint	
27c	Lenient Standard with $30 Feebate	1%	-	-	CA	2011	$30	Linear	Footprint	
28a	Aggressive Standard Reference Case	3%	-	-	-	-	-	-	-	
28b	Aggressive Standard with Base Feebate	3%	-	-	CA	2011	$20	Linear	Footprint	
28c	Aggressive Standard with $30 Feebate	3%	-	-	CA	2011	$30	Linear	Footprint	
29a	Very Aggr Standard Reference Case	4%	-	-	-	-	-	-	-	
29b	Very Aggr Standard with Base Feebate	4%	-	-	CA	2011	$20	Linear	Footprint	
30a	CA Alone Reference Case	0%	2%	CA	-	-	-	-	-	
30b	CA Alone with Base Feebate	0%	2%	CA	CA	2011	$20	Linear	Footprint	
31a	Opt-In Alone Reference Case	0%	2%	Opt-In	-	-	-	-	-	
31b	Opt-In Alone with Base Feebate	0%	2%	Opt-In	Opt-In	2011	$20	Linear	Footprint	
32a	CA More Stringent Reference Case	2%	4%	CA	-	-	-	-	-	
32b	CA More Stringent with Base Feebate	2%	4%	CA	CA	2011	$20	Linear	Footprint	
32c	CA More Stringent with $30 Feebate	2%	4%	CA	CA	2011	$30	Linear	Footprint	
Additional Cases										
33	LEV 3 Replacement	0%	0%	CA	CA	2017	?	Linear	Footprint	Find rates s.t. emission rate similar to case 29a
34	Max Incremental Benefit	2%	-	-	US	2011	$30	Linear	Single	Choose parameters to maximize redxns in CA
35a	Banking Reference Case	2%	-	-	-	-	-	-	-	Banking no pricing
35b	Banking with Base Feebate	2%	-	-	CA	2011	$20	Linear	Footprint	Banking no pricing

Cases 3 and 4 examine the impact of implementing feebate systems in Opt-in states and nationwide instead of only in California. Cases 5 and 6 look at the effect of changing feebate rates from $20 to $10 or $30. Case 7 studies the program delay. Cases 8 and 12 explore the functional form effect: an increasing linear feebate rate (case 8) and a step function (case12). For background information on functional forms refer to Sections 3.4.1 and 3.4.2.

Case 9 represents a feebate system nationally with $30/g/mi feebate rate. Finally, cases 10 and 11 examine alternative options to the footprint-based benchmark in the feebate base case (case2): a single benchmark and two benchmarks (one for passenger cars and one for light duty trucks).

7.3.2. Sensitivity analysis cases

For cases 13 and 14, we adopted the high and low fuel prices from AEO 2009 (EIA Annual Energy Outlook 2009e) to analyze the effect of higher and lower fuel prices on the model results. Figure 7.4 shows the high and low gasoline and diesel price projections as well as the base case prices. We also used the high and low E85 prices (from AEO 09) for these scenarios (not shown).

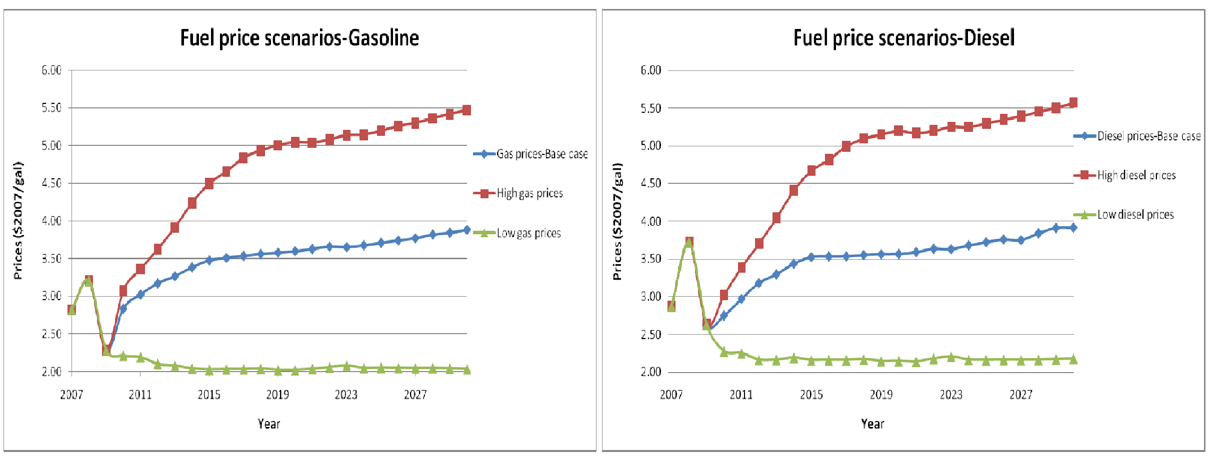

Figure 7.4 High and low fuel prices (cases 13 and 14) vs. the base prices

In the remainder of this section, we provide a brief overview of additional cases that were developed for sensitivity analysis. For many cases, section 8.1.2 provides a more detailed discussion.

We analyzed the effect of alternative conventional technology costs in cases 15 and 16. Case 15 (high cost) and case 16 (low cost) represent conditions in which the costs of improving fuel economy/reducing emissions are one-third higher or lower than the base case costs, which is compatible with NAS technology costs curves. Figure 7.5 shows the technology costs to improve mpg from 20 mpg to a desired level for the compact and small station wagon class (class 8). It should be noted that this figure is for gasoline-fueled vehicles only and it shows the short, medium, and long term curves. We used similar modifications to all the classes of conventional vehicles.

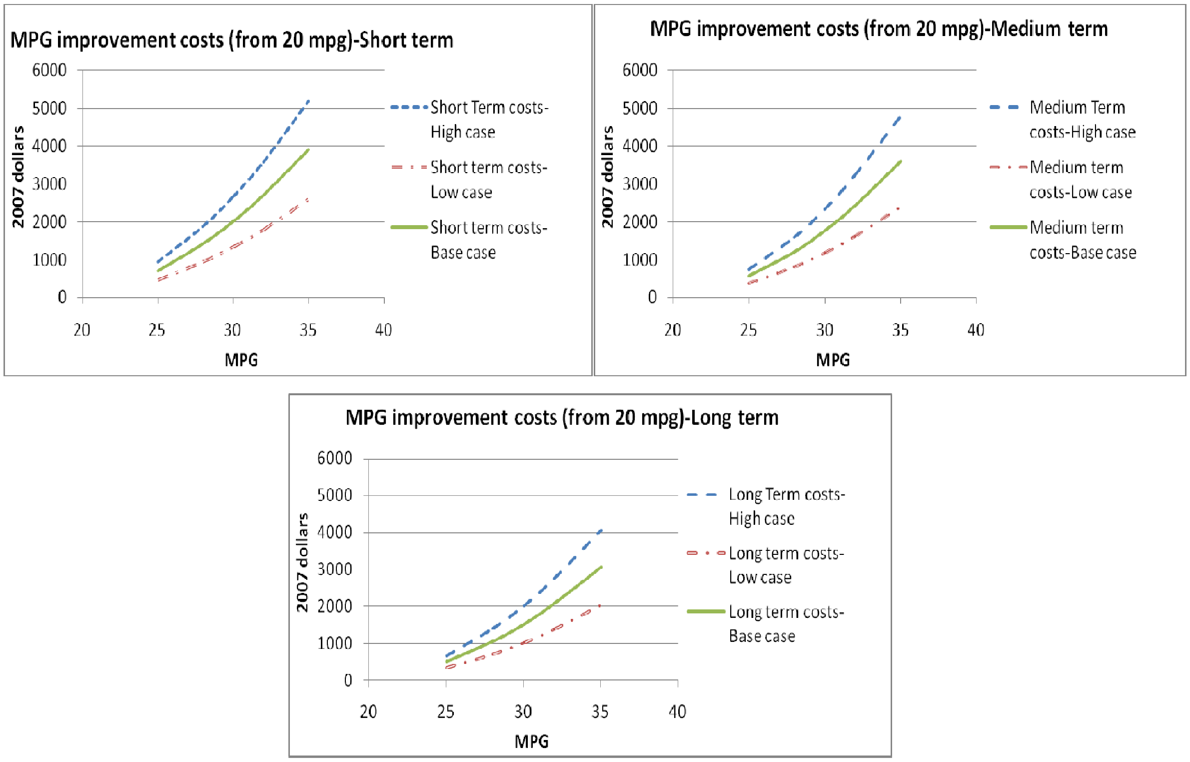

Figure 7.5 Alternative conventional MPG improvement costs for gasoline compact cars (Cases 15 and 16 vs. the base case)

We adopted lower conversion costs to hybrid vehicles in case 17. Compared to the base case, the conversion costs do not change before 2014. For this case, the conversion costs of hybrid vehicles decrease about 40% between 2015 and 2022 and 90% between 2023 and 2025.

Case 18 represents a scenario with an alternative fuel saving valuation to the one used in the feebate base case. In the feebate base case, we assumed consumers require a 3-year payback period, 6% discount rate, and 15600 annual VMT, which is consistent with manufacturers' expectations of consumer behavior in real-life. But for the case 18, alternative fuel valuation, we assumed that consumers consider lifetime fuel savings in their calculations (instead of only three years). So, the main assumptions are 14-year payback time, 7% discount rate, 15600 annual VMT declining 4.7% per year.

Cases 19 and 20, were developed to perform sensitivity analysis on our model by altering the nested logit vehicle choice model's price sensitivity. In the feebate Base Case (and reference case), elasticities are calibrated based on AEO 2009 total sale projections: a value of -0.8 is assumed for the aggregate price elasticity of demand, and a set of assumed values for the elasticities are provided as inputs. These are reviewed in greater detail in section 8.1.2. Case 19 was designed for greater price sensitivity. Case 20 was designed for less price sensitivity, and to have a different pattern of elasticities, as described below.

For case 19, higher elasticities, we multiplied all the base case elasticities (in all the levels of our nested logit choice model) by 1.25, e.g. the elasticity at the buy-no buy level changes from -0.8 (feebate base case) to -1.0 (case 19). In this case, the elasticities have the same pattern as the base case elasticities, only they are larger by a factor of 1.25. The reason behind this adjustment was to match the aggregate price elasticity of demand to NERA's value of -1.0 which is frequently seen in the literature.

In case 20, elasticities were adopted to have a similar pattern to those of a model developed by NERA. In addition, we used an aggregate elasticity that is a factor of 0.8 smaller than NERA's elasticity (-0.8 instead of -1.0). Based on this, we developed a special set of elasticities that, when fed into the MDM model, produce the desired choice model with the proper aggregate elasticity.

Case 21 explores the result of a change in ZEV (BEV and FCV) vehicle emissions from 0 to 130 g/mi, to reflect the upstream emissions used in the original Pavley regulation (ARB-1). Case 22 tries to measure the result of an aggressive ZEV standard, by increasing ZEV vehicle sales by a factor of 4. Finally, cases 23 through 25 examine the impact of various administration costs.

7.3.3. Emission standard cases

Cases 26 to 32 study the role of complementary emission standards. For more information on the current and expected emission standards (plus our main assumptions) see Section 3.2. Cases 26 to 29 look at the various unified nationwide standards (same for all states) while cases 30 to 32 study the effect of distinct regional standards (more stringent California and opt-in states standards).

7.3.4. Additional cases

Case 33 calculates the feebate rate that can replicate the effect of the LEV-III standard on emissions (this is for a feebate program that starts in 2017 instead of 2011). Case 34 considers a nationwide feebate market with a high feebate rate ($30) and a single benchmark to illustrate the maximum potential benefits of a feebate program in California. Case 35 analyzes the effect of running the model with banking and without pricing (see Section 5.1.2).

8. MODEL DEVELOPMENT

8.1. Manufacturer Decision Model

Feebates based on GHG emissions will establish a monetary value for reducing emissions and may change manufacturers' decisions about product offerings and pricing, vehicle designs and technological content. In making these decisions, manufacturers will consider the technology cost for GHG emissions reductions as well as consumers' likely responses to changes in vehicle cost and design. The Manufacturer Decision Model (MDM) has been developed to forecast manufacturer decisions and consumer choices and thereby estimate the impacts of alternative feebate programs on California's automobile market. The model takes base year vehicle data (e.g. vehicle prices, sales, fuel economy rating and other characteristics) as input and produces predictions of future year vehicle characteristics (e.g. fuel economy and GHG emissions level), vehicle prices, sales and market shares. Other outputs include the change in aggregated GHG emissions over the planning horizon, manufacturers' sales and revenues, and consumer surplus. Before detailing the design of the MDM, we first review previous feebate analysis models in the literature.

8.1.1. Literature Review on Existing Feebate Models

Previous studies provide a variety of insights into how feebate systems and their impacts can be successfully modeled. On the manufacturer decision side, models have been constructed making use of the full detail of EPA's test car list and representing every major car manufacturer individually. Vehicle class-specific technology cost models for GHG mitigation as well as fuel economy improvement have been developed. Models have been constructed that simultaneously represent different regions with different policies and different consumer preferences. Models have also been constructed that represent multi-period decision making, and take into account the normal redesign cycles for individual makes and models. On the consumer side, detailed, disaggregate models of vehicle choice, use and ownership have been developed capable of predicting impacts in new and used car markets and the behavior of and economic impacts on different demographic and income groups. Yet to date, no model has combined all the features necessary to comprehensively evaluate alternative feebate programs and adequately address the requirements for implementing a feebate program in California.

Existing models of feebate systems have used differing but related designs to address a variety of issues (e.g., Greene, 2009; McManus, 2007; Dumas et al., 2007; Johnson, 2006; Greene et al., 2005; Davis et al., 1995). Davis et al. (1995) is the first thorough study of feebates for the United States automobile market, which examined a wide variety of definitions and forms of feebates using manufacturer supply and consumer demand models. The supply side Fuel Economy Model (FEM, developed by ICF International (Duleep, 1992)) ranked fuel efficiency technologies by cost-effectiveness and then adopted them sequentially (taking into consideration engineering constraints) until the retail price equivalent of the last technology exceeded the sum of its feebate and fuel savings benefits. The outputs of FEM (vehicle fuel economy and other characteristics) were then inputs to the demand side vehicle choice model, which forecasted consumers' response to vehicle changes and resultant sales mix. The FEM assumed that consumers would undervalue fuel savings relative to expected full lifetime discounted present value. In the vehicle choice model, on the other hand, consumers were represented as placing a much higher value on fuel savings. As a consequence, the study found that feebate systems generally increased social surplus. Among other important findings was that manufacturers' adoption of fuel economy technologies accounted for about 90 percent of the overall increase in fuel economy brought about by feebate systems.

Changes in consumers' choices (shifting sales toward higher fuel economy vehicles) were a minor factor.

Greene et al. (2005) and Greene (2009) developed feebate models that integrated technology application and consumer choices in an optimization framework. Instead of ranking technologies according to their cost-effectiveness and applying them sequentially, Greene's optimization model found the optimal fuel economy level for individual makes and models and drivetrain configurations (approximately 1,000 vehicles) by maximizing consumer surplus while simultaneously considering the consumer response. Technology was represented by quadratic cost curves fitted to fuel economy cost data developed by the National Research Council (2002). Consumer demand was modeled using a representative consumer nested multinomial logit model. Consumers are considered to be part of a population that can be characterized by a common utility function that represents the population's "average" utility for vehicles, plus a random error term to capture individual differences across consumers. Makes and models with similar features were assigned to vehicle classes (e.g., Small Cars, Luxury Cars, Minivans, Midsize SUVs) based on the notion that they are "substitutes," i.e., makes and models within the same vehicle class are more likely to compete with one another than they are with makes and models from other vehicle classes. Vehicle choices were assumed to be a function of vehicle price and fuel economy. Choice model parameters were calibrated using price elasticities drawn from the literature and base year sales data. The optimization model was solved by nonlinear programming solvers and the outputs were predictions on manufacturer decisions and consumer choices.

Greene et al. (2005) predicted technology application and vehicle sales mix for a single year approximately 10-15 years in the future. Manufacturers were assumed to have the opportunity to redesign all their product lines to respond to the feebate system. The impacts on vehicle manufacturers of a single unified feebate schedule with one benchmark for all vehicles versus feebate systems with benchmarks for 2 to 11 vehicle classes were studied. The results indicated that class based systems would produce more equitable impacts on manufacturers. Assuming that consumers undervalued fuel savings, Greene et al. (2005) found that feebate programs would produce a small decline in vehicle sales but a small increase in revenues received by manufacturers. The relative increase in vehicle prices exceeded the relative decline in sales because the value of fuel savings offsets a portion of the vehicle price increase. If the full lifetime value of fuel savings were taken into account, feebate systems were found to produce net economic benefits even without considering the value of reduced external costs, e.g., reduced dependence on foreign oil, value of GHG emissions reductions, etc. Greene et al. (2005) reported that the majority of feebates' impact on fleet fuel economy improvement is due to manufacturers' adoption of fuel economy technologies, consistent with the results of Davis et al. (1995).

Greene (2009) differed from Greene et al. (2005) by examining the dynamics of technology application and market evolution in response to a footprint (wheelbase times track width) based feebate system. Manufacturers cannot change the design and technological content of all the vehicles they manufacture in a single year, but follow a redesign schedule (typically every five years). Greene (2009) solved a single year optimization model at each year of the 10 year planning horizon. The results showed that the impacts of a feebate system change significantly over the first five years, indicating a possible need for a phase-in strategy to address the issue of redesign cycles.

Using a methodology similar to Greene et al. (2005), Dumas et al. (2007) considered the impacts of feebates implemented in Canada but not the entire North American car market. The results indicated that if only Canada implemented a feebate system, the impacts on fuel economy would be smaller than if the same system were implemented throughout North America, and that a greater proportion of the fuel economy gain (on the order of 50%) would come from sales mix shifts.

McManus (2007) estimated the impacts of a feebate program applied to California for the year 2016, separately and in combination with the Pavley GHG standards. Similar to Davis et al. (1995) but different from Greene et al. (2005) and Greene (2009), McManus (2007) did not have an integrated model that simulated the behavior of both manufacturers and consumers simultaneously. Instead the manufacturer model was solved by first minimizing the cost to meet the Pavley standard. Then vehicle characteristics predictions from the manufacturer model were input to a nested multinomial logit model to simulate consumer choices. Vehicle choices were assumed to be a function of vehicle price, performance, size, and fuel economy. Choice model parameters were estimated using hedonic price regression on aggregated sales data from 2002. Like Davis et al. (1995), McManus' model assumes that manufacturers believe that consumers undervalue fuel economy improvements but that consumers actually fully value the expected, discounted lifetime fuel savings. As a consequence, McManus' model estimates net economic benefits for a feebate program, even excluding the value of reduced external costs.

In summary, a great deal has been learned from the models developed by previous studies about how manufacturer decisions can be realistically represented at a high level of detail and how consumers' responses and economic impacts can be estimated. However, none of the previous feebate models has all the features that are necessary to perform feebate analysis in this research project:

a) Most previous studies assumed that feebates would be implemented in the absence of more stringent future fuel economy or GHG emissions regulations. Today, however, the Energy Independence and Security Act of 2007, together with an agreement between the federal government and the State of California have resulted in significant new fuel economy and GHG emissions standards through 2016, at least. It is also likely that further reductions in GHG emissions will be required at the national level after 2016, and that the new standards would also be harmonized with future California standards. Modeling how manufacturers will respond to feebates in the presence of continuously tightening emissions standards adds constraints to the feebate model but also creates the possibility that manufacturers might themselves use pricing based on vehicle emissions rates as a tool to help meet future emissions standards. If so, establishment of a California, Opt-in state or National feebate system would, to a greater or lesser degree, interact with the manufacturers' pricing strategies.
b) Most previous feebate studies modeled manufacturers' decisions in a single year. The ARB feebate research project requires a dynamic multi-period model in order to predict manufacturers' decisions over a 15-year planning horizon.
c) The analysis of different GHG polices in different regions (e.g. California-only feebate program) requires that the feebate model be able to represent consumer demand in different regions with different policies.

The MDM has been designed to meet all these needs. In addition, it has a high level of detail in representing the vehicle market and technologies. The MDM also allows alternative representation of consumers' valuation of fuel savings.

8.1.2. MDM Design

Overview

The MDM integrates manufacturer decisions and consumer choices in one dynamic optimization framework. Facing a feebate policy and regulatory standards, manufacturers are assumed to adopt emission reduction technologies and/or change the prices of vehicles to shift sales toward lower emission configurations and thus reduce fleet average emissions. Vehicle fuel economy (or GHG emissions) is assumed to be the only design factor and other characteristics (e.g. vehicle weight, size and horsepower) are assumed to be unchanged over the planning horizon. Vehicle fuel economy improvement and manufacturers' pricing strategy will induce changes in vehicle price, fuel savings, and feebate value. The impact of these changes on consumer demand and surplus is estimated using a nested multinomial logit model. The objective of manufacturers is to maximize consumer surplus while simultaneously considering consumer response and meeting fuel economy and emissions standards.

The MDM operates at a high level of detail. For the base model year of 2007, every vehicle in the EPA test car list (approximately 1,000 makes, models and drivetrain combinations) is represented as an individual choice. Recognizing the extensive changes that have occurred in the automotive industry in the past two years, we have updated the 2007 data to reflect the restructuring of the industry and to incorporate available information about product plans through 2015. Having a detailed representation of the vehicle market is important for predicting manufacturer decisions and consumer choices. The automobile market is highly heterogeneous, reflecting the different tastes of the car-buying public. This fact is recognized by including twenty different vehicle class segments in the MDM. Within each segment, consumers' responses to price and operating cost changes are different.

To reflect the impact of regional GHG policies (e.g. a California-only feebate program), the national automobile market is divided into two regions (either California and Rest of US, or, Opt-in States and Rest of US). Consumer choices in these two regions are separately modeled. Different regions may have different sales mixes due to the existence of regional feebate programs. However, manufacturers are assumed to offer for sale the same vehicle designs in all regions. The vehicles designed will therefore be a compromise between the demands of the two different markets.

The MDM incorporates a high degree of technological detail. The technical potential to reduce GHG emissions is represented by technology cost curves that take into account base year implementation of mitigation technologies as well as future potential applicability. Each of the twenty vehicle classes (see Table 8.1 for a list of classes) has its own individually calibrated cost curve for three time periods in the future. Conventional internal combustion engine and hybrid vehicles have different cost functions within each vehicle class and time period. This allows cost curves to vary according to the functional requirements of the different vehicle classes. In addition, the UC Davis research team estimated adjustment factors for every manufacturer based on a statistical analysis of each manufacturer's realized fuel economy, taking into consideration the weight and power of its product offerings (see Appendix E). This allows the MDM to recognize differences across manufacturers with respect to the extent to which each has already implemented emissions reduction technologies.

The MDM also recognizes the inherent time constraints of product redesign in automotive manufacturing. Each vehicle has its own redesign schedule and the redesign cycle is typically five years, at which point new technologies to reduce greenhouse gas emissions and improve fuel economy may be adopted. Although we recognize that some tweaking of vehicle designs is possible over a shorter time frame and that some technology components have longer time requirements, five years is a reasonable reflection of the typical lifetime of a vehicle design.

In the following sections, we will detail the design of the MDM in the order of manufacturer decisions, important factors considered in decision making (technology cost, fuel savings, and feebate values), objective, constraints, and consumer choice submodule.

Manufacturer Decisions

In the MDM, manufacturers are assumed to have two means of responding to a feebate policy and regulatory standards: 1) They may adopt additional technologies that reduce emissions but increase the costs of vehicles; 2) They may change the prices of vehicles to shift sales toward lower emission configurations and thus reduce fleet average emissions. A pricing strategy consists of manufacturers charging more for vehicles whose emissions are above the target level specified in emissions standards and subsidizing vehicles whose emissions are below it. We have proved that the manufacturers' optimal pricing strategy turns out to be a self-applied internal feebate system, i.e., the charges and subsidies are proportional to a vehicle's deviation from the emissions standards. The details of the derivation will be presented in the following discussion (Formulation-Some properties of the MDM Equations). Here, we focus on manufacturers' technological options.

The MDM has two types of decision variables to represent manufacturers' technological options: continuous variables for each vehicle configuration in each redesign year, indicating continuous fuel economy improvement along technology cost curves; and binary variables for each vehicle configuration in each redesign year, indicating whether or not to introduce advanced technologies (e.g. hybridization). The cost of emissions reductions as a function of these decision variables is calculated according to technology cost curves.

Technology Cost Curves

The technological potential to reduce emissions is represented by technology cost curves that estimate retail price equivalent (RPE) per vehicle as a function of the relative increase in fuel economy or reduction in GHG emissions rate. RPE is an estimate of the incremental price that the purchaser of a car would pay based on fully burdened manufacturing costs plus transportation, retailing costs and normal profit in a competitive market. ICF, International developed cost curves under contract to UC Davis that estimate RPE as a function of percent increase in fuel economy for all twenty vehicle classes, for gasoline, hybrid and diesel powertrains, and for three time periods: 1) 2007-2013, 2) 2014-2022 and, 3) 2023-2030. The RPE and fuel economy improvement data are fitted very well by quadratic curves with zero intercept: $RPE = a\Delta^2 + b\Delta$ where Δ equals the relative increase in fuel economy. Example cost curves for midsize SUVs are shown in Figures 8.1 and 8.2. Each curve has an upper limit, set at the point where the cost of technologies diverges from the fitted quadratic curve (in general, the final three points fall above the fitted curve). Coefficients for gasoline vehicle cost curves and their upper bounds are provided in Table 8.1. The complete set of cost curves and the underlying data (assumptions on fuel economy improvement technologies and their cost) used to construct these curves are available on the ARB website. Section 8.1.5 provides a brief overview of ICF's technology assumptions compared with other studies.

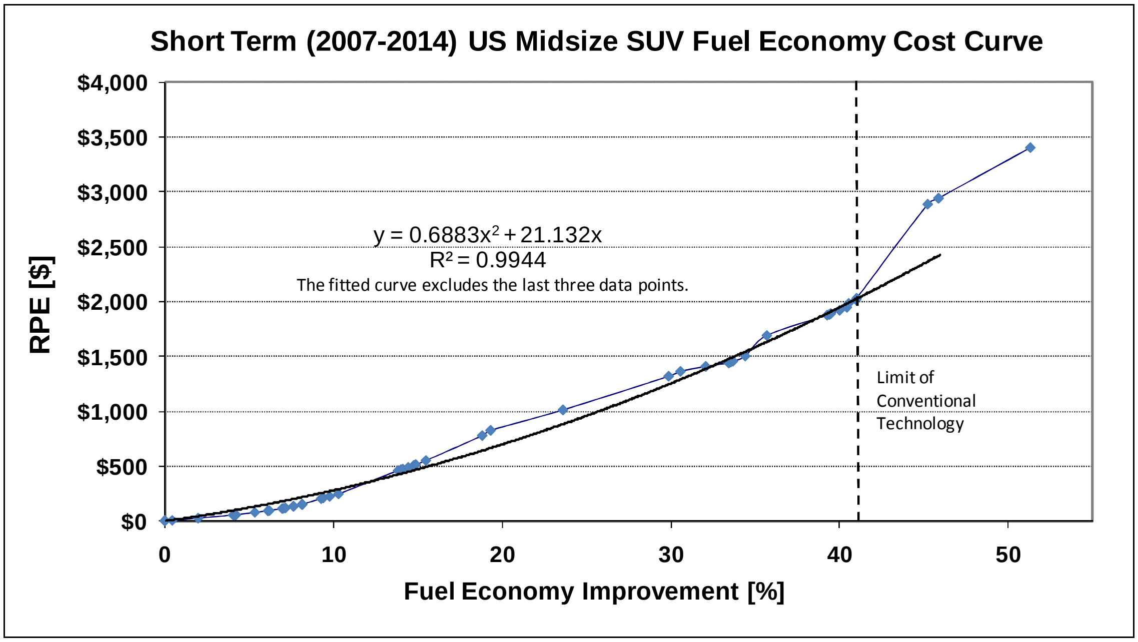

Figure 8.1 Fuel Economy Improvement/Greenhouse Gas Mitigation Cost Curve for 2007-2014 for a Midsize SUV Based on Spreadsheet Models Provided by ICF International, Inc., 2009

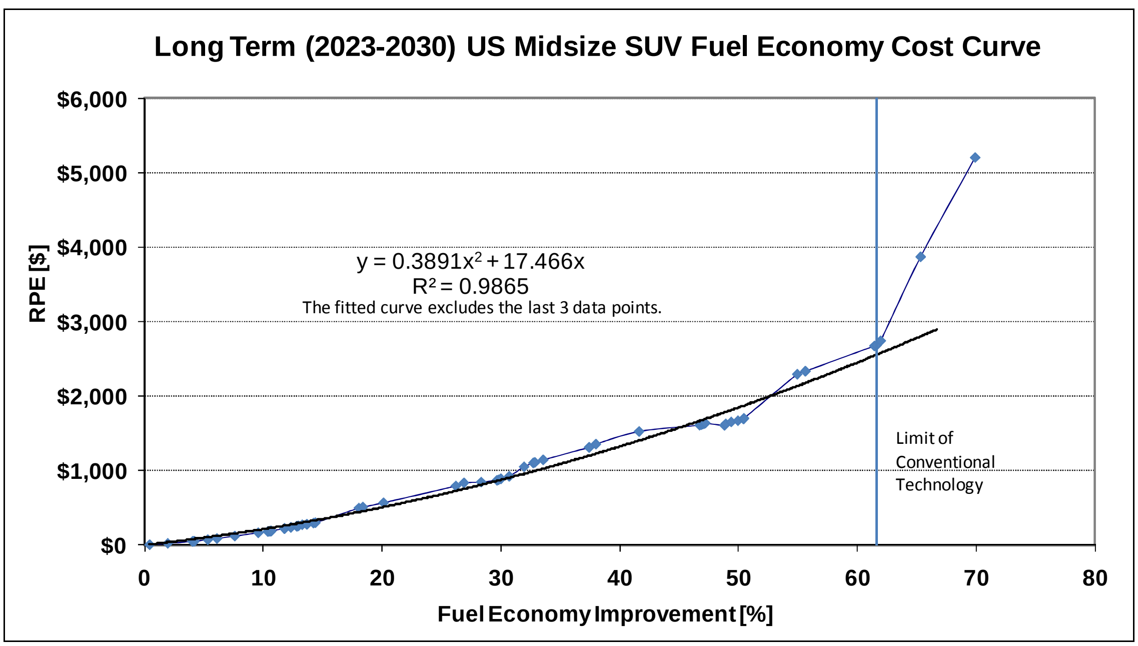

Figure 8.2 Fuel Economy Improvement/Greenhouse Gas Mitigation Cost Curve for 2023-2030 for a Midsize SUV Based on Spreadsheet Models Provided by ICF International, Inc., 2009.

Table 8.1 Coefficients of the gasoline Vehicle Cost Curves ($a\Delta^2 + b\Delta$) by Class and Time Period.

	Near Term: 2007-2014			Mid Term: 2015-2022			Long Term: 2023-2025		
Vehicle Class	a	b	Upper Limit (%)	a	b	Upper Limit (%)	a	b	Upper Limit (%)
Subcompact Car	0.5171	15.944	42.84	0.4568	11.828	60.22	0.3722	11.596	60.22
Compact Car	0.4793	16.150	38.22	0.5119	9.6537	55.20	0.4137	9.6584	55.20
Midsize Car	0.6007	16.774	42.51	0.4913	13.119	61.61	0.4062	12.542	61.61
Large Car	0.5452	24.678	46.38	0.3775	21.673	68.11	0.3008	20.612	68.11
2-seater	0.7108	16.068	41.59	0.5378	13.494	58.86	0.4424	12.999	58.86
Minivan	0.5494	25.339	43.45	0.3940	21.527	65.13	0.3058	20.599	65.13
Standard Van	0.3015	35.787	51.39	0.2920	26.838	74.23	0.2313	25.547	74.23
Small Pickup	0.6442	21.252	41.91	0.4713	17.846	61.74	0.3746	17.134	61.74
Standard Pickup	0.9102	18.549	45.20	0.7333	14.835	64.50	0.6367	14.441	64.50
Small SUV	0.5994	18.088	43.12	0.4748	14.453	62.55	0.3870	13.869	62.55
Midsize SUV	0.6883	21.132	40.99	0.4919	18.097	61.68	0.3891	17.466	61.68
Large SUV	0.9315	21.900	45.62	0.7493	17.973	64.74	0.6633	17.033	64.74
Prestige Subcompact Car	2.1194	9.1418	23.91	1.4204	7.5307	41.48	1.0979	9.9805	41.48
Prestige Compact car	1.2719	17.337	32.09	0.8952	15.782	50.87	69.51	16.252	50.87
Prestige Midsize Car	1.0962	23.231	36.35	0.6899	22.867	56.69	0.5253	22.299	56.69
Prestige	1.5683	10.001	39.57	1.1182	11.112	58.20	0.9456	11.908	58.20

Large Car									
Prestige 2-seater	1.4837	16.167	35.55	1.0379	15.023	52.99	0.8613	15.060	52.99
Prestige Small SUV	1.0859	21.768	38.30	0.8578	16.678	58.09	0.6877	16.974	58.09
Prestige Midsize SUV	1.1387	24.111	37.87	0.8463	19.658	57.91	0.6785	19.384	57.91
Prestige Large SUV	1.5353	24.701	38.72	1.330	17.723	56.90	1.1713	17.246	56.90

The cost curves were calibrated for individual manufacturers using a method explained in Appendix E. It takes into consideration the fuel economy of a manufacturer's fleet given the horsepower and weight of the vehicles it makes. If a manufacturer's fleet is above the average fuel economy for all manufacturers, given its power and weight, it is assumed that the manufacturer is already making use of some of the advanced technologies used to construct the fuel economy cost curves used in the MDM. If a manufacturer's fuel economy is below the average, it is assumed to have a greater ability to increase fuel economy than reflected in the fuel economy cost curves. If A_m is the adjustment factor for manufacturer *m* from Appendix E, and if the industry average cost curve is $RPE = a\Delta^2 + b\Delta$, then the adjusted cost curve is given by $RPE_m = (1+A_m)(a\Delta^2 + b\Delta)$. The adjustment factors used are shown in Table 8.2 below. Nearly all of the adjustment factors are less than ±10%, indicating a fairly consistent use of technology across manufacturers.

Table 8.2 Fuel Economy Cost Curve Adjustment Factors for Manufacturers

Passenger Cars			**Light Trucks**	
Manufacturer	A_m **Cars**		**Manufacturer**	A_m **Trucks**
DAEWOO	-0.083		ROVERGROUP	-0.121
AMC	-0.076		KIA	-0.072
KIA	-0.070		SUZUKI	-0.051
VOLKSWAGEN	-0.046		PORSCHE	-0.042
HYUNDAI	-0.042		VOLKSWAGEN	-0.027
MAZDA	-0.033		NISSAN	-0.016
SUBARU	-0.018		CHRYSLER	-0.012
SUZUKI	-0.012		MITSUBISHI	-0.010

MITSUBISHI	-0.007		BMW	-0.007
BMW	0.001		MERCEDES	-0.006
FORD	0.005		ISUZU	-0.002
AUDI	0.005		AMC	0.004
PORSCHE	0.007		FORD	0.006
SAAB	0.007		MAZDA	0.011
CHRYSLER	0.011		HYUNDAI	0.016
MERCEDES	0.026		GMC	0.027
VOLVO	0.030		TOYOTA	0.035
GMC	0.038		AUDI	0.050
NISSAN	0.041		VOLVO	0.063
TOYOTA	0.056		HONDA	0.065
JAGUAR	0.057		SUBARU	0.089
HONDA	0.103			

Acceleration performance and weight can also be traded off for fuel economy improvement and GHG emissions reductions. In general, weight reduction via materials substitution (while maintaining the size of a vehicle) is included as a technology in the technology cost curves. Thus, the only opportunity for further weight reduction would be downsizing, which would fundamentally change vehicle design, in effect creating a new make and model. Since a wide range of sizes of makes and models are already available for consumers to choose from, we decided to address weight reduction by downsizing via sales mix shifts as predicted by the consumer vehicle choice model (discussed in below in the sub-section on Consumer Choices). Although we explored the possibility of including the option to trade off performance (measured by the ratio of horsepower to weight) for fuel economy, in the end we elected to hold performance constant. We found a lack of consensus in the literature on the value of horsepower and its impact on fuel economy. In addition, vehicle performance and size can produce relative, as well as absolute, utility, implying that they may be currently over-consumed in the market. Attempting to adequately represent this situation would only add complexity to the model in an area where an empirical basis for making such assumptions is lacking.

Introducing Advanced Technologies

There is considerable experience and success in modeling the uptake of proven technologies to reduce vehicle emissions or improve fuel economy. However, the ability to predict the introduction of truly novel technologies, especially at the level of detail required for this study, is lacking. As a result, the MDM treats Zero Emission Vehicles (ZEVs)[21] under the California ZEV mandate as exogenous data, i.e., the emission rates of ZEVs are not decision variables, and ZEVs are not choices in the consumer choice set. ZEVs do get rebates from the feebate program and are considered in the calculation of feebate program revenue. To make the feebate program revenue neutral, additional fees need to be collected from conventional vehicles to cover the rebates to ZEVs. In addition, ZEVs are part of the fleet average calculation and used to meet the emission standards. So, the inclusion of ZEVs essentially relaxes emission constraints. The specific assumptions on the sales and emission rates of ZEVs are discussed in the Regulatory standards part of Section 8.1.3.

However, the MDM does have the capability of modeling and predicting the market penetration of hybrid vehicles. Hybrid vehicles are among the choices provided to car buyers. On the supply side, more hybrid vehicle makes/models/configurations are expected to be introduced by manufacturers in response to the tightened standards and the feebate program. The MDM represents the introduction of an additional hybrid vehicle by converting an existing gasoline vehicle make/model/configuration to a hybrid powertrain.

An integer programming model is used to decide which vehicles will be converted and when. The necessity of an integer programming approach is due to the discontinuity of gasoline and hybrid vehicle technology cost curves, as shown in Figure 8.3. There is a fixed cost for converting a gasoline vehicle to a hybrid[22]. The conversion costs are proportional to vehicle's curb weight and dependent on the year in which the vehicle is converted:

$$Conv\_\cos t_i(t) = coef(t) * w_i$$

where w_i is the curb weight of vehicle *i,* and *coef(t)* is the cost coefficient in year *t*.

for $2007 \le t \le 2014$: $coef = 1.7$

for $2015 \le t \le 2022$: $coef = 1.5$

for $2023 \le t \le 2030$: $coef = 1.3$

The coefficients were obtained from ICF, International.

Thus, depending on when a vehicle is hybridized, converting a 3,000 lbs. vehicle would increase its long-run average retail price by $5,100 in 2007, $4,500 in 2015 and $3,900 in 2023. The cost coefficients are input data that can be varied for alternative assumptions about future progress in hybrid technology.

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[21] ZEVs in the MDM include plug-in hybrid vehicles (PHEVs), battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (FCVs).

[22] Right after hybridization, the fuel economy of the vehicle is assumed to be 1.45 times the starting mpg of the base year gasoline version.

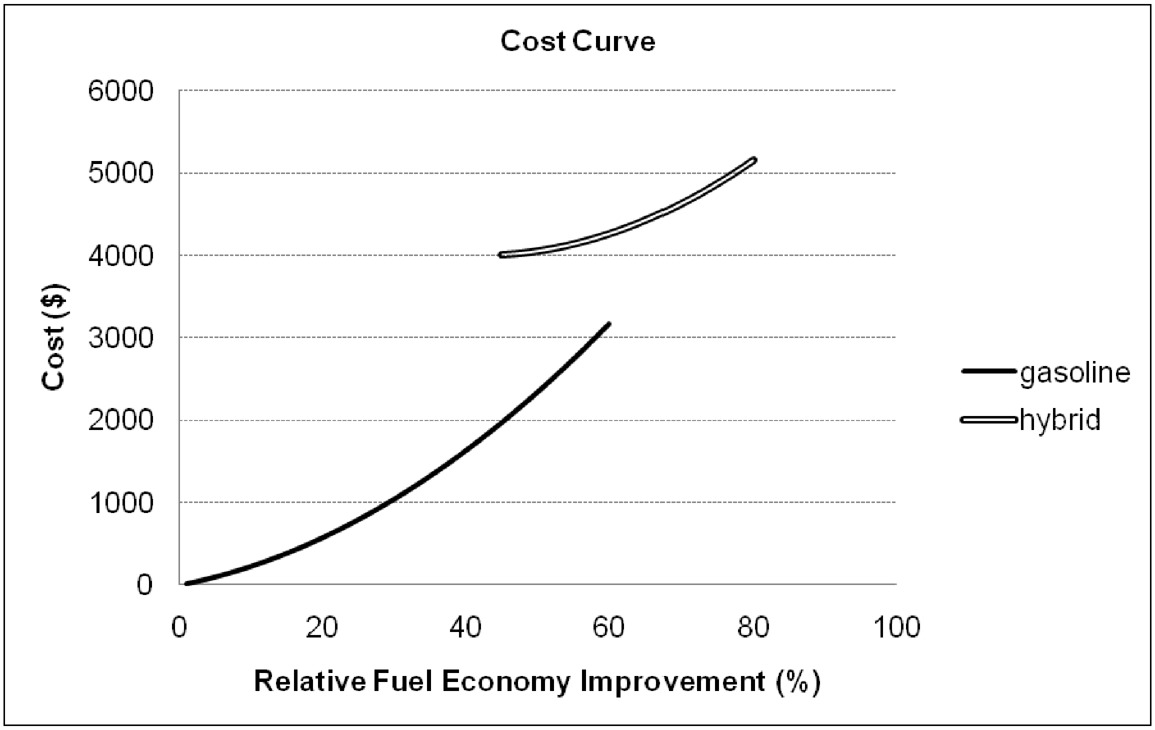

Figure 8.3 Technology cost curves for gasoline and hybrid Midsize cars for 2007-2014

The following procedure is used to convert an ICE to a hybrid vehicle. Take vehicle A as an example. It has a starting fuel economy of 20 mpg in 2007 and a curb weight of 3000 lbs. The fuel economy increases in response to the feebate program. Suppose its fuel economy improves by 50% to 30 mpg in model year 2016 and reaches the upper bound of the gasoline cost curve. In the next redesign year (2020) it has the option to convert to hybrid. If the MDM decides to do so, then there is an incremental cost of $4500 added to the 2007 retail price, and the starting mpg as a hybrid (the origin of the hybrid cost curve) is assumed to be 1.45*20=29 (20 is the mpg in the base year 2007). In 2020, the vehicle will continue improving its fuel economy along the hybrid cost curve until it reaches the optimal point determined by the model, say 35 mpg. The RPE of this vehicle in 2020 will be the RPE in 2007 plus the $4500 conversion cost plus the incremental cost from the origin (29 mpg) to the optimal point (35mpg) on the hybrid cost curve. The calculation of RPE is represented by the following equation:

$$RPE_{ik}(t)=[1-HY_i(t)][a_{ik}(t)(\frac{MPG_i(t)-MPG_i^0}{MPG_i^0})^2+b_{ik}(t)\frac{MPG_i(t)-MPG_i^0}{MPG_i^0}]+$$

$$HY_i(t)[conv\_cost_i(t)+a_{ik}^H(t)(\frac{MPG_i(t)-1.45MPG_i^0}{1.45MPG_i^0})^2+b_{ik}^H(t)\frac{MPG_i(t)-1.45MPG_i^0}{1.45MPG_i^0}]$$

where

$MPG_i(t)$: Continuous decision variable, fuel economy of vehicle *i* in year *t* (miles /gallon),

$HY_i(t)$: Binary decision variable, defined only for vehicles that are fueled by gasoline in the base year, $HY_i(t)$=1, if vehicle *i* is a hybrid version in year *t*; $HY_i(t)$=0, if vehicle *i* is a gasoline version in year *t*;

MPG_i^0 : Base year fuel economy (miles/gallon) for vehicle *i*

$a_{ik}(t)$ and $b_{ik}(t)$: Coefficients for quadratic technology cost curve for vehicle *i* in class *k*,

$a^H_{ik}(t)$ and $b^H_{ik}(t)$: Coefficients for quadratic technology cost curve for hybrid version of vehicle *i* in class *k*.

Calculation of Fuel Savings and Feebate Value

The adoption of emission reduction technologies will increase vehicle prices, save fuel costs, and potentially help the buyers to get more rebates (or pay less fees). The net value (fuel savings + feebate value –vehicle price increase) of vehicles will determine consumer choices, which will in turn have an impact on manufacturer decisions.

Fuel Savings

How consumers are assumed to value fuel economy improvements is key to manufacturer decisions and the impact of a feebate program in general. Economically-rational consumers would measure the value of fuel savings by the expected discounted present value of fuel saved over the full life of the vehicle. There is evidence that very few consumers actually make such quantitative assessments (Turrentine and Kurani, 2007). Greene et al. (2009) show that typical consumer loss aversion combined with the uncertainty of future fuel savings could lead to a significant undervaluing of future fuel savings relative to the expected present value. On the other hand, econometric studies are nearly evenly divided about whether car buyers value fuel savings in accord with rational economic principles or significantly undervalue future fuel savings (Greene, 2010a). The subject remains controversial and has very significant implications for the costs and benefits to consumers of fuel economy policies (e.g., Fischer, 2007). Reflecting this controversy, the National Research Council (2002) fuel economy study considered two alternative methods of valuing fuel savings, full lifetime discounted fuel savings and a 3-year simple payback. Greene et al. (2009) showed that the 3-year simple payback produces approximately the same effect as loss aversion plus uncertainty.

$$FS_i(t) = \int_{\tau=0}^{L} P(\tau) M_0 e^{-\delta\tau} (G_i^0 - G_i^t) e^{-r\tau} d\tau \approx \frac{1}{\delta + r}[1 - e^{-(\delta+r)L}] P(t) M_0 (\frac{1}{MPG_i^0} - \frac{1}{MPG_i(t)})$$

$$FS_i(t) = \frac{1}{\delta}[1 - e^{-3\delta}] P(t) M_0 (\frac{1}{MPG^0} - \frac{1}{MPG_i(t)})$$

where

$FS_i(t)$: fuel savings of model year *t* vehicle *i* relative to its base year configuration

$P(t)$: price of fuel in year t

M_0 : annual miles traveled for a new vehicle

e : base of naperian logarithms

δ : rate of decline in vehicle use (annual miles traveled) per year

G_i^0: base year fuel economy

G_i^t: fuel consumption in model year t

MPG_i^0: fuel economy in base year

$MPG_i(t)$: fuel economy in year t

r = consumer discount rate

L = vehicle lifetime, in years

Both versions of consumer value for fuel economy have been implemented in the MDM and can be chosen and modified for specific runs.

Feebate Value

For most policy cases, the MDM adopts a linear feebate function as follows:

$$F_i(t) = R(t)[e_i^B(t) - e_i(t)]$$

with

$R(t)$ = the feebate rate in year t

$e_i^B(t)$ = the feebate program benchmark for vehicle i in model year t.

$e_i(t)$ = emission rate of vehicle i in model year t.

A single step function is also tested as an alternative (Figure 8.4).

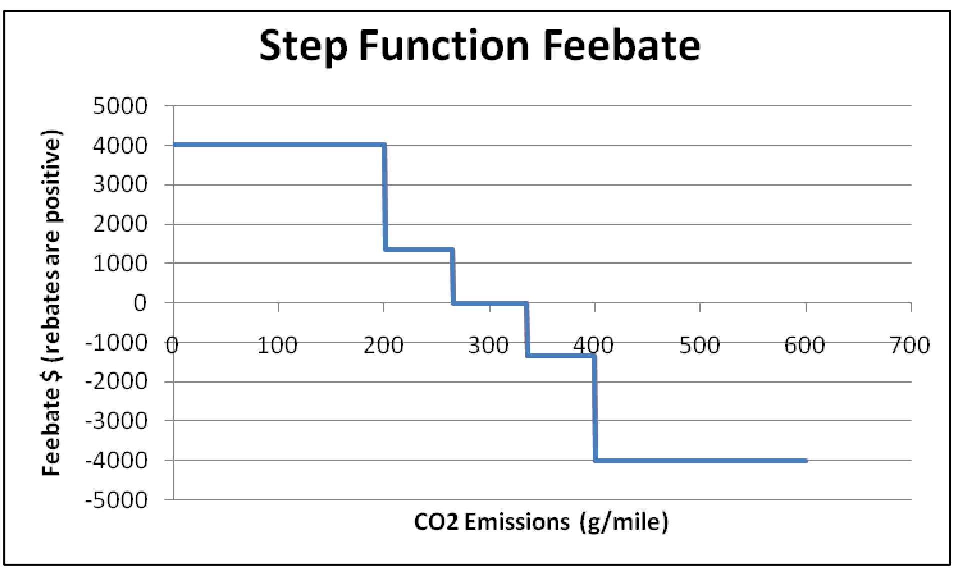

Figure 8.4 Step Function Feebate Schedule used in the MDM

Model Objective

It is reasonable to assume that manufacturers' decisions will reflect their intent to maximize profits while satisfying regulatory constraints. In a competitive market, maximizing profits is equivalent to maximizing consumers' surplus. In other words, manufacturers will make the greatest profit by maximizing the net value of their vehicles to consumers. In economic terminology, we assume a perfectly competitive or monopolistically competitive market on the supply side. A monopolistically competitive market is highly competitive in the common sense of the word, but manufacturers attempt to differentiate their products and thereby achieve short-term rents. In the long run, however, products are priced at the long-run average cost of production, including normal returns to capital. This allows us to make use of existing estimates of the costs of technologies for reducing greenhouse gas emissions, and to simulate profit maximization by maximizing consumer surplus. The specific formula for calculating consumer surplus is introduced in the Consumer Choices section below. Intuitively, consumer surplus can be viewed as the composite net utility of all vehicles offered for sale in the automobile market.

Model Constraints: Fuel Economy and GHG Emissions Standards

The MDM has included fuel economy and GHG emissions standards[23] as constraints to the optimization model. The new joint fuel economy and GHG emissions standards (2012 -2016) are defined according to vehicle footprint[24]: each vehicle model has its own emissions (or fuel economy) target as a function of the vehicle's footprint (there are separate footprint functions for passenger cars and light trucks, see Figure 8.5 and Figure 8.6). These footprint curves are piecewise linear and in parallel with each other. The curves for the later model years are below the ones for earlier model years, indicating that the standards are tightened over the years. The standards require that the fleet average GHG emissions (or fuel economy) for a manufacturer must be lower (or higher) than the sales-weighted average emissions (or fuel economy) target of vehicles sold by the manufacturer.

The emissions targets as defined by these footprint functions can also be used as the default benchmarks of the feebate program. In the MDM, feebate benchmarks can be shifted uniformly upwards or downwards from the values of emission targets specified by the standards in order to achieve revenue neutrality.

[23] The MDM includes CAFE standards for the period of 2007-2011, and national GHG emissions standards for the period of 2012 to 2016. Post-2016 standards are not issued yet and their values are assumed.

[24] The footprint of a vehicle is the product of its wheelbase and track width.

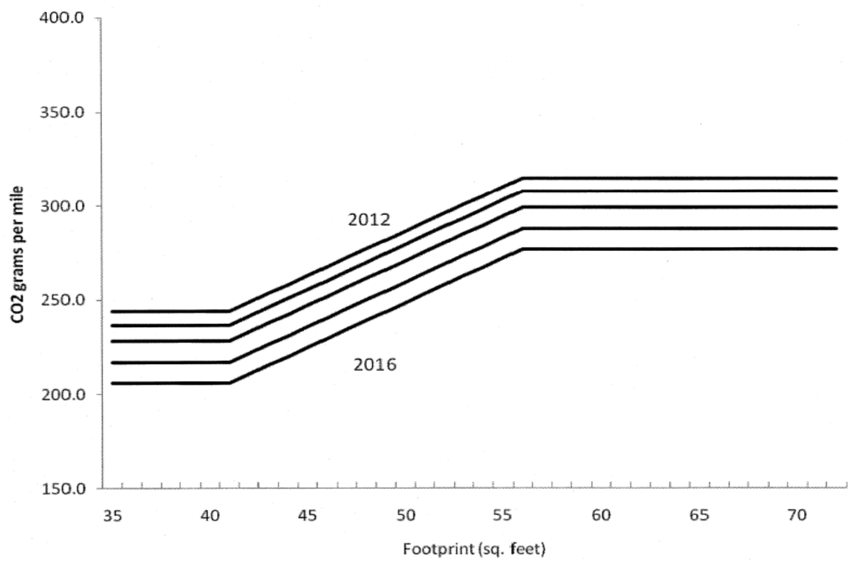

Figure 8.5 GHG emissions target for passenger cars (source: EPA/NHTSA, 2009)

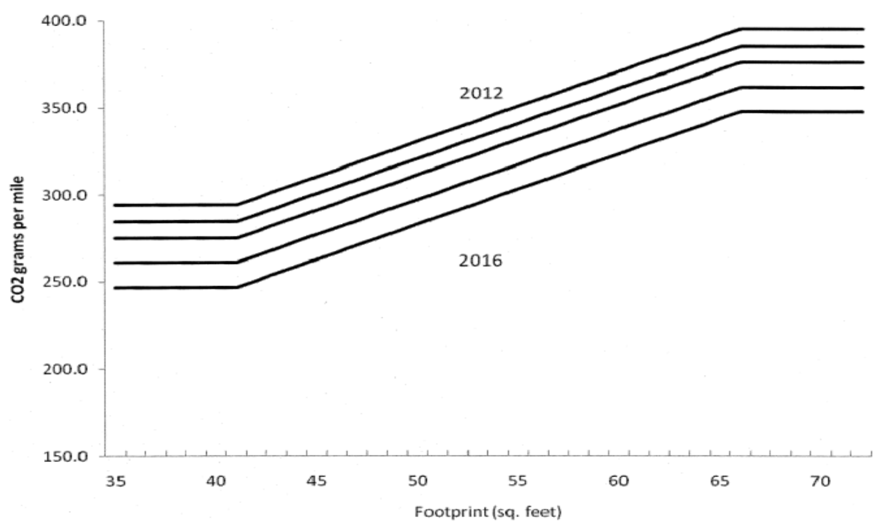

Figure 8.6 GHG emissions target for light trucks (Source: EPA/NHTSA, 2009)

It is not a straightforward task to model the full complexities of GHG emissions standards. Provisions allow credits for improvements to air conditioning systems and for flexible fuel vehicles (FFV). The FFV credits will be phased out over time and may, in the future, require documentation of alternative fuel use. Manufacturers may bank credits earned by exceeding standards in the past and use them up to five years in the future. They may also borrow credits against plans to exceed standards in the future. In addition, manufacturers may trade credits with each other. The modeling principle in the MDM is to retain the essentials of the standards while reducing some complexities in order to obtain fast and valid projections for various policy cases. In its full version, the MDM assumes credit trading and banking, but not borrowing. The inclusion of credit trading enables the MDM to simplify manufacturer-specific constraints to one industry-wide constraint. But the interaction among credit banking, technology improvement and manufacturer pricing greatly expands the search space for finding optimal solutions. We have found through experimentation that solving such a model is generally slow and cannot meet the need to analyze large numbers of policy cases. Thus a reduced version of MDM that omits banking was developed and implemented for most cases. The reduced version is much easier to solve and provides similar results to the full version.

Consumer Choices

Choice Structure

The MDM includes an aggregate consumer vehicle choice model, implemented as a nested multinomial logit model. Choice alternatives are represented in detail, by make, model, engine and transmission type, at the same level of detail available in EPA's test car list. There are on the order of 1,000 choice alternatives per year. Individual vehicles are grouped into twenty classes, arranged according to the nesting structure illustrated in Figure 8.7.

The structure has 5 levels: lev0 (buy/no-buy), lev1 (vehicle category: passenger vehicle or cargo vehicle), lev2 (vehicle type), lev3 (vehicle class) and lev4 (vehicle configurations). One dimension included in the structure is whether passenger vehicles are considered "Prestige" or "Standard" ("Non-Prestige") vehicles. For an assignment of manufacturers to these categories, see Table 8.3. Consumer demand is represented separately for two regions: either California and the Rest of US, or Opt-in States and the Rest of US, depending on the geographic scope of the feebate program.

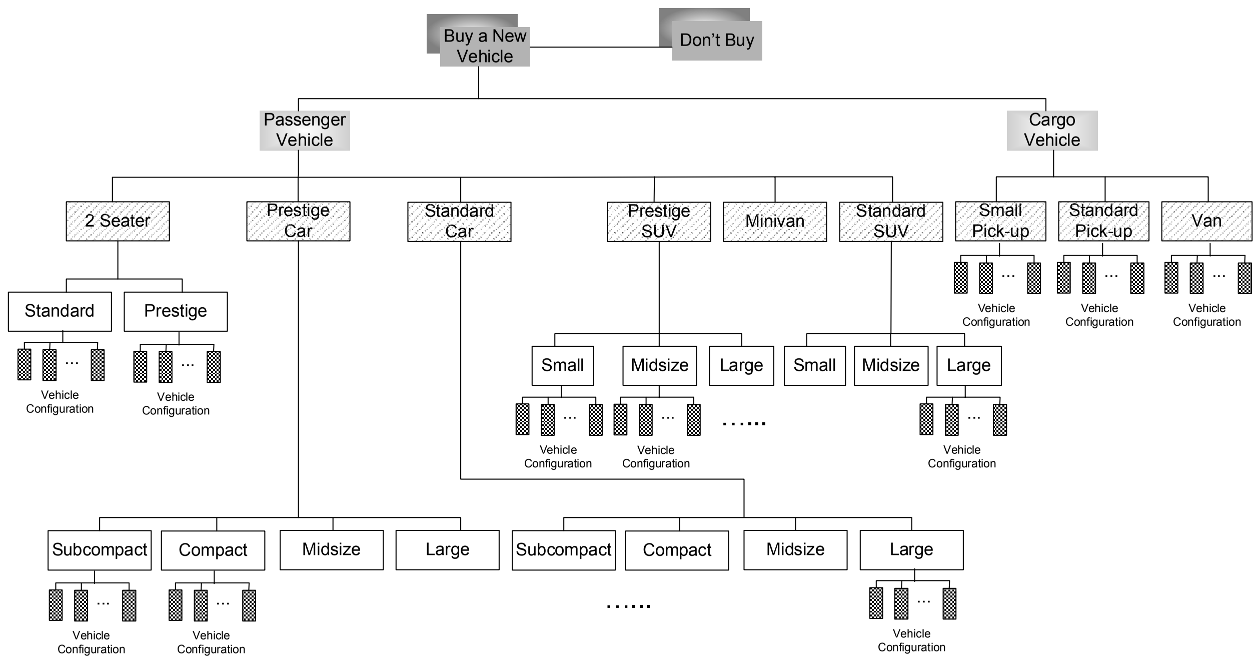

Figure 8.7 Nested Multinomial Logit Structure of Vehicle Choice Implemented in MDM

Table 8.3 Assignment of Manufacturers to Categories

Domestic-Standard*	Asia-Standard	Europe-Prestige
Buick Chevrolet Chrysler Dodge Ford GMC Jeep Mercury	Honda Hyundai Kia Mazda Nissan Scion Toyota	Audi Bentley BMW Jaguar Land Rover Mercedes-Benz Mini Saab Volvo
Domestic-Prestige	**Asia-Prestige**	**Europe-Standard**
Cadillac Lincoln	Acura Infiniti Lexus	Volkswagen

* "Standard" is synonymous with "Non-Prestige"

Logit Model Equations

Utilities and Consumer Surplus

The MDM adopts a bottom-up approach to represent utilities in the 5-level nested logit model. Assuming fuel economy (or emissions rate) is the only change in a vehicle's design, the utility of vehicle *i* in class *k* to the representative consumer is defined as:

$$U_{ik}(t) = A_{ik} + B_k[C_{ik}(t) - FS_{ik}(t) - F_{ik}(t)]$$

where

A_{ik}: constant term for vehicle *i*, which represents the average value of the unmeasured attributes of vehicle *i*,

B_k: Price slope for vehicles in class *k*, which is the derivative of utility with respect to price

C_{ik} : Retail Price Equivalent (RPE) for improving fuel economy of vehicle *i*,

FS_{ik} : Fuel savings from improved fuel economy

F_{ik} : Feebate value which is positive if the vehicle receives rebates and negative if it pays fees.

RPE, fuel savings, and feebate value are all functions of fuel economy and emission rates, which are defined in previous sections.

Greene (1994) calls $C_{ik} - FS_{ik} - F_{ik}$ the generalized value since vehicle attributes are converted into present monetary value, and utility is the product of this monetary value and the price slope. The expected generalized value of vehicles in class *k* is then

$$\overline{V_k}(t) = \frac{1}{B_k}\ln\left(\sum_{i\in I_k} e^{A_{ik}+B_k[C_{ik}(t)-FS_{ik}(t)-F_{ik}(t)]}\right)$$

where I_k is the set of vehicles in class *k*. The representative utility of class *k* in the nest *h* of level 2 is given by the following equation:

$$U_{kh}(t) = A_{kh} + B_h\overline{V}_{kh}(t) = A_{kh} + \frac{B_h}{B_k}\ln\left(\sum_{i\in I_k} e^{A_{ik}+B_k[C_{ik}(t)-FS_{ik}(t)-F_{ik}(t)]}\right)$$

where

A_{kh}: constant term for class *k* which represents the average value of the unmeasured attributes of vehicle class *k*,

B_h: Price slope for vehicles in nest *h* of level 2. In theory the absolute value of the upper nest price slope should be less than the lower nest price slope, i.e.,$|B_h| < |B_k|$.

The representative utilities of the upper level nests are defined similarly by aggregating lower level utilities. Particularly, the utility of buying a new vehicle is

$$U_{Buy}(t) = A^t_{Buy} + B\overline{V}_{Buy}(t) = A^t_{Buy} + \frac{B}{B_{Buy}} \ln(e^{U^t_{car}} + e^{U^t_{truck}})$$

where B is the price slope in the level of buy/no-buy and B_{Buy} is the price slope in level 1 (car/truck). The utility of no-buy is

$$U_{No\_Buy}(t) = A^t_{No\_Buy}$$

Consumer surplus per household in model year *t* is calculated as

$$CS(t) = -\frac{1}{B}\ln(e^{U^t_{Buy}} + e^{U^t_{No\_Buy}}) + con = -\frac{1}{B}\ln[e^{A^t_{Buy} + \frac{B}{B_{Buy}}\ln(e^{U^t_{car}} + e^{U^t_{truck}})} + e^{A^t_{No\_Buy}}] + con$$

Where *con* is an unknown constant that represents the fact that the absolute value of utility cannot be measured. The change of consumer surplus per household compared to the base year is

$$\Delta CS(t) = -\frac{1}{B}\ln(\frac{e^{U^t_{Buy}} + e^{U^t_{No\_Buy}}}{e^{U^0_{Buy}} + e^{U^0_{No\_Buy}}}) = -\frac{1}{B}\ln(\frac{e^{A^t_{Buy} + \frac{B}{B_{Buy}}\ln(e^{U^t_{car}} + e^{U^t_{truck}})} + e^{A^t_{No\_Buy}}}{e^{A^0_{Buy} + \frac{B}{B_{Buy}}\ln(e^{U^0_{car}} + e^{U^0_{truck}})} + e^{A^0_{No\_Buy}}})$$

Choice Probabilities

The probability of buying a new vehicle is

$$p_{buy} = \frac{e^{U_{Buy}}}{e^{U_{Buy}} + e^{U_{No\_Buy}}}$$

and the conditional probability of buying a passenger car given the choice of buying a new vehicle is

$$p_{car|Buy} = \frac{e^{U_{car}}}{e^{U_{car}} + e^{U_{truck}}}$$

Thus the probability of buying a passenger vehicle is

$$p_{car} = p_{Buy}\ p_{car|Buy}$$

The probabilities of lower level choices can be calculated in a similar way.

Logit Model Calibration

Price slopes and constant terms need to be calibrated to base year sales data so that the nested logit model prediction replicates the true market shares in the base year. It is convenient to deduce price slopes from elasticities according to following logit model equation:

$$B_i = \frac{\eta_i}{Price_i(1-S_i)}, \forall i \in k$$

where η_i is the elasticity of choice probability or market share of vehicle *i* with respect to its price, B_i is the price slope, $Price_i$ is vehicle price and S_i is market share. Price slopes of vehicles within the same class are assumed to be same, i.e., $B_i = B_j = B_k, \forall i, j \in k$. An estimation of B_k is obtained by adopting a typical value of S_i from empirical data (e.g. a market share of 1.5%), the average price of vehicles in class *k*, and price elasticity of demand for vehicles in class *k*, which is assumed based on published studies. For example, Greene (1994) reports an elasticity of -5.5 at a 1.5 percent market share for individual makes, models and engine/transmission configurations. The price slopes for other levels are calibrated in the same way. The price elasticity assumptions and calculated price slopes in the MDM are shown in Table 8.4. The price elasticity assumptions were examined by the Alliance of Automobile Manufacturers, and Resource for the Future, and they generally agreed that they were reasonable given what is known in the literature.

Table 8.4 Price elasticities and slopes in MDM

LEVEL 1		Choice of Make, Model, Engine Transmission Configuration within a Class		
Class		Name	Elasticity	Slope
	1	Prestige Two-Seater	-5.5	-0.0000984
	2	Prestige Subcompact car	-4.5	-0.0001019
	3	Prestige Compact car	-4.5	-0.0001273
	4	Prestige Midsize Car	-4.5	-0.0001134
	5	Prestige Large car	-4.5	-0.0001024
	6	Two-Seater	-5.5	-0.0001634
	7	Subcompact car	-6	-0.0003281
	8	Compact car	-6	-0.0003426
	9	Midsize Car	-6	-0.0002815
	10	Large Car	-6	-0.0002492
	11	Prestige Small SUV	-4.5	-0.0001103
	12	Prestige Midsize SUV	-4.5	-0.0001011
	13	Prestige Large SUV	-4.5	-0.0001002
	14	Small SUV	-6	-0.0002448
	15	Midsize SUV	-6	-0.0002043
	16	Large SUV	-6	-0.0001689
	17	Minivan	-6	-0.0002433
	18	Standard van	-6	-0.0002821
	19	Small Pickup	-6	-0.0002788
	20	Standard Pickup	-6	-0.0002022
LEVEL 2		Choice Among 20 Vehicle Classes within Vehicle Type		
Type		Name	Elasticity	Slope
	21	Two-Seater	-1.9	-0.0000925
	22	Prestige Car	-3	-0.0000967
	23	Standard Car	-3	-0.0001944
	24	Prestige SUV	-3	-0.0000979
	25	Standard SUV	-3	-0.0001604
	26	Minivan	na	-0.0002433
	27	Standard Van	na	-0.0002821
	28	Pickup	-2	-0.0001398
Level 3		Choice of Vehicle Type within Passenger or Cargo Categories		
Category		Name	Elasticity	Slope
	31	Passenger Vehicle	-2	-0.0000897
	32	Cargo Vehicle	-1.5	-0.0001050
Level 4		Choice of Passenger or Cargo Vehicle		
		Name	Elasticity	Slope
	41	Vehicle	-1.1	-0.0000815
Level 5		Choice to Buy a New Vehicle or Not		1.6972
			Elasticity	Slope
	51	Buy/No-buy	-0.8	-0.0000339

Given the fact that constant terms represent base year utility before any changes to vehicles, it is easy to calibrate constants from base year market shares. For example, the following equation indicates that the difference of two vehicle-specific constants equals the difference of the logarithm of these two vehicles' market shares.

$$\frac{p^0_{i|k}}{p^0_{j|k}} = \frac{e^{A_{ik}}}{e^{A_{jk}}} = \frac{S^0_i}{S^0_j}, \forall i, j \in I_k$$
$$=> A_{ik} - A_{jk} = \ln S^0_i - \ln S^0_j$$

where *i* and *j* are two vehicle configurations in class *k*, I_k represents the set of all vehicles in class *k*, $p^0_{i|k}$ and $p^0_{j|k}$ are conditional probabilities of choosing alternative *i* or *j* given class *k* has been chosen, and S^0_i and S^0_j are the market shares of vehicles *i* and *j* in the base year. If we normalize the constant A_{1k} to be zero, then

$$A_{ik} = \ln S^0_{ik} - \ln S^0_{1k}, \forall i \in I_k$$

For vehicle classes, the following equation holds:

$$\frac{S^0_k}{S^0_l} = \frac{e^{A_{kh} + \frac{B_h}{B_k}\ln(\sum_{i \in I_k} e^{A_{ik}})}}{e^{A_{lh} + \frac{B_h}{B_l}\ln(\sum_{i \in I_l} e^{A_{il}})}}, \forall k, l \in nest\, h$$

where S^0_k and S^0_l are base year market shares of vehicle classes *k* and *l*, and A_{kh} and A_{lh} are class-specific constant terms in nest *h* of level 2. Normalizing A_{1h} to be zero, we get

$$A_{kh} = \frac{B_h}{B_1}\ln(\sum_{i \in I_1} e^{A_{i1}}) - \frac{B_h}{B_k}\ln(\sum_{i \in I_k} e^{A_{ik}}) + \ln S_k - \ln S_1, \forall k \in nest\, h$$

The constant terms in other levels are calibrated in the same way. Particularly, the constant for not buying is assumed to be 0, and the constant for buying is calibrated to the total vehicle sales projection from the Annual Energy Outlook 2009 by EIA.

Formulation

Before introducing the complete MDM formulation, the major model assumptions and notations are summarized below.

Model Assumptions Summary

Before introducing the complete MDM formulation, the major model assumptions are summarized below.

a) The vehicle market is competitive (perfectly competitive or monopolistically competitive) and firms therefore maximize profits by maximizing social surplus. Since producer surplus is zero for the case of perfect competition or close to zero in the long run for the case of monopolistic competition, manufacturers' behavior can be approximated by consumer surplus maximization. This assumption is consistent with the calculation of Retail Price Equivalent (RPE) for installing emission reduction technologies, which includes long-run technology costs plus normal profits in a competitive market.

b) Manufacturers design vehicle configurations that are always offered for sale nationwide. Specifically, manufacturers won't sell specially designed vehicles for California and/or feebate Opt-in States.
c) Vehicle fuel economy or GHG emission rate is the only design factor that manufacturers adjust in response to regulations or policies. Other factors including vehicle size, weight and horsepower are assumed to be constant over the planning horizon.
d) Consumers are assumed to undervalue fuel savings in most MDM cases, but we also include cases that fully value fuel savings for sensitivity analysis.
e) The new CAFE and GHG emissions standards allow trading of compliance credits among firms. The MDM assumes complete credit trading, which implies manufacturers behave as a single large manufacturer in meeting standards, and the system achieves maximum efficiency. This allows the MDM to model manufacturer-specific constraints as one industry-wide constraint.
f) Some gasoline vehicles may be converted to hybrid vehicles if the MDM determines that the conversion is cost-effective.

Model Notations

<u>Subscripts:</u>

m refers to different manufacturers

i refers to different vehicle configurations (level 4 of nested logit model structure)

k refers to different vehicle classes (level 3 of nested logit model structure)

h refers to different vehicle types (level 2 of nested logit model structure)

q refers to different vehicle categories (level 1 of nested logit model structure)

ik refers to vehicle configuration *i* in class *k*

kh refers to vehicle class *k* in level 2 type *h*

hq refers to level 2 type *h* in level 1 category *q*

I_k refers to the set of all the vehicle configurations in the vehicle class *k*

t refers to model year

<u>Exogenous Data & Parameters:</u>

G_i^0: Base year fuel consumption (gallons/mile) for vehicle *i*

MPG_i^0 : Base year fuel economy (miles/gallon) for vehicle *i*

e_i^0 : Base year GHG emissions rate (grams CO2 equivalent/mile) for vehicle *i*

$e_i^B(t)$: Benchmark of feebate program (grams CO2 equivalent /mile) for vehicle *i* in year *t*

$e_i^*(t)$: Emission target in GHG emissions standards for vehicle *i* in year *t*, which is a function of vehicle footprint

r: discount factor

$a_{ik}(t)$ and $b_{ik}(t)$: Coefficients in quadratic technology cost curve for vehicle *i* in class *k*

$a^H_{ik}(t)$ and $b^H_{ik}(t)$: Coefficients in quadratic technology cost curve for hybrid version of vehicle *i* in class *k*

$Bound_i(t)$: Upper bound of technology cost curve for vehicle *i*

$Bound^H_i(t)$: Upper bound of technology cost curve for hybrid version of vehicle *i*

$conv\_cost_i(t)$: Fixed cost of converting vehicle *i* to a hybrid in year *t*

fp_i: The footprint of vehicle *i*

timing(i,t): If vehicle *i* is scheduled to be redesigned in year *t*, *timing(i,t)*=1; Otherwise, *timing*(*i,t*)=0

g2e: Conversion multiplier that converts fuel consumption to GHG emissions. It is 8887 g/gal for gasoline and 10180 g/gal for diesel fuel (EPA/NHTSA, 2010a).

Total_sales(t): Total vehicle sales in year *t*, data obtained from the Annual Energy Outlook (AEO) 2009 of the Energy Information Administration (EIA)

MS(t): U.S. light-duty vehicle market size in year *t* which is estimated by the number of households.

<u>Decision Variables:</u>

$MPG_i(t)$: Fuel economy of vehicle *i* in year *t* (miles/gallon)

$HY_i(t)$: Binary decision variable, defined only for vehicles that are fueled by gasoline in the base year, $HY_i(t)$=1, if vehicle *i* is a hybrid version in year *t*; $HY_i(t)$=0, if vehicle *i* is a gasoline version in year *t*;

$\Delta p_i(t)$: Price adjustment to vehicle *i* in year *t*

$CC(t,\tau)$: Compliance credits transferred from period *t* to period τ .

<u>Intermediate Variables:</u>

$e_i(t)$: GHG emission rate of vehicle *i* in year *t* (grams CO2 equivalent /mile)

Credit(t): Credits earned by manufacturers in each year (positive or negative)

ΔMPG: Relative change in mpg, defined as $\frac{MPG_i(t)-MPG_i^0}{MPG_i^0}$

$C_{ik}(t)$: Retail Price Equivalent (RPE) of improving the fuel economy of vehicle *i* in class *k* in year *t*

$FS_{ik}(t)$: The value of vehicle *i*'s fuel savings as perceived by customers in year *t*

$F_{ik}(t)$: The feebate received or paid by the buyer of vehicle *i* in year t. Define positive $F_{ik}(t)$ as rebate and negative $F_{ik}(t)$ as fee.

$U_{ik}(t)$: The utility of vehicle *i* in class *k* in year *t*

$U_{kh}(t)$: The utility of vehicle class *k* in nest *h* in year *t*

$S_i(t)$: The market share of vehicle *i* in year *t*

$S_k(t)$: The market share of vehicle class *k* in year *t*

CS(t): Consumer surplus per household in year *t*

ΔCS(t): Consumer surplus change per household in year *t* compared to base year

The MDM is formulated as a mixed integer nonlinear program with the objective of maximizing social surplus (consumer surplus + producer surplus) and the main constraint of GHG emissions standards. As mentioned earlier, this document includes two versions of MDM formulation depending on the assumption of emissions standards: full and reduced versions.

MDM Equations (Full Version)

In its full version, the MDM assumes credit trading and banking, but not borrowing. Manufacturers can adjust the price of each vehicle ($\Delta p_i(t)$) in order to maximize profit or equivalently maximize social surplus. The equations have been listed in the order of following groups:

1) **Objective**

Maximizing the summation of accumulated consumer surplus and producer surplus[25]

$$\max \sum_t \{(1+r)^{-t} MS(t)[\Delta CS(t) + p_{Buy}(t)\sum_i S_i(t)\Delta p_i(t)]\}$$

[25] The producer surplus will be zero when the optimal solutions are achieved. More details can be found in the later parts of this section (Some properties of the MDM equations).

The formula of consumer surplus will be given in the group of Logit Model Equations

1. Constraints

Some of the equations in this group are equalities that define relationships between variables, e.g., the derivation of emissions rate from fuel economy and the calculation of compliance credits. Some of the equations are inequalities that constraint the model, e.g., redesign cycle constraint, fuel economy improvement upper bound, and restriction on converting vehicles to hybrids. Particularly, GHG emissions standards are represented together by the equality calculating credits, banking equation 1, banking equation 2, and nonnegativity of credit flows.

The relationship between fuel economy and emissions rate

$$e_i(t) = g2e_i / MPG_i(t)$$

Redesign Cycle constraint: fuel economy must be the same as last year if not yet redesigned

$$MPG_i(t) = MPG_i(t-1),\ \forall i,t \text{ satisfying timing(i,t)} = 0$$

Fuel economy improvement must be within upper bound of technology cost curves

$$MPG_i(t) \le [1 - HY_i(t)]Bound_i(t) + HY_i(t)Bound_i^H(t), \forall i,t$$

Some vehicles (e.g. existing hybrids) are not allowed to convert to hybrids

$$HY_i(t) = 0 \text{ for some } i \text{ and } t$$

Calculate credits: share of vehicle i $S_i(t)$ *is defined in the group of Logit Model Equations*

$$Credit(t) = \sum_{i=1}^{N} total\_sales(t) S_i(t)(e_i^*(t) - e_i(t)),\ \forall t$$

Banking equation 1: total net credits in each year must be nonnegative

$$Credit(t) + \sum_{\tau=t-5}^{\tau=t-1} CC(\tau,t) - \sum_{\tau=t+1}^{\tau=t+5} CC(t,\tau) \ge 0, \forall t$$

Banking equation 2: credit in-flow and out-flow cannot simultaneously exist

$$\sum_{\tau=t-5}^{\tau=t-1} CC(\tau,t) * \sum_{\tau=t+1}^{\tau=t+5} CC(t,\tau) = 0$$

Credits flows are nonnegative

$$CC(t,\tau) \geq 0, \forall t,\tau$$

2) Logit Model Equations

This group of equations defines or calculates utility of each nest in the nested logit model, including the calculation of RPE of improving fuel economy, fuel savings and feebate values. Consumer surplus (or literally consumer surplus change here) is also given as a function of utility of buy and no-buy. In addition to utilities and consumer surplus, this group also calculates the market share of a vehicle configuration and the probability of buying a new vehicle.

Utility of vehicle i in class k

$$U_{ik}(t) = A_{ik} + B_k[C_{ik}(t) - FS_{ik}(t) - F_{ik}(t) + \Delta p_i]$$

RPE of improving fuel economy

$$C_{ik}(t) = [1 - HY_i(t)][a_{ik}(t)(\frac{MPG_i(t) - MPG_i^0}{MPG_i^0})^2 + b_{ik}(t)\frac{MPG_i(t) - MPG_i^0}{MPG_i^0}] +$$
$$HY_i(t)[conv\_cost_i(t) + a_{ik}^H(t)(\frac{MPG_i(t) - 1.45MPG_i^0}{1.45MPG_i^0})^2 + b_{ik}^H(t)\frac{MPG_i(t) - 1.45MPG_i^0}{1.45MPG_i^0}]$$

Three-year payback fuel savings

$$FS_i(t) = \frac{1}{\delta}[1 - e^{-3\delta}]P(t)M_0(\frac{1}{MPG^0} - \frac{1}{MPG_i(t)})$$

or alternative equation for full life time discounted fuel savings

$$FS_i(t) = \frac{1}{\delta + r}[1 - e^{-(\delta + r)L}]P(t)M_0(\frac{1}{MPG_i^0} - \frac{1}{MPG_i(t)})$$

Feebate value

$$F_i(t) = R(t)[e_i^B(t) - e_i(t)]$$

Utility of vehicle class k

$$U_{kh}(t) = A_{kh} + b\overline{V}_{kh}(t) = A_{kh} + \frac{B_h}{B_k}\ln(\sum_{i \in I_k} e^{A_{ik} + B_k[C_{ik}(t) - FS_{ik}(t) - F_{ik}(t)]})$$

Utilities of alternatives in other levels are defined in a similar way by aggregating lower-level utilities. Particularly, *Utility of Buying*

$$U_{Buy}(t) = A^t_{Buy} + B\overline{V}_{Buy}(t) = A^t_{Buy} + \frac{B}{B_{Buy}} \ln(e^{U^t_{car}} + e^{U^t_{truck}})$$

Utility of Not Buying

$$U_{No\_Buy}(t) = A^t_{No\_Buy}$$

Consumer surplus change

$$\Delta CS(t) = -\frac{1}{B} \ln(\frac{e^{U^t_{Buy}} + e^{U^t_{No\_Buy}}}{e^{U^0_{Buy}} + e^{U^0_{No\_Buy}}}) = -\frac{1}{B} \ln(\frac{e^{A^t_{Buy} + \frac{B}{B_{Buy}} \ln(e^{U^t_{car}} + e^{U^t_{truck}})} + e^{A^t_{No\_Buy}}}{e^{A^0_{Buy} + \frac{B}{B_{Buy}} \ln(e^{U^0_{car}} + e^{U^0_{truck}})} + e^{A^0_{No\_Buy}}})$$

Market share of vehicle i

$$S_i(t) = P_{q|Buy}(t) P_{h|q}(t) P_{k|h}(t) P_{i|k}(t)$$

where *conditional probability of choosing vehicle i given class k is chosen is*

$$p_{i|k} = \frac{e^{U_{ik}}}{\sum_{j \in I_k} e^{U_{jk}}} = \frac{e^{[A_{ik} + B_k(C_{ik} - FS_{ik} - F_{ik})]}}{\sum_{j \in I_k} e^{[A_{jk} + B_k(C_{jk} - FS_{jk} - F_{jk})]}}$$

conditional probabilities of upper level choices are calculated in a similar way and

The probability of buying a new vehicle is

$$p_{buy} = \frac{e^{U_{Buy}}}{e^{U_{Buy}} + e^{U_{No\_Buy}}} = \frac{e^{A^t_{Buy} + \frac{B}{B_{Buy}} \ln(e^{U^t_{car}} + e^{U^t_{truck}})}}{e^{A^t_{Buy} + \frac{B}{B_{Buy}} \ln(e^{U^t_{car}} + e^{U^t_{truck}})} + e^{A^t_{No\_Buy}}}$$

MDM Equations (Reduced Version)

For policy cases with a 15-year planning horizon and 1000 vehicle configurations, the above full version of the MDM is large in scale (around 38,000 variables). In addition, the interaction between pricing and banking makes the model more difficult to solve. Thus a reduced version of the MDM was developed for reducing the computational burden. Both the full and reduced versions have been solved for a few typical policy cases. Generally the reduced version of the model provides results that approximate well the ones from the full version.

Two simplifications are made in the reduced version. Firstly, the banking option for manufacturers is disabled. Banking equations are replaced by one constraint requiring that manufacturers, as an industry, must meet the standards in each year. Secondly, a firm's optimal pricing strategy turns out to be a self-applied feebate system, internal to the firm (Please refer to Some properties of the

MDM equations section below for the derivation). This greatly simplifies the modeling of pricing decisions, because it implies that the MDM does not need to include a pricing decision variable for each vehicle, but only determine the feebate rate of this industry-wide internal feebate system.

The reduced version of the MDM is represented by the following equations:

$$\max \sum_t \{(1+r)^{-t} MS(t)\Delta CS(t)\}$$

$$e_i(t) = g2e_i / MPG_i(t)$$

$$MPG_i(t) = MPG_i(t-1), \forall i,t \text{ satisfying timing(i,t)} = 0$$

$$MPG_i(t) \le [1-HY_i(t)]Bound_i(t) + HY_i(t)Bound_i^H(t), \forall i,t$$

$$HY_i(t) = 0 \text{ for some } i \text{ and } t$$

$$\sum_{i=1}^{N} S_i(t)(e_i(t) - e_i^*(t)) \le 0 \text{ , } \forall t$$

$$\lambda(t) \ge 0, \forall t,$$

$$\lambda(t)[\sum_{i=1}^{N} S_i(t)(e_i(t) - e_i^*(t))] = 0, \forall t,$$

The nested logit model equations remain the same as in the full version except that

$$U_{ik}(t) = A_{ik} + B_k\{C_{ik}(t) - FS_{ik}(t) - F_{ik}(t) + \lambda(t)[e_i(t) - e_i^*(t)]\},$$

where *λ(t)* is an additional decision variable, the feebate rate of manufacturers' self-applied feebate system. Equation "$\lambda(t) \ge 0, \forall t,$" constrains λ to be non-negative and the following equation is a complementary condition stating that the system has no pricing if the emission constraint is non-binding. The last equation is used to replace the equation for the Utility of vehicle *i* in class *k* and $\lambda(t)[e_i(t) - e_i^*(t)]$ is the price adjustment to vehicle *i*.

Some properties of the MDM Equations

In general, faced with a greenhouse gas emission constraint, firms will change the technological content and designs of their vehicles *and* change their prices in order to maximize profits. Under reasonable assumptions, a firm's pricing strategy turns out to be a self-applied feebate system, internal to the firm.

We start from a simplified formulation which disables the banking option and assumes a two-level nested logit model (level 1: vehicle configurations and level 2: Buy or No Buy).

$$\max \sum_t [\Delta CS(t) + S_{Buy}(t) \sum_i S_i(t)\Delta p_i(t)]$$

$$s.t. \sum_{i=1}^{N} S_i(t)(e_i(t) - e_i^*(t)) \le 0 \text{ , } \forall t$$

$$U_i(t) = A_i + B_1[c_i(e_i) + \Delta p_i], \forall i,t$$

$$S_i(t) = \frac{e^{U_i(t)}}{\sum_j e^{U_j(t)}}, \forall i, t$$

$$U_{Buy}(t) = A_{Buy}(t) + \frac{B_0}{B_1} \ln \sum_i e^{U_i(t)}$$

$$U_{No\_Buy} = 0$$

$$S_{Buy}(t) = \frac{e^{U_{Buy}(t)}}{e^{U_{Buy}(t)} + 1}$$

$$CS(t) = -\frac{1}{B_0} \ln(e^{U_{Buy}(t)} + 1)$$

where S_{Buy} is the share of households buying new vehicles; $c_i(e_i)$ is the generalized cost including technology cost, feebate and fuel savings; and other notations are the same as before.

Denote the Lagrangian multiplier associated with the first constraint of the optimization as $\gamma(t)$ and $(e_i(t) - e_i^*(t))$ as $\Delta e_i(t)$. The Lagrangian function is

$$\ell(e, \Delta p, \underset{\gamma \geq 0}{\gamma}) = \sum_t [\Delta CS(t) + S_{Buy}(t) \sum_i S_i(t) \Delta p_i(t)] - \sum_t \sum_i \gamma_t [S_i(t) \Delta e_i(t)]$$

The first order conditions are represented by the following equations (suppressing subscript *t* for simplicity)

$$\frac{\partial \ell}{\partial \Delta p_i} = B_0 S_{Buy}(1 - S_{Buy}) S_i \sum_j S_j \Delta p_j + B_1 S_i [(S_{Buy} \Delta p_i - \gamma \Delta e_i) - \sum_j S_j (S_{Buy} \Delta p_j - \gamma \Delta e_j]$$
$$= 0, \forall i$$

$$\frac{\partial \ell}{\partial \gamma} = \sum_i S_i \Delta e_i \leq 0$$

$$\gamma \geq 0$$

$$\gamma \sum_i S_i \Delta e_i = 0$$

$$\frac{\partial \ell}{\partial e_i} = S_i(-S_{Buy} \frac{\partial c_i}{\partial e_i} - \gamma) + \frac{\partial S_{Buy}}{\partial e_i} \sum_j S_j \Delta p_j + \sum_j (S_{Buy} \Delta p_j - \gamma \Delta e_j) \frac{\partial S_j}{\partial e_i} = 0, \forall i$$

From the first FO equation, we get

$$-\frac{B_0 S_{Buy}(1 - S_{Buy})}{B_1} \sum_j S_j \Delta p_j = [(S_{Buy} \Delta p_i - \gamma \Delta e_i) - \sum_j S_j (S_{Buy} \Delta p_j - \gamma \Delta e_j], \forall i$$

which implies

$$S_{Buy} \Delta p_i - \gamma \Delta e_i = S_{Buy} \Delta p_j - \gamma \Delta e_j, \forall i, j$$

and

$$\sum_j S_j \Delta p_j = 0.$$

Equations together imply that

$$\Delta p_i = \frac{\gamma}{S_{Buy}} \Delta e_i, \forall i$$

Since the last two terms in the last FO equation are equal to zero, the following equation holds

$$\frac{\partial c_i}{\partial e_i} = -\frac{\gamma}{S_{Buy}}, \forall i$$

Thus, Equation $\Delta p_i = \frac{\gamma}{S_{Buy}} \Delta e_i, \forall i$ tells us that manufacturers' optimal pricing strategy is to impose an internal feebate system in which the feebate rate is proportional to the marginal value of relaxing the emissions constraint (i.e. the shadow price of the constraint). Equation $\sum_j S_j \Delta p_j = 0.$ states that the producer surplus from pricing is zero, and equation $\frac{\partial c_i}{\partial e_i} = -\frac{\gamma}{S_{Buy}}, \forall i$ says that at the optimum, the marginal generalized cost of emission reduction is the same for all vehicles and equal to the feebate rate of the internal feebate system. Moreover the complementarity condition $\gamma \sum_i S_i \Delta e_i = 0$ implies that the internal feebate rate is zero if the emission constraint is nonbinding.

The results here are useful because they imply that we do not need to include one pricing variable for each vehicle. Instead, only one internal feebate rate per year needs to be determined. Similar derivations can be done for the more general case with a banking option and more complicated nested logit model. The major results derived here are still applicable.

8.1.3. MDM Input and Output

Data Inputs and Assumptions

The subsections below summarize required input data and their sources.

Dynamic vehicle database

ICF, International supplied a detailed database of vehicles offered for sale in the U.S. in model year 2007, their national sales volumes, their prices and technical attributes, their expected year of major redesign, and their fuel economy. Sales data for California and the Opt-in States were purchased from R.L. Polk & Co and matched to the ICF database for each vehicle configuration. The enhanced vehicle database then included complete sales data for both the national and regional markets.

There have been major changes in the structure of the automobile market since 2007 as a result of the recession of 2008-9 and a gasoline price shock in 2008. As a consequence, the UC Davis team considered it necessary to update the 2007 data in order to reflect changes in product offerings, the realignment of manufacturers, and changes in sales volumes. ICF provided data and projections of new model introductions from 2007 to 2015, along with estimated sales volumes and prices. A dynamic database was constructed reflecting these expected changes through 2015.

The dynamic database was simplified by excluding vehicle configurations either made by small manufacturers or with small sales volumes (less than 500 in 2007). Those manufacturers excluded are Fuji (includes Subaru), Mitsubishi, Suzuki, Porsche, Maserati, Aston Martin, and Ferrari, whose vehicle sales account for around 3% of the market. The database size reduction has little impact on model results, but improves the MDM's computational performance.

Technology Cost Curves

Technology cost curves were provided by ICF for each of 20 vehicle classes, in each of 3 time periods, for each of 3 technologies (gasoline, diesel, and hybrid). The coefficients of these quadratic curves and upper bounds (see Table 8.1) are direct inputs to the model.

The cost of converting a gasoline vehicle to a hybrid is also provided by ICF, and described in Section 8.1.2, Introducing Advanced Technologies.

The estimated sales of ZEVs

The sales projections of ZEVs are provided by ARB (Table 8.5). Note that our model does predict sales of conventional hybrids, so ZEV refers here to only BEV, FCV, and PHEV[26]. ZEV sales in Opt-in states (combined, including CA) are assumed to be twice the sales in CA alone (per ARB staff). ZEV sales in the rest of the country are assumed to be zero.

The tailpipe emission rates for BEVs and FCVs are assumed to be zero. The fuel economy and tailpipe emission rates for PHEVs are calculated assuming that 83% of VMT (vehicle miles traveled) is powered by fuel in 2011and 62.5% of VMT by fuel in 2030[27] (assumption is provided by ARB staff) and the data between 2011 and 2030 is obtained by interpolation.

The upstream emissions of ZEVs are not included in most of the MDM runs. However, the model is capable of including these emissions in the fleet average calculation. One case was run including upstream emissions as a sensitivity analysis.

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[26] The Air Resources Board ZEV Regulation categorizes a PHEV as an "Enhanced AT-PZEV", not a true ZEV.

[27] This corresponds to an "all electric range (AER)" of 10 miles in 2011 and 25 miles in 2030, per the correlation defined in SAE J1711 standard.

Table 8.5 estimated ZEV sales in California

	2010	2011	2012	2013	2014	2015	2016	2017
BEVs	0	5,000	2,000	2,400	2,400	9,500	9,500	9,500
FCVs	0	0	1,000	1,100	1,100	4,800	4,800	4,800
PHEVs	0	0	20,000	22,000	22,000	32,000	32,000	32,000
Annual Vehicle Sales in CA (millions)	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.6
	2018	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
BEVs	17,000	17,000	17,000	17,000	17,000	17,000	17,000	17,000
FCVs	14,000	14,000	14,000	14,000	14,000	14,000	14,000	14,000
PHEVs	35,000	35,000	35,000	35,000	35,000	35,000	35,000	35,000
Annual Vehicle Sales in CA (millions)	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7

Regulatory Standards

CAFE (2007-2011) and GHG emission (2012-2016) standards are obtained from NHTSA and EPA websites.[28] The MDM used the 2012-2016 standards in the proposed rulemaking (EPA/NHTSA, 2009) instead of the final rule because the model was developed before the standards were finalized. The proposed rulemaking is slightly different from the final standards in the specification of footprint curves and flex-fuel vehicle and air conditioning credits. But these small differences do not change the overall feebate analysis results. Post-2016 emissions standard have not been established yet. Thus, sensitivity analyses based on various assumptions on post-2016 standards were run.

The MDM assumes 15 g/mile CO2-equivalent Air Conditioning (A/C) credits per vehicle for MY 2011-2025. Based on consultation with ARB, all vehicles are assumed to take the full value of the credit in the first year they are redesigned and then continuously through MY2025. Since it takes time for all vehicles to be redesigned to take the full value of the credit, the fleet average A/C credit is less than 15 g/mile CO2-e in the early years and comparable to the estimate from EPA (see the projected A/C credit column in Table 8.6). We recognize that A/C credits may be eliminated in the

[28] Although CAFE standards will continue past 2011, the concurrent GHG standards are expected to be more stringent due to its crediting system and thus the binding case of the two.

future; however we continue them for modeling purposes to capture improvements in A/C systems that are not accounted for elsewhere.

The assumption on fleet average Flex-Fuel Vehicle (FFV) credits is from EPA's projections (as shown in the projected FFV credit column in Table 8.6).

Table 8.6 Projected A/C and FFV credits (g/mile) from EPA
Source: EPA/NHTSA, 2009, page 4951

Model year	Projected CO_2 emissions for the footprint-based standard	Projected FFV credit	Projected TLAAS credit	Projected CO_2 emissions	Projected A/C credit	Projected 2-cycle CO_2 emissions
2011	....	....	....	(325)	....	(325)
2012	295	6	0.3	302	3.1	305
2013	286	5.7	0.2	291	5.0	296
2014	276	5.4	0.2	281	7.5	289
2015	263	4.1	0.1	267	10.0	277
2016	250	0	0	250	10.6	261

Other Data

Price elasticities of different levels in the nested logit model are input to the procedure for calibration of price slopes. The specific values of price elasticities are obtained from the literature (e.g. Greene, et al. 2005).

Fuel prices are obtained from the 2009 Annual Energy Outlook (AEO), and used for calculating fuel savings.

Vehicle sales projections are also from AEO 2009, used for calibrating the Buy/No-Buy constant in the nested logit model.

Market Size is used in the consumer choice module to calculate total vehicle sales. Market size is approximated by the number of households, which is obtained from U.S. Census and American Community Survey. Total vehicle sales are equal to the product of market size and the share of households buying a new vehicle.

Model Output

The MDM produces estimates of feebate impacts on a wide array of variables at a high level of detail. Each MDM run generates an Excel file that records raw outputs for each vehicle configuration in each year, including: fuel economy, emissions rate, market share, sales, pricing adjustment, feebate value, retail price equivalent for improving fuel economy, fuel savings, and net price change. The raw outputs are then aggregated or averaged by fleet (all light duty vehicle or passenger cars/light trucks, vehicle classes), region (CA and Rest of US, or Opt-in States and Rest of US), manufacturers, and technology types (gasoline, diesel, and hybrid). Examples include fleet average emissions rates for new vehicles in CA, or the average net feebate obtained by passenger cars. Other important outputs include industry revenue by manufacturer, government revenue, consumer surplus change, and social cost of the feebate program.

The aggregate outputs for each MDM run are assembled into one Excel file and are available on the ARB website.

8.1.4. MDM Implementation

The MDM has been implemented in the GAMS[29] programming language. The code is available from the California ARB on request.

Solving the MDM

The MDM is a mixed integer nonlinear program. Experiments confirmed that, as is typical with such models, the solution found by the mixed integer solver (GAMS/SBB) is highly dependent on the starting points of binary variables $HY_i(t)$ that determine which ICE vehicles are converted to hybrids. We designed a procedure to automatically identify good starting points. The procedure compares the estimated value of each vehicle as a gasoline and as a hybrid vehicle in terms of maximizing consumer surplus subject to the emission constraint. If the value as a hybrid is larger than as a gasoline vehicle, then the initial value of $HY_i(t)$ is 1. Certainly this procedure can only estimate the value of a vehicle very roughly, since it does not have the exact knowledge of the vehicle's future fuel economy and the shadow price of the emission constraint. However, via numerical experimentation, we found that first implementing this comparison procedure and then solving the MDM generates much better solutions than solving the MDM directly.

The planning horizon is from 2007 to 2025. For policy cases that allow credit banking, the period is extended to 2030 to eliminate the effect of "cashing out" credits at the end of period. The MDM is solved in two time stages. First, it is solved for the short period of 2007 to 2010. The old definition of passenger cars and trucks in the CAFE rule (2007-2010) is used. The fuel economy ratings of vehicles in 2010 are updated and saved as output. Second, starting with these new fuel economy ratings of 2010, it is solved for the period 2011 to 2025 with the new definition[30] of passenger cars and light trucks from the new emissions standards. Note that the first stage problem only needs to be solved once and the second stage problem can then be solved for various policy cases. The reasons for dividing the problem into two time stages are:

1) Different definitions of passenger cars and light trucks are used in these two stages;
2) Manufacturers would not have been able to predict the tightened 2012-2016 CAFE/emission standards in the early years of the planning horizon. Solving the model from 2007 to 2025 assumes that manufacturers have the ability to predict future standards with perfect foresight and would potentially overestimate fuel economy improvement;

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[29] The General Algebraic Modeling System (GAMS) is a modeling system for mathematical programming and optimization. More details are available from www.gams.com.

[30] Minivans and SUVs not equipped with 4-wheel drive are defined as passenger cars in the new standard (2011-2016), instead of light trucks as in the old standard (2007-2010).

3) It saves computing time since the size of the problem is reduced by decomposition into two stages.

Revenue Neutralization Procedure

Government revenue is defined as the fees collected from high-emitting vehicles minus the rebates paid to low-emitting vehicles (including ZEVs) minus administrative costs of the program. A feasible feebate program in California requires net government revenue to be close to zero.

Government revenue is mainly determined by feebate program benchmarks. The MDM initializes benchmarks using next year's GHG emissions target based on vehicle footprints. However, pre-defined benchmarks often do not guarantee government revenue neutrality. By shifting benchmarks downwards (or upwards) uniformly, government revenue is expected to increase (or decrease). The MDM includes a revenue neutralization procedure that iterates the process of solving the MDM and adjusts benchmarks. Typically within 3 to 4 iterations the procedure finds the appropriate benchmark levels that yield revenue neutrality. Those interested in details are referred to the GAMS codes of the model.

8.1.5. RPE and Fuel Economy Comparison from Recent Studies

The tables below provide cost data from other recent studies on emissions reduction technologies. These values are not used directly in the MDM but are presented here to provide readers with additional context for evaluating the technology cost curves developed for this project.

The studies include:

- ICF, International, "Technologies to Improve Light-duty Vehicle Fuel Economy", Draft Report Prepared for National Academy of Sciences, September 2007 (ICF-2007).
- NESCCAF, "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles", September 2004; Cost Analysis Performed by MARTEC (MARTEC-2004).
- "Expert Report of Thomas C. Austin", Prepared at the Request of Counsel, Submitted to United States District Court, Eastern District of California – Fresno, May 2, 2006 (SIERRA-2006).

Table 8.7 Spark Ignition Engine Technologies

Technology	**$RPE**			**Fuel Economy Increase [%]**		
	ICF-2007*	**MARTEC-2004****	**SIERRA-2006**	**ICF-2007***	**MARTEC-2004****	**SIERRA-2006*****
DOHC Variable Valve Timing (Intake)	52 to 104	98		1.4	1.0	
Variable Valve Timing (Intake +Exhaust) DOHC	80 to 184	196		2.2	4.2	
Variable Valve Lift and Timing - Continuous (DOHC)	330 to 600 Intake	483 Intake	899 w/DCP	9.4 (CVVL+Int. VVT)		14.4

Cylinder Deactivation	215 to 310 With NVH Control	161	175	6.6	6.4 (const. perf.)	9.4
Camless Valve Actuation	650 to 900	910		13.6	19.0	
Stoichiometric Gasoline Direct Injection	160 to 285	259	337	3.5	1.0	2.0
Turbocharging	500 to 660		820	-1.0		0.3 (const. displ.)
Turbocharging with engine downsized	0 to 160	-420		7.0 (const. perf.)	8.7 (const. perf.)	
Improved Lubricating Oil	16 to 24	5 to 15		1.0	0.5	

*- ICF baseline is PFI, 4-Valve, fixed valve engine with Compression Ratio of 9.7. Unless otherwise noted, the figures are at constant displacement.
**- RPE and FE values for "Large Car" class vehicle. Unless otherwise noted, FE improvement is at constant displacement. The Martec figures are converted from fuel consumption reductions.
***- Converted from "Sierra CAFE" Fuel Consumption figures.

Table 8.8 Body and Accessory Technologies

Technology	$RPE			Fuel Economy Increase [%]		
	ICF-2007	MARTEC-2004	SIERRA-2006	ICF-2007	MARTEC-2004***	SIERRA-2006**
Weight Reduction by 5%	0.62 per pound	180 to 300		3.2	3.1	
Rolling Resistance Reduction by 10%	18 to 22	20 to 90		1.5	2.0	
Drag Reduction by 10%	23 to 33	0 to 125		2.0	2.0	
Alternator Improvements	30 to 50	56	73	0.5	1.0	1.0
Electric Accessories	45 to 55 (Water Pump)	70		0.5 (pump)	2.0	
Electric Power Steering	75 to 85	56	82	2.0	1.0	1.5

**- Converted from "Sierra CAFE" Fuel Consumption figures.
***- Martec's figures converted from fuel consumption.

Table 8.9 Transmission Technologies

Technology	$RPE			Fuel Economy Increase [%]		
	ICF-2007*	MARTEC-2004*	SIERRA-2006	ICF-2007*	MARTEC-2004*	SIERRA-2006**
Six Speed Automatic Transmissions	190 to 220	105		4.5	3.1	
Automated Manual Transmissions (6-speed)	195 to 225	0	192 vs. 5-speed	7.0	7.5	3.8 w/ASL vs. 5sp.
Continuously Variable Transmissions	225 to 400	245		7.5 (<2.8L)	3.1	
Early Torque Converter Lockup	4 to 6	0 to 10		0.5	0.5	
Aggressive Shift Logic	20 to 40	0 to 50	66	1.5	0.5 to 2.6	2.8

*- All figures compared to Four Speed Automatic.
**- Converted from "Sierra CAFE" Fuel Consumption figures.

Table 8.10 Hybrid and Diesel Technologies

Technology	$RPE			Fuel Economy Increase [%]		
	ICF-2007*	MARTEC-2004	SIERRA-2006	ICF-2007	MARTEC-2004***	SIERRA-2006**
BAS Hybrid	660 to 800			32.8 to 35.1		
IMA Hybrid	2,100 to 2,525	2,709		53.6 to 55.8	87.6	
2-Motor Hybrid	5200 in 2005 falling to 3900 by 2015 based on Toyota	5,299	5,370	65.0 to 70.1	119.3	36.1
Diesel	2,200 (I-4) to 3,200 (V-6) w/ after-treatment	1,225 for I-4 (w/o after-treatment?)	5,515 based on HD V-8?	33 to 43	28.2	n/a consumption reduction (11.1%) is on mass basis

*- For hybrids, ICF lower values represent cost reductions expected by 2015 timeframe.
**- Converted from "Sierra CAFE" Fuel Consumption figures.
***- Martec's figures converted from CO2 reduction (or fuel consumption for the diesel).

8.2. California Vehicle Market Simulation Model

CARBITS is a response model for the light-duty vehicle (LDV) market in the State of California, developed at the Institute of Transportation Studies (ITS)-University of California, Davis (UC Davis) for the use of staff at the California Air Resources Board (CARB, or, the Air Board, or, ARB).[31] CARBITS was originally developed to support policy analysis related to California's AB 1493 legislation on motor vehicle greenhouse gas emissions[32]. Since then it has been revised twice: the current version, which is the subject of this chapter, is denoted "CARBITS 3.0". The second version of CARBITS (version 2.0) was developed under a follow-up project funded by ARB, concluding in May 2009. Although CARBITS 2.0 was substantially different from CARBITS 1.0, CARBITS 3.0 is more of a direct (although non-trivial) extension of CARBITS 2.0. Specifically, both CARBITS 2.0 and 3.0 are "vehicle holdings models," whereas CARBITS 1.0 modeled the choice of vehicle transactions, and did so using pure microsimulation. Both CARBITS 1.0 and CARBITS 2.0 modeled vehicle choice in terms of vehicle classes (e.g., Subcompact Car, Midsize Car, etc.). However, CARBITS 3.0 has been extended to a much higher level of detail, modeling vehicle choices in terms of specific vehicle configurations. This feature enabled CARBITS to be combined with the Manufacturer Decision Model to comprise this project's Feebate Analysis Model.

The next section begins with an overview of how CARBITS simulates vehicle market behavior. Next, CARBITS inputs and outputs, respectively, are documented. This is followed by a discussion of the household vehicle holdings choice models that are used to simulate the vehicle market. The final three subsections give an overview of three different types of data used by CARBITS. The material is presented in an order consistent with what a reader would want or need to know about how CARBITS can be used for analysis purposes. This section focuses on model details only. For a discussion of results produced by CARBITS, see section 9.2.

8.2.1. Overview

CARBITS integrates market response and demographic sub-models to simulate the behavior of the California light-duty vehicle market over a multi-year period. Yearly results are based on simulation of household-level behavior in the personal vehicle market, which comprises the vast majority of the light-duty vehicle market in California. There are two major inputs that define a forecast scenario: a Vehicle Technology Forecast, and a Fuel Forecast. An overview of the procedure by which CARBITS 3.0 simulates vehicle market behavior can be summarized as follows:

1. For Base Year, initialize:
    a. Household database
    b. Current Market Vehicles (Vehicle Technology) and Fuel Costs
    c. Current Vehicle Counts

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[31] More accurately, CARBITS is a model of household vehicle market behavior for light-duty vehicles, a.k.a. the "personal vehicle market". Although a portion of the light-duty vehicles in California are non-personal (business, government, rental cars, etc.) for a number of practical reasons the household vehicle market is used as a proxy for the entire LDV market.

[32] The acronym CARBITS, denoting the collaboration of CARB-plus-ITS researchers, was suggested by Fereidun Feizollahi in an early planning meeting for the CARBITS 1.0 development project.

    d. Current Year = Base Year
2. Begin Loop
    a. Previous Vehicle Count = Current Vehicle Count
    b. Current Year = Current Year + 1
    c. Update Vehicle Technology and Fuel Costs
    d. Age Households
    e. Update ("age") Current Market Vehicles
        i. Introduce New Vehicles for Model Year = Current Year
        ii. Update Vehicle Characteristics (e.g., re-compute fuel operating costs using current fuel prices)
        iii. Depreciate prices for Used Vehicles
    f. Simulate Vehicle Market Behavior for Current Year using Household Vehicle Holdings Model
    g. Summarize Current Vehicle Counts, and report results.
3. Does Current Year = Final Year?
    a. If Yes, Stop
    b. If No, Go To Step 2.

Results are obtained by aggregating estimates of household-level vehicle holdings to represent the California market. CARBITS incorporates a database of households with weights that are constructed to "scale up" the database so that it represents all households in California—see later discussion. CARBITS includes a module that updates the household database at each period to simulate demographic changes over time (e.g., number of households, total population, etc.) Although it is possible that a model user might wish to explore different "demographic scenarios," it is anticipated that a built-in demographic scenario would be treated as part of the baseline set of assumptions for policy analysis (particularly since vehicle behavior depends on demographics, and not vice-versa). Similarly, details of the household behavioral models can be viewed as "hard-coded" when using the model for policy analysis, where the primary focus will be on creating model scenarios by changing inputs, and generating outputs. At the same time, CARBITS has an open implementation so that any aspect of the model can be examined if so desired. A high level description of how these models function is included here. More details are provided in later sections.

The consumer response model in CARBITS 3.0 is a household vehicle holdings choice model that was developed in accordance with discrete choice theory. Households (with varying characteristics) are assumed to choose vehicle portfolios so as to maximize the utility they derive from holding them. Utility is based on their preferences for the various vehicle types and their attributes. Specifically, this requires that all vehicles (for both the new and used vehicle markets, see below) be characterized on the basis of competing vehicle types (e.g., a 1994 gasoline-powered subcompact car), as well as generic vehicle attributes (e.g., market value/purchase price, fuel economy, performance) associated with each type. Because CARBITS addresses behavior in the used vehicle market as well as the new vehicle market, it requires historical data for those vehicles that exist in the model's base year. Forecasts of vehicle types and their attributes for *future* model years are required inputs. Note that purchase decisions by households are influenced by vehicle fuel operating costs that are in turn dependent on fuel prices, and thus CARBITS requires a set of assumptions on future fuel prices.

For purposes of analysis the emphasis is on the model inputs and outputs: these are documented in sections 8.2.2 and 8.2.3, respectively. In this regard, it is worth noting that the major difference between CARBITS 2.0 and CARBITS 3.0 is the level of detail used to characterize vehicle choices. CARBITS 2.0 followed the typical practice in the literature of defining household choice in terms of *vehicle classes* (e.g., subcompact car, minivan, SUV), based on the conventional wisdom that a higher level of detail is precluded by the computational challenges associated with the large numbers of vehicle choice options that would be generated. However, a special method was developed for CARBITS 3.0 that allows it to handle vehicle alternatives at a much higher level of detail, i.e., at the level of individual vehicle configurations. CARBITS 3.0 is based on using vehicle configurations that can generally be characterized as follows:

Model Year
Manufacturer
Division (Make)
Model Name
Engine Characteristics (e.g., type, size)
Transmission
Drivetrain
Body type and size

For purposes of choice modeling, vehicle configurations at this level of detail will exhibit variation for the following key generic attributes that are considered to play a role in vehicle choice[33]:

Vehicle Body Type and Size (e.g., Compact Car, Minivan, Small SUV)
Prestige level
Fuel economy (Combined MPG)
Performance (estimated 0-60 time)
Purchase Price

In CARBITS, households are assumed to choose how many and which vehicles to own based on these specific attributes (not physical characteristics such as engine type, horsepower, curb weight, etc.). In addition, household preferences are assumed to differ based on demographic variables such as income and household size. Generally speaking, CARBITS 3.0 integrates market response and demographic sub-models to produce results for the period 2001-2025. More specific details on the implementation are:

1. The behavioral models in CARBITS are estimated for a base year of 2001 using data from the 2000-2001 Caltrans Statewide Travel Survey of households. The behavioral models consist of discrete choice models of household vehicle holdings behavior: Choice of how many vehicles to hold (0, 1, or 2-plus), and which ones. For example, a 2-vehicle household might choose a vehicle portfolio consisting of a 1991 Toyota Corolla and a 1999 Ford Explorer. (However, specific make and model names are not used to

[33] This is the level of detail that corresponds to the vehicle configurations produced by the MDM. For model estimation purposes, vehicle configurations at the same general level of detail were constructed using a combination of data from Chrome and the EPA Fuel Economy Guide—see section 8.2.8.

determine vehicle choice. Rather, households are assumed to make their choices based on the generic attributes listed above.)

2. CARBITS is then subjected to calibration, in which certain constants are adjusted so that vehicle fleet totals match data from external sources (e.g., vehicle counts from the DMV). A calibration is performed first for the original base year of 2001. Then the model is run for the period 2001 to 2006 and additional calibration constants are estimated using additional external vehicle count data.

3. Beginning in 2007, vehicle technology input to CARBITS comes from the so-called "CAFE Model" portion of the Manufacturer Decision Model (MDM). The database of vehicle offerings in the MDM is dynamically modified during the period 2008-2013 to reflect short-term expected changes in the automobile industry. The MDM is used to produce a calibration scenario based a reference case defined using data the EIA Annual Energy Outlook (AEO)—see, e.g., sections 7.2 and 8.1.2. The MDM is run using CAFE standards through 2010, and then switches to the proposed standards starting in 2011. Accordingly, CARBITS is run for the period 2008-2010 so that the base year is moved again to 2010. Finally, some additional calibration constants are computed to match expected new vehicle sales from the AEO scenario in 2013.

4. Subsequent CARBITS runs for the period 2011-2025 are performed to provide scenario analyses using MDM results as inputs.

5. Although the MDM specifically models the new vehicle market, CARBITS models both the new and used vehicle markets and how they evolve over time. Moreover, the behavioral models incorporate multiple household demographics (e.g., income, household size, number of workers). Additional output formats have been developed to examine the impact of policies by household income group.

A few additional remarks on the behavioral models are in order. To review: the choice models in CARBITS are a function of vehicle attributes and demographic effects. Specifically, CARBITS is a bottom-up choice model based on preferences for generic vehicle attributes (e.g., purchase price, vehicle class, fuel operating cost, performance, etc.) as demonstrated by observed vehicle holdings of households in the Caltrans data. In contrast, the MDM uses alternative-specific constants at the individual vehicle configuration level that have been calibrated using aggregate vehicle sales data. The fact that these two models use different methodologies has implications for the results they produce. This is discussed in section 9.2.

Finally, note that, although CARBITS *in theory* produces vehicle counts for individual vehicle configurations, it would be imprudent (with respect to both CARBITS and the MDM) to regard these counts as actual forecasts. It is appropriate to look at *aggregated* results as a measure of overall market response, and to regard individual, detailed vehicle counts to be a type of "microsimulation" that, when aggregated, captures the overall net effect of changes to individual vehicle prices, fuel economy, etc., on the market.

With this as background, the following sections provide additional details to give a more complete picture of CARBITS. Sections 8.2.2 and 8.2.3 address inputs and outputs, respectively. Section 8.2.4 discusses the household vehicle holding models. Section 8.2.5 reviews issues related to calibration data.

8.2.2. CARBITS Inputs

As described in the background, CARBITS assumes that households make decisions based on the type of vehicle as well as generic vehicle attributes associated with individual vehicle configurations. For purposes of characterizing vehicle types, we have defined an attribute denoted "Vehicle Class," which incorporates important aspects of vehicle market structure, including the body type, size, and prestige level of vehicles. The vehicle classes that provide the framework for choice modeling are given in Table 8.11. It also reports the number of vehicle configurations for the 2007 base year, and the estimated sales and market shares in California for the MDM base year of 2007 (based on data from R. L. Polk).

Table 8.11 Feebate Vehicle Classes and Estimated California Sales (2007, R. L. Polk)

	Vehicle Class	**No. Configs**	**Est. CA Sales**	**Est. CA Share**
1	Prestige Two-Seater	14	5,804	0.3
2	Prestige Subcompact	43	48,858	2.9
3	Prestige Compact and Small Station Wagon	52	64,714	3.8
4	Prestige Midsize Car and Station Wagon	58	95,513	5.6
5	Prestige Large	23	28,575	1.7
6	Two-Seater	23	11,726	0.7
7	Subcompact	35	138,541	8.1
8	Compact and Small Station Wagon	52	179,652	10.6
9	Midsize Car and Station Wagon	70	329,454	19.4
10	Large Car	36	75,227	4.4
11	Prestige Small SUV	22	47,904	2.8
12	Prestige Midsize SUV	21	34,210	2.0
13	Prestige Large SUV	5	17,228	1.0
14	Small SUV	97	175,314	10.3
15	Midsize SUV	65	89,642	5.3
16	Large SUV	26	75,122	4.4
17	Minivan	20	61,594	3.6
18	LargeVan	4	2,053	0.1
19	Pickup Small	37	58,232	3.4
20	Pickup Standard	115	162,219	9.5
	Total	**818**	**1,701,582**	**100.0**

These vehicle classes represent the bottom level of an assumed multi-level market structure that is also used in the MDM nested logit model. For a depiction of vehicle market structure using these classes, see Figure 8.7. The first level is Passenger versus Cargo vehicles. Under Passenger there are six levels: Two-Seaters, Prestige Cars, Standard Cars, Prestige SUVs, Standard SUVs, and Minivans. Two-Seaters are sub-divided into Prestige and Non-Prestige. The four Car and SUV categories are sub-divided by size. (Minivan is not further divided). Cargo vehicles are sub-divided into Cargo Vans and Pickups; Pickups are further sub-divided by size (Small and Standard).

The classes in Table 8.11 generally represent the level of detail at which the CARBITS choice models capture preference effects for body type, size, and prestige. However, as noted previously, the MDM yields 800+ individual vehicle configurations for each year starting in 2007. The characteristics of the 800+ vehicle configurations in each model year (starting in 2007) are based on data from ICF International. The specific attributes required by the CARBITS choice models are: Purchase price ($), combined MPG, and 0-60 time (in seconds). It is important to note that the Feebate Analysis Model assumes that performance characteristics do not change; however, purchase price and MPG *will* change due to redesign decisions by manufacturers simulated by the MDM. In other applications of CARBITS the user may decide to change performance characteristics as part of the scenario development.

As noted in the background, CARBITS requires an annual forecast of fuel prices. Although the MDM includes flex-fuel and diesel vehicles and incorporates prices on ethanol and diesel fuel, CARBITS does not[34]. CARBITS uses the same fuel cost projections for gasoline as the MDM, i.e., those that come from EIA's AEO—see section 7.2.

8.2.3. Model Outputs

As noted in the background, it is not advisable to consider vehicle counts at the level of individual vehicle configurations. In previous versions of CARBITS, we have generally summarized vehicle counts at a much lower level of detail. Two obvious choices are: Passenger Cars versus Light-Duty Trucks. However, one standardized CARBITS output format gives total vehicle counts by model year broken down by a variable denoted "BT4": Car, Pickup, Van, SUV—See Table 8.12.

[34] The numbers of these vehicles are very small, and appear to have an insignificant effect on the final results.

Table 8.12 Sample CARBITS Output using Four Body type-Sizes [Four CARBITS Classes, Annual Counts of Vehicles on the Road]

FCYear	AllVeh	Cars	Trucks	Vans	SUVs
2004	23039374	15390098	3385432	2455664	1808179
2005	23731740	15783068	3507329	2580425	1860918
2006	24359200	16150641	3596104	2681942	1930513
2007	25154870	16653900	3683631	2808588	2008755
2008	26047296	17251932	3818199	2945990	2031173
2009	26884112	17756372	3932128	3105164	2090449
2010	27642724	18203548	4075275	3225496	2138403
2011	28297172	18621700	4206884	3304601	2163990
2012	29125002	19199146	4285089	3409314	2231454
2013	29761244	19684490	4347592	3448613	2280546
2014	30679916	20266228	4561024	3528705	2323960
2015	31793626	20960806	4702259	3683397	2447164

Another possible set of vehicle classes is used by EMFAC. See Table 8.13 for the definition of EMFAC classes. Table 8.14 gives an example of an output format broken down by both forecast year and vehicle age.

Table 8.13 EMFAC2000 Vehicle Classes

Class	Code	Description	Weight (lbs.)
1	PC	Passenger cars	ALL
2	T1	Light-duty trucks	0 - 3,750 LVW
3	T2	Light-duty trucks	3,751 - 5,750 LVW
4	T3	Medium-duty trucks	5,751 - 8,500 LVW
5	T4	Light-heavy duty trucks	8,501 - 10,000 GVW
6	T5	Light-heavy duty trucks	10,001 - 14,000 GVW
7	T6	Medium-heavy duty trucks	14,001 – 33,000 GVW
8	T7	Heavy-heavy duty trucks	33,001 – 60,000 GVW
9	OB	Other Buses	ALL
10	UB	Urban buses	ALL
11	MC	Motorcycles	ALL
12	SB	School buses	ALL
13	MH	Motor homes	ALL

Table 8.14 CARBITS Output [Four EMFAC Classes, 20 Age Groups (excerpt for 2005)]

FCYear	AgeGroup	Decript	All	Cars	T1	T2	T3
2005	0	New	1556545	1050636	239948	194537	71424
2005	1	1 yr old	1553604	1022105	263532	200468	67499
2005	2	2 yrs old	1674123	1103494	285943	208816	75869
2005	3	3 yrs old	1610459	1108016	236062	190579	75802
2005	4	4 yrs old	1471974	969189	258970	180336	63480
2005	5	5 yrs old	1362158	941695	183980	171861	64622
2005	6	6 yrs old	1305967	879218	204353	159887	62509
2005	7	7 yrs old	1204081	795651	172452	171199	64778
2005	8	8 yrs old	1282777	874800	181658	163837	62483
2005	9	9 yrs old	1144256	721638	178221	174711	69685
2005	10	10 yrs old	1250502	813134	215157	148621	73590
2005	11	11 yrs old	1049107	656518	182611	136936	73041
2005	12	12 yrs old	897564	623556	117716	106760	49531
2005	13	13 yrs old	672144	437514	104183	92264	38182
2005	14	14 yrs old	722676	476900	102135	92622	51019
2005	15	15 yrs old	711710	469094	109913	87704	44999
2005	16	16 yrs old	711341	500913	92435	78588	39405
2005	17	17 yrs old	701479	447475	87640	109741	56623
2005	18	18 yrs old	620727	417072	83700	80955	39000
2005	19	19 yrs old	570627	393900	77851	68418	30457
2005	20	20 yrs old	1552193	1080551	187974	174423	109244

It would also be possible to produce results broken down according to the 20 vehicle classes in Table 8.11. However, this is a relatively large number of classes to examine. One potentially useful market segmentation definition (denoted “BTS7") is given in Table 8.15. This set of categories represents a clustering of the original 20 classes, and captures some key aspects of preference observed in the market.

Table 8.15 Body-Type-Size Classes (7 Categories) – BTS7

1	Small Car (Includes 2-Seaters)
2	Midsize/Large Car
3	Prestige Small Car
4	Prestige Midsize/Large Car
5	Pickup
6	Van
7	SUV

8.2.4. Output Using Household Demographics

CARBITS 3.0 uses a base year of 2001 to coincide with data collected in the 2000-2001 California Statewide Travel Survey. Data from this survey are used for estimating vehice choice models, but are also the source of the household database used to represent the California personal vehicle market. For more on this data set, see section 8.2.6. In this section we focus on those details that support discussion of the types of policy analyses that can be performed.

In theory, the types of analyses that are possible is determined by the level of demographic detail used in the vehicle choice models. CARBITS households are primarily characterized on three dimensions: Household Size, Number of Workers, and Household Income Category (in 2001 dollars). In addition, the current version of CARBITS keeps track of which of the original households owned more than two vehicles.[35] The categories used are given in the Table 8.16.[36]

Table 8.16 Demographic Variables and Levels in CARBITS 3.0

Household Income	Number of Workers	Household Size	Vehicle Holdings
<$10K	0	1	0-9
$10-25K	1	2	
$25-50K	2	3	
$50-75K	3 or more	4	
>= $75K		5 or more	
[Missing]			

[35] This information is currently being used by the model to generate a “correction factor” for reweighting households with 3, 4, etc., vehicles when the two-vehicle conditional choice model is used.

[36] In order to avoid losing households for the choice model estimations due to missing income, models were estimated including an interaction between vehicle purchase price and “Missing” in the utility function. Subsequently, a re-weighted household database excluding {?? Why are you excluding if you are trying to avoid losing households with missing income?}} households with missing income was developed to use in the market simulation.

The full factorial of the above categories from the Caltrans survey (excluding the "missing" income category—see Footnote) yields 675 combinations. Not only would it be impractical to create cross-tabbed results for all of these combinations, it is actually unnecessary because the vehicle choice models do not use this full level of detail. All income levels have been interacted with vehicle purchase price in some portions of the model. Dummy variables such as "three-or-more household members," or "two-or-more workers" are used to capture relevant demographic effects in various sub-models for, e.g., preference of vehicle body type and size—see section 8.2.4. This effectively reduces the number of household types to 65, a fact that has been exploited to gain computational efficiency in both model estimation and market simulation. For additional information regarding the distribution of these variables in the Caltrans Survey, see section 8.2.6.

In the current version of CARBITS, we have added code to collect more detailed results by demographic group, indexed by the variable "hhType," which varies from 1 to 65. Results are stored during a model run, and can then be imported into SPSS for further analysis. Excerpts illustrating CARBITS demographic household-related variables as seen in SPSS output are given in Tables 8.17 and 8.18. Table 8.18 is the same as Table 8.17, but with the "Value Labels" feature turned on.

Table 8.17 Household Variables in CARBITS SPSS Output (Numeric) [Excerpt]

calendarYear	hhType	inCat6	hhSize4plus	nWork3plus	hhWeight
2010	1	1	1	1	463330.4
2010	2	1	1	2	79658.3
2010	3	1	2	1	91247.1
2010	4	1	2	2	76943

Table 8.18 Household Variables in CARBITS SPSS Output (Value Labels) [Excerpt]

calendarYear	hhType	inCat6	hhSize4plus	nWork3plus	hhWeight
2010	1	<$10K	1	No Workers	463330.4
2010	2	<$10K	1	1 Worker	79658.3
2010	3	<$10K	2	No Workers	91247.1
2010	4	<$10K	2	1 Worker	76943

An important variable is hhWeight. Results from each household type must be weighted by this value to produce numbers that represent the California personal vehicle market. In CARBITS, the definition of the household types stays the same throughout a model run, but the household weights are updated for each year to reflect demographic changes over time.

There are many possible ways to aggregate results. In what follows, we briefly describe some current formats that are being used. The first format (HHOutput1) focuses on high-level statistics aggregated over the variables calendarYear and hhType. Using this format, results can be further aggregated by, e.g., income (inCat6) or household size (hhSize4plus). A key feature of CARBITS is that it functions as a vehicle holdings model whose structure can be viewed as a tree—see section 8.2.4. At the top level is the decision of how many vehicles to hold. The options in the current version of CARBITS are: 0, 1, and 2-plus. HHOutput1 reports the probability of each of these states. Additional statistics are reported in Table 8.19. Note that, in this format, each household type has one record per calendar year. Aggregate statistics are provided on a "total expected value" basis for each household type.

The statistics of most obvious interest to the current study relate to rebates and fees. HHOutput1 reports the expected number of rebates, the expected (dollar) value of rebates, the expected number of fees, and the expected (dollar) value of fees on a per-household basis. Recall that values for *all* households of a given household type are computed by multiplying the per-household values by the household weight.

Table 8.19 HHOutput1 Output Format Variable Definitions

Variable Name	**Variable Label**
calendarYear	Calendar Year
hhType	Unique index of Household Type
inCat6	Total HH Income - 6 Categories
hhSize4plus	Number of HH Members
nWork3plus	Number of Workers
hhWeight	Household Weight
probZeroVeh	Prob(Zero Vehicle HH)
probOneVeh	Prob(One Vehicle HH)
probTwoPlusVeh	Prob(Two-plus Vehicle HH)
expNumVeh	Exp Number of Held Vehicles
expValueVeh	Exp Dollar Value of Held Vehicles
avePriceOneVeh	Exp Dollar Value of Vehicle held by 1-Veh HH
expValueTwoVeh	Exp Value of Vehicles held by 2+ Veh HH
expNumNewVeh	Exp Number of New Vehicles in HH
expNewOneVeh	Prob(New Vehicle) in a 1-Veh HH
expNewTwoPlusVeh	Exp Num of New Vehicles in 2+ Veh HH
expValueNewVeh	Exp Dollar Value of New Vehicles (in HH holding vehicles)
avePriceNewOneVeh	Ave Value of New Vehicle held by 1-Veh HH
aveValueNewTwoPlusVeh	Ave Value of New Vehicle held by 2+ Veh HH
probRebate	Total Prob HH Receives a Rebate

probRebateOne	Prob of Rebate in 1-Veh HH
probRebateTwoPlus	(Total) Prob of Rebate in 2+ Veh HH
expRebateDollars	Total Exp Value of Rebate Dollars
aveRebateDollarsOne	Ave Rebate Dollars in 1-Veh HH
aveRebateDollarsTwoPlus	Ave Rebate Dollars in 2+ Veh HH
probFee	Total Prob HH Receives a Fee
probFeeOne	Prob of Fee in 1-Veh HH
probFeeTwoPlus	(Total) Prob of Fee in 2+ Veh HH
expFeeDollars	Total Exp Value of Fee Dollars
aveFeeDollarsOne	Ave Fee Dollars in 1-Veh HH
aveFeeDollarsTwoPlus	Ave Dollars in 2+ Veh HH
aveMPG	Ave MPG of Held Vehicles (given vehicles are held)
aveMPGOneVeh	Ave Value of MPG in 1-Veh HH
aveMPGTwoPlusVeh	Ave Value of MPG in 2+ Veh HH
aveMPGNew	Ave Value NewVeh MPG (given New Vehicles are held)
aveMPGNewOneVeh	Ave Value of NewVeh MPG in 1-Veh HH
aveMPGNewTwoPlusVeh	Ave Value of NewVeh MPG in 2plus-Veh HH
aveGPMNew	Ave Value of New Vehicle Grams Per Mile (GPM)
aveGPMNewOneVeh	Ave Value of NewVeh GPM in 1-Veh HH
aveGPMNewTwoPlusVeh	Ave Value of NewVeh GPM in 2plus-Veh HH
expNumNewHybridVeh	Expected Number of New Hybrid Electric Vehicles
expNewHybridOneVeh	Expected Number of New Hybrids in 1-Veh HH
expNewHybridTwoPlusVeh	Expected Number of New Hybrids in 2-Veh HH
expConsumerSurplus	Exp Value of Consumer Surplus
aveConsumerSurplus	Ave Value of CS per household

There are some features of these statistics that could benefit from additional discussion. For example, consider the "expected (dollar) value of (held) vehicles," and the various related conditional statistics that have been reported for one- and two-plus vehicle households. There are some subtleties to consider. First, there is a non-zero probability that a household will hold *no* vehicles. The total expected dollar value includes the effect of this probability. For a one-vehicle household, we can report the "average vehicle price," which is the same as the expected value of held vehicles, because of the conditioning of being a one-vehicle household. (They are one and the same.) However, for two-plus vehicle households we elect to report the expected value of the *total* vehicle portfolio, rather than the average price per vehicle. This enables the analyst to consider the value of the entire vehicle portfolio, if desired. (The average price can be obtained by dividing by two.)

However, consider the case of *new* vehicles. Similar to the statistics for all vehicles, we report the (total) probability of owning a new vehicle, and the (total) expected dollar value of new vehicles held by the household type. In this case, a one-vehicle household may or may not hold a new vehicle, and a two-plus vehicle household might own zero, one, or two new vehicles. For these cases we have elected to report the "average (dollar) value of a new vehicle" for both one and two-plus vehicle households, conditional on the purchase of one (or more) new vehicles. For the case of two-plus vehicle households, the total expected dollar value of (all) held new vehicles is obtained by multiplying this value times the expected number of new vehicles. For the case of MPG, average figures are reported for both the case of all held vehicles, and for new vehicles. Finally, we have included a calculation of consumer surplus (CS). The expected value of consumer surplus for all households, and also the average value of consumer surplus per household are computed.

As noted, HHOutput1 gives summary statistics for each household type in each year. HHOutput2 expands the level of detail to include the 20 feebate vehicle classes from Table 8.11. Specifically, there are 20 records per household type per year. The statistics in this format are for *new* vehicles sold in each year. The information provided is similar to HHOutput1, broken out by vehicle class. See Table 8.20. Note that the variable BTS7 (see Table 8.15) is also included to facilitate aggregation of results using this variable.

Finally, HHOutput3 expands the level of detail to include used as well as new vehicles. The format currently reports results by Vintage Group rather than by individual model year (although this could be changed if necessary). See Table 8.21. This file gives information on the distribution of vehicles by vehicle count and expected dollar value, as well as information about the average MPG of held vehicles by household type.

Table 8.20 HHOutput2 Format Variable Definitions

Variable Name	**Variable Label**
calendarYear	Calendar Year
hhType	Unique index of Household Type
inCat6	Total HH Income - 6 Categories
hhSize4plus	Number of HH Members
nWork3plus	Number of Workers
hhWeight	Household Weight
FBClass	Feebate Study Vehicle Class (20 levels)
BTS7	Bodytype-Size 7 Category
expNumNewVeh	Exp Number of New Vehicles in HH
expNewOneVeh	Prob(New Vehicle) in a 1-Veh HH
expNewTwoPlusVeh	Exp Num of New Vehicles in 2+ Veh HH

expValueNewVeh	Exp Dollar Value of New Vehicles
avePriceNewOneVeh	Ave Value of New Vehicle held by 1-Veh HH
aveValueNewTwoPlusVeh	Ave Value of New Vehicle held by 2+ Veh HH
probRebate	Total Prob HH Receives a Rebate
probRebateOne	Prob of Rebate in 1-Veh HH
probRebateTwoPlus	(Total) Prob of Rebate in 2+ Veh HH
expRebateDollars	Total Exp Value of Rebate Dollars
expRebateDollarsOne	Exp Value Rebate Dollars in 1-Veh HH
expRebateDollarsTwoPlus	Exp Value Rebate Dollars in 2+ Veh HH
probFee	Total Prob HH Receives a Fee
probFeeOne	Prob of Fee in 1-Veh HH
probFeeTwoPlus	(Total) Prob of Fee in 2+ Veh HH
expFeeDollars	Total Exp Value of Fee Dollars
expFeeDollarsOne	Exp Value Fee Dollars in 1-Veh HH
expFeeDollarsTwoPlus	Exp Value Dollars in 2+ Veh HH
aveMPGNew	Ave Value NewVeh MPG
aveMPGNewOneVeh	Ave Value of NewVeh MPG in 1-Veh HH
aveMPGNewTwoPlusVeh	Ave Value of NewVeh MPG in 2plus-Veh HH

Table 8.21 HHOutput3 Format Variable Definitions

Variable Name	**Variable Label**
[calendarYear, hhType, inCat6, hhSize4plus, nWork3plus, hhWeight]	
VintageGroup	Vintage Group (5 levels)
FBClass	Feebate Study Vehicle Class (20 levels)
BTS7	Bodytype-Size 7 Category
expNumVeh	Exp Num of Vehicles in HH
expNumOneVeh	Exp Num in 1 Veh HH
expNumTwoPlusVeh	Exp Num in 2+ Veh HH
expValueVeh	Exp Dollar Value in HH
expValueOneVeh	Exp Dollar Value in 1 Veh HH
expValueTwoPlusVeh	Exp Dollar Value in 2+ Veh HH
aveMPG	Ave MPG of Held Vehicles

aveMPGOneVeh	Ave Value of MPG in 1-Veh HH
aveMPGTwoPlusVeh	Ave Value of MPG in 2+ Veh HH

8.2.5. Household Vehicle Holdings Choice Models for CARBITS 3.0

This section discusses the vehicle holdings models estimated for CARBITS 3.0 using the Caltrans Travel Survey Data. The models are of the conditional-multinomial-logit/nested-multinomial-logit type similar to those that have appeared elsewhere in the literature. A full discussion is beyond the scope of this report, but relevant references include Train (1986), Berkovec (1985), Hensher, et al. (1992), and Bunch and Chen (2008).

As noted in the background, a complete vehicles holdings choice model includes both the choice of *how many* vehicles to own, and *which* vehicle(s). One model form that has been applied in these settings is the nested logit model. The top level has "branches" that correspond to the decision of how many vehicles to own (0, 1, 2, etc.). Under each (non-zero) branch are the options for vehicle portfolios that a household may choose to own. A typical nested logit model structure for vehicle holdings is illustrated in Figure 8.8.[37]

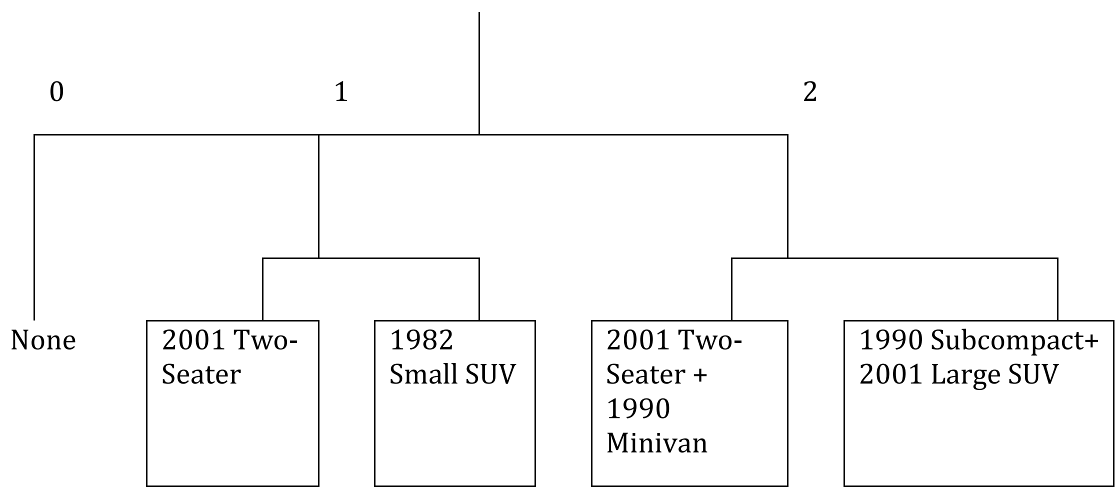

Figure 8.8 Nested-logit Structure for a Vehicle Holdings Model

One decision required when developing a holdings model is how large the maximum vehicle portfolio size should be. Most models in the literature (e.g., Train 1986) stop with vehicle pairs, as depicted in Figure 8.8. A few references estimate models for three-vehicle households (e.g., Berkovec 1985). A practical issue is that the number of possible vehicle portfolios increases dramatically when the portfolio size increases. As an example, consider a model that uses 350 vehicle classes to represent the combined new and used vehicle market. A one-vehicle household

[37] The figure includes only a few branches for illustrative purposes. The full tree would contain a very large number of branches.

therefore has 350 options to choose from. A two-vehicle household could theoretically hold one of the possible pairs that can be constructed from the 350 vehicle classes, yielding 350*351/2 = 61,425 portfolio options. There are over 7 million possible vehicle portfolios of size 3. Even if the model is limited to pairs, some type of sampling procedure has typically been employed to construct choice sets with a smaller number of options.

However, as previously noted, we have developed a procedure that allows us to handle large numbers of alternatives; specifically, we have developed a method that allows us to compute probabilities using all possible pairs of vehicle configurations. At this time we forgo consideration of triples, and follow the typical practice of estimating holdings models with 0, 1, and 2 vehicles. When simulating market behavior, a weighting procedure is employed so that the 2-vehicle model is used to represent the vehicle choices of households with more than two vehicles.[38]

A main modeling concern is capturing the interaction effects that would be expected to occur when a household decides to hold more than one vehicle. Some combinations are more attractive than others, e.g., households frequently hold more than one body type so that their fleet can be used for multiple purposes. In such cases, there is a parameter in the utility function representing the positive interaction between two body types. If it were possible to ignore such interactions, then the joint probability of holding a portfolio of two vehicles *i* and *j* could be simply written as $P_{ij} = P_i * P_j$, i.e., the probabilities could be treated as independent, and this could be exploited to make model estimation more computationally tractable. (For example, Berkovec 1985 ignores all such interaction effects, which allowed him to estimate models for 1, 2, and 3 vehicle households.) For now, we proceed to discuss model specifications that include interaction effects without considering the computational issues.

In a nested logit model, the "utility" of how many vehicles to own (one or two) is a function of the "expected maximum utility" conditional on the quantity choice. Consider the case of the choice of a vehicle configuration, conditional on the assumption that one vehicle is being chosen. A household (*n*) will choose to hold one of the *J* vehicles that are available. Using a multinomial logit model (MNL), household *n*'s choice probability for vehicle *c* is given by

$$P_{cn,1} = \frac{e^{V_{cn}}}{\sum_{j=1}^{J} e^{Vjn}}$$

where V_{jn} is household *n*'s preference (or utility) index for vehicle *j*. The preference function V_{jn} is typically given by the linear-in-parameters form

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[38] The vehicle count from the original household database is maintained in the simulation and this information is used for re-weighting. For example, a three-vehicle household is weighted by a factor of 3/2 when the two-vehicle choice model is used.

$$V_{jn} = \sum_{k=1}^{K} \beta_k Z_{k,jn}$$

where Z_{jn} is a vector of explanatory variables for vehicle j and household n, and β is a vector of parameters to be estimated. When choosing *whether* to own one or two vehicles, the expected maximum utility from the decision to purchase one of the J vehicles is given by the so-called Inclusive Value (IV):

$$IV_{n1} = \ln \sum_{j=1}^{J} e^{Vjn}.$$

An analogous expression can be derived for the conditional two-vehicle choice model. These inclusive values and some additional factors (e.g., household income, size, etc.) would be expected to determine the probability of choosing one versus two vehicles. The vehicle quantity choice model (conditional on the one- and two-vehicle models) for household n can be written as

$$Q_{nm} = \frac{e^{W_{nm}}}{e^{W_{n0}} + e^{W_{n1}} + e^{W_{n2}}} = \frac{e^{W_{nm}}}{1 + e^{W_{n1}} + e^{W_{n2}}}$$

where Q_{nm} is the probability that household n holds m vehicles, W_{n0}, W_{n1} and W_{n2} are the preference functions for holding 0, 1, and 2 vehicles, respectively, and in this model the utility of holding zero vehicles has been normalized to zero, i.e., $W_{n0} = 0$. The utilities W_{n1} and W_{n2} each would include terms for their respective inclusive values as explanatory variables, as well as other factors (e.g., number of workers, household size). The full, unconditional model obtained from combining the above sub-models could be directly estimated; however, this can be difficult, and a typical practice is to perform sequential estimation by first estimating the conditional one- and two-vehicle choice models, and then use the results to estimate the vehicle-quantity choice model.

This approach has been used to estimate household-level vehicle holdings choice models for the Caltrans data. Earlier versions of CARBITS were limited to conditional MNL models. In CARBITS 3.0 we have introduced extensions so that the conditional vehicle choice models are nested multinomial logit models that take into account some market structure—see discussion below. More details on model results are discussed next.

a) Explanatory Variables

As noted, the vector Z_{jn} contains explanatory variables that are a function of vehicle attributes for vehicle *j* and household demographics from household *n*. Also, the vector W_{nj} makes use of demographic variables. Explanatory variables based on household demographics used in various sub-models are:

1. Household income categories
    a. Income < $10K
    b. $10K ≤ Income < $25K
    c. $25K ≤ Income < $50K
    d. $50K ≤ Income < $75K
    e. Income ≥ $75K
    f. Income < $75K
2. Household size
    a. Household Size > 3
    b. Household Size ≤ 3
    c. Household Size > 2
    d. Household Size ≤ 2

Vehicle attributes include:

1. Dummy variables for Body-Type-Size classes
    a. TwoSeater [Car]
    b. Small [Car]
    c. Midsize [Car]
    d. Large [Car]
    e. Truck [Pickup]
    f. Van
    g. SUV
    h. LargeSUV
    i. SmallSUV
2. Prestige Dummy variable
3. Price (vehicle market price, in year-2001 $)
4. OpCost (fuel operating cost, in cents per mile)
5. Accel (acceleration time, seconds for 0-60 mph)
6. Vehicle Age

Vehicle attributes were chosen based a number of factors, including the literature and past experience, and numerical testing. Price, fuel operating cost, and acceleration cover three very important aspects of vehicle choice that are included in essentially all (household-level) choice models found in the literature. There are a number of possible measures of performance that could be used (e.g., top speed, horsepower, horsepower to weight ratio, etc.). We chose to use acceleration time because it is a measure that consumers can relate to in terms of their direct experience (in contrast to the engineering characteristics).[39] This measure is frequently used in choice experiments in which respondents are asked to indicate their most preferred alternative. Using acceleration time as the performance measure therefore keeps open the possibility of updating these choice models using stated choice data should the possibility arise. The other important dimension of vehicle functionality and size is captured relatively well by the dummy variables related to vehicle class. In addition to directly using the variables listed above as explanatory variables, variables for interactions are also constructed to capture other preference-related effects (e.g., interaction of income category with Price, and interaction of household-size dummy variables with different body-type-size dummy variables)—see the discussion in the next sections.

b) Conditional One-Vehicle Choice Models

Consider the case of a Caltrans Household that has already decided to hold one vehicle. A (conditional) one-vehicle-household choice model can be estimated using the sample of one-vehicle households from the survey. The complicating factor in this work is the large number of vehicle configurations. For the base year of 2001, the Vehicle Technology File used for estimation contains 6,509 vehicle configurations covering the years 1985-2001 (or about 380 vehicles per year on average). Estimation of MNL models with a choice set size of 6,509 are not routinely done, and particularly not in standard statistical packages. To estimate a MNL model, we used two approaches: (1) a commercially-available statistical package (Stata) using choice sets of sampled alternatives, and (2) a special-purpose routine coded in MATLAB and Fortran using the full choice set of 6,509. Results of the two estimations are provided in Table 8.22.

MNL Estimation using Stata with Sampled Alternatives (One-Vehicle Choice)

Choice sets were generated using a stratified random sampling approach discussed in McFadden (1978). Strata were defined using the original 20 vehicle classes in Table 8.11. Each choice set contained one new vehicle from each class, one vehicle 1-6 years old from each class, and one vehicle 7 years or older from each class. Simple multiplication would suggest 3 vintage groups x 20 classes = 60 possible combinations. However, the total choice set size was 57 vehicles rather than 60 because three vehicle classes did not exist in the oldest vintage category. To make the estimation consistent, an "offset" variable containing the log of the number of vehicle configurations in the class was added to the preference index—see McFadden (1978). A weighted estimation was performed using household weights from the Caltrans survey. Estimates were obtained by using the Stata command 'clogit'.

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[39] Estimates of 0-60 mph acceleration time were computed using the following relationship obtained from the US Environmental Protection Agency (2007):

$$t = F(HP / WT)^{-f}$$

where *HP* is horsepower, *WT* is curb weight, and the values used for *F* and *f* are 0.892 and 0.805 for vehicles with automatic transmissions, and 0.967 and 0.775 for vehicles with manual transmissions, respectively.

The sign of the coefficient for Price/Ln(Inc) is negative (conforming with theory) and is similar in magnitude to estimates we have seen elsewhere in the literature. For purposes of comparison, we have included the coefficient adjusted by the log of representative values for the five income groups used in the model. A separate coefficient is estimated for households with missing income, so that these observations are not lost to the analysis. The signs for the two key generic attributes, OpCost and Accel, are both negative as would be expected. With regard to Vehicle Age, we estimated separate coefficients for Cars and Trucks: both are negative, as expected. The coefficient VehAge_Cars is larger in magnitude that VehAge_Trucks, which is consistent with the empirical fact that cars loose their value more quickly than trucks. This is likely to be due in part to the fact that they accumulate miles more quickly.

The remaining coefficients involve vehicle-type dummy variables. In this model, the base alternative is (non-prestige) compact car, which has a coefficient of zero by definition. From a behavioral perspective, the most interesting cases are those with an interaction between a vehicle type and a household characteristic. In these cases the signs of the coefficients conform to expectations. For example, consider the interaction between Van and household size (dummies for > 3 or <=3). The interactions with these household size dummies are positive and negative, respectively. In other words, larger households prefer vans all else equal. Similarly, households with 2 or fewer members have a stronger preference for pickup trucks than do larger households. There are also interaction effects with household income using a higher income group (>$75K), and a lower income group (<=$75K). The interaction between Prestige and higher income is positive, and the interaction between Prestige and lower income is negative. Similarly, the interaction with SUV is positive and negative for higher and lower income groups, respectively, consistent with a stronger preference for SUVs by higher income groups.

MNL with Full Choice Sets (One-Vehicle Choice)

Estimation results for MNL using the special-purpose computer code are also provided in Table 8.22. By and large, the results are fairly similar to the Stata results, particularly with respect to sign. The Price/Ln(Income) coefficient is a bit more negative, and there is some movement with the vehicle-type dummy variables. However, again, the results are quite similar. We regard the stratification scheme we used to be a good one, and were careful to include the offset variable prescribed by McFadden (1978). Moreover, we used a sample size of 57 when a typical value in the literature might be 15. So, these results might not be surprising. Having said this, this is the first case we are aware of where it was possible to compute results with such large choice sets so that a direct comparison was even possible.

Table 8.22 Coefficient Estimates for One-Vehicle Choice Models

		Stata with random CS		MNL with full CS		NMNL with full CS	
		Coeff	**t-stat**	**Coeff**	**t-stat**	**Coeff**	**t-stat**
Price(000)/Ln(Inc)		-0.3224	-11.77	-0.4551	-515.45	-0.3414	-224.72
Coeff/ln(7.5)		-0.1600		-0.2259		-0.1694	
Coeff/ln(17.5)		-0.1126		-0.1590		-0.1193	
Coeff/ln(37)		-0.0893		-0.1260		-0.0945	
Coeff/ln(62.5)		-0.0780		-0.1101		-0.0826	
Coeff/ln(130)		-0.0662		-0.0935		-0.0701	
Price_Missing_Income		-0.0771	-6.56	-0.1257	-327.77	-0.0917	-194.26
OpCost		-0.2475	-6.99	-0.2322	-323.25	-0.1745	-196.25
Accel		-0.1382	-7.55	-0.1385	-287.76	-0.1036	-188.10
Prestige_GT75		0.5110	2.79	0.2381	53.00	-0.2048	-30.46
Prestige_LE75		-0.6933	-6.36	-0.5676	-157.73	-1.0563	-158.61
Car_GT3		-0.1786	-0.67	-0.1490	-27.62	-0.1425	-26.41
TwoSeater		-0.9996	-3.14	-1.0527	-117.29	-0.7745	-102.95
TwoSGT2		-0.4907	-0.47	-0.4758	-24.22	-0.3502	-23.82
PresTwoSeat		0.4558	0.55	0.4450	17.39	0.1907	9.99
Subcompact		-0.2461	-3.02	-0.2660	-146.48	-0.1985	-126.30
Midsize		0.1622	2.39	0.2641	137.68	0.0331	10.03
Large		-0.1692	-1.38	0.0314	9.13	-0.1528	-43.90
PrestigeLCar		0.9832	4.93	1.1047	181.31	0.9673	177.55
Truck_GT2		-0.1956	-0.72	-0.1684	-29.34	-0.5679	-77.01
Truck_LE2		0.2021	1.16	0.2309	63.51	-0.1717	-29.68
Van_GT3		1.2413	4.05	1.3147	193.85	0.8259	91.91
Van_LE3		-0.3265	-1.71	-0.2875	-65.36	-0.7806	-110.30
SUV_GT75		0.9587	3.86	0.5033	85.25	0.0480	6.17
SUV_LE75		0.0951	0.51	0.1182	25.78	-0.3804	-52.18
LargeSUV		0.5702	2.31	0.3987	58.89	0.2965	57.90
SmallSUV		-0.7955	-4.44	-0.9086	-181.23	-0.6712	-144.59

New		-0.3963	-3.4	-0.0961	-26.99	-0.8239	-85.10
VehAge_Car		-0.1385	-13.97	-0.1802	-580.76	-0.1340	-224.54
VehAge_Truck		-0.0975	-6.89	-0.1386	-364.10	-0.1034	-205.52
OneYearOld		-0.1028	-1.03	0.0825	29.00	0.0622	29.17
μ						1.3443	61.75

Nested Multinomial Model Estimates (One-Vehicle Choice)

For disaggregated, bottom-up models of this type researchers have typically been satisfied with using the MNL functional form due to the capability of complex preference functions to directly capture various effects attributable to heterogeneity. At the same time, with this large number of vehicle configurations assigned to classes we might expect the bottom level of the "tree" to exhibit properties similar to those of a nested logit model. For this reason, we extended our special-purpose code to include a single nesting parameter to capture the effects of substitutability among similar vehicles according to some general groupings. The groupings are based on the seven body-type and size classes listed in Table 8.15. We defined separate groupings for new and used vehicles, for a total of fourteen groups (e.g., New Small Car, Used Small Car, New Midsize/Large Car, Used Midsize/Large Car, etc.). Although there are many possible formulas that could be used, the nested logit probability is given by

$$P_c = P_{c|g(c)} P_{g(c)} = \frac{e^{\mu_{g(c)} V_c}}{\sum_{j \in g(c)} e^{\mu_{g(c)} V_j}} \frac{e^{\frac{1}{\mu_{g(c)}} IV_{g(c)}}}{\sum_{g=1}^{G} e^{\frac{1}{\mu_g} IV_g}}$$

where the household subscript *n* has been suppressed, *g(c)* denotes the group that vehicle *c* belongs to, m_g is a structural parameter (a scale parameter) associated with group *g*, and IV_g is the inclusive value for group *g* given by

$$IV_g = \ln \sum_{j \in g} e^{\mu_g V_j} .$$

It is readily shown that when $\mu_g = 1$ for all g the expression reduces to multinomial logit. Although it would be possible to estimate a separate μ_g for each group, we estimated a single $\mu = \mu_g$ for all g as has been done elsewhere in the literature. Extending the MNL with this single parameter allows the model to capture the effect of unobserved correlations in preference among vehicles of similar types, i.e., vehicles within the same group.

Our special-purpose MNL code was extended to include the structural parameter μ. For results, see Table 8.22. On one hand, the coefficient estimates appear similar to the MNL estimates in most cases. On the other hand, the estimate for μ is 1.34, indicating the existence of a certain amount of correlation within groups of similar vehicles. In terms of estimates, it is interesting to note that the Price/Ln(Income) coefficient for the NMNL results appears closer to the Stata results than to the MNL full-choice-set results. On the other hand, it can be tricky to make such comparisons between MNL and NMNL models. For example, the coefficients for OpCost and Accel are noticeably smaller in the NMNL results; however, their *ratio* is similar to those in the MNL estimates, indicating that the actual tradeoff between the two attributes is similar. And, if one multiplies the NMNL coefficients for Price/Ln(Income), OpCost, and Accel by 1.34, the results are similar to those obtained for the MNL model with full choice sets. Note: An analysis using the Price/Ln(Inc) and OpCost coefficients from the NMNL model reveals that these coefficients are generally consistent with behavior in which consumers value fuel savings over the lifetime of a vehicle that has been purchased new. This is a notable difference from the assumption used by the Manufacturer Decision Model. For a discussion of this issue, see section 9.2.

c) Conditional Two-Vehicle Choice Models

Starting from first principles, it is challenging to say what the functional form of a preference function should look like for the case of choosing a portfolio of two vehicles. However, there is a substantial historical literature on this problem. The general practice is to simply sum the attributes of both vehicles, and use preference functions similar to those for one-vehicle choice. For example, we use the following: the sum of vehicle prices, the sum of fuel operating cost, the sum of acceleration times, the sum of vehicle age, the number of vehicles that are new, and the number of two-seaters.

However, there are also interaction terms, as discussed previously. For our models, we use dummy variables to identify specific combinations of vehicle types. For example, in a two-vehicle household it might be more desirable to have one small car and one midsize/large car than to have either two small cars or two midsize/large cars (all else equal). It is also possible to interact these dummy variables with demographic variables. For example, a Car-Van dummy variable can be interacted with dummy variables that indicate if the household size is greater than or equal to three, or less than three, respectively.

Finally, a major challenge is addressing the huge number of possible vehicle *combinations* from which to choose. As in the case of one-vehicle choice models, one approach to model estimation is to generate choice sets by random sampling of alternatives. In addition, as has been stated, we have developed a new way to compute the complete set of choice probabilities for all possible pairs. Finally, we have also extended the formulation to a simple nested logit model with a single structural parameter μ.

MNL Estimation using Stata with Sampled Alternatives (Two-Vehicle)

As in the one-vehicle case, choice sets were sampled using strata based on the fourteen vehicle groups discussed previously for the one-vehicle nested logit model. There were three different types of vehicle pairs: new-new, new-used, and used-used. Using the seven body-type size classes from Table 8.15, there are 7*8/2 = 28 possible combinations of new-new, 7*7 = 49 possible combinations of new-used, and 28 possible combinations of used-used, giving a total of 105 vehicle pair combinations. Vehicle profiles were randomly sampled from within these strata. As in the one-vehicle case, an offset variable for the log of the total number of vehicle combinations was included.

For coefficient estimates, see Table 8.23. Generally, the pattern of results for the two-vehicle model is similar to those of the one-vehicle model, with the signs of the coefficient generally conforming to expectations. However, recall that the two-vehicle model uses the sum of attributes over both vehicles for generic variables, e.g., Price, OpCost, and Accel. The coefficients for these attributes are systematically smaller than in the one-vehicle case, perhaps reflecting the fact that these attribute sums are systematically larger. In considering the ratio of coefficients OpCost/PriceLn(Inc), it would appear that two-vehicle households have a higher willingness to pay for fuel savings than do one-vehicle households. The same can be said for performance (as measured by Acceleration). The coefficient on TotalAge of the vehicle fleet is negative, as expected. Interestingly, the coefficient for HasNew is positive in this model; however, it is not statistically significant at the 10% level.[40]

Table 8.23 Coefficient Estimates for Two-Vehicle Choice Models

	Stata with random CS		MNL with full CS		NMNL with full CS	
	Coeff	t-stat	Coeff	t-stat	Coeff	t-stat
Price(000/Ln(Income)	-0.1980	-12.36	-0.2520	-466.32	-0.1770	-373.47
Coeff/ln(7.5)	-0.0983		-0.1250		-0.0878	
Coeff/ln(17.5)	-0.0692		-0.0880		-0.0618	
Coeff/ln(37)	-0.0548		-0.0698		-0.0490	
Coeff/ln(62.5)	-0.0479		-0.0609		-0.0428	
Coeff/ln(130)	-0.0407		-0.0518		-0.0364	
Price_Missing_Income	-0.0287	-4.41	-0.0397	-210.75	-0.0291	-196.87
OpCost	-0.1846	-10.34	-0.1714	-411.21	-0.1193	-348.17
Accel	-0.1317	-11.62	-0.1266	-373.90	-0.0853	-310.66
SmallSmall_GT3	-0.5124	-3.08	-0.1981	-52.28	-0.0307	-8.05
SmallSmall_LE3	-0.1462	-1.60	0.1388	58.22	0.3127	127.90
MidL_MidL	-0.0063	-0.06	0.0266	4.42	-0.0392	-6.51
HasPrestigeCar_GT75	0.7179	7.93	0.6227	238.82	0.1220	37.61
HasPrestigeCar_LE75	-0.5313	-5.38	-0.6579	-208.59	-1.1718	-322.62
Car_Truck	1.2753	14.43	1.0451	432.49	0.8410	339.81
MidL_Truck	0.4161	5.03	0.4722	174.57	0.2082	73.03
PrestigeCar_Truck_GT75	-0.7534	-3.63	-0.6075	-100.53	-0.5867	-97.01
PrestigeCar_Tr_LE75	-0.3345	-1.90	-0.1748	-27.56	-0.1654	-26.07
Car_Van_GT3	1.9553	15.97	1.7623	600.76	1.3624	431.95
Car_Van_LE3	0.8036	7.52	0.5779	189.53	0.1776	53.95
Car_SUV	0.6760	6.18	0.4064	138.71	0.1602	53.78

[40] For the two-vehicle model, HasNew is a dummy variable indicating that either one or both of the vehicles are new, i.e., a model year 2001 vehicle.

Car_SUV_GT75	0.7840	6.11	0.8690	260.39	0.8714	261.00
Truck_SUV	2.1990	17.50	1.8948	518.37	1.1692	272.82
Van_SUV	1.7984	9.15	1.5056	337.04	0.6736	127.59
TruckVan_GT3	3.1935	17.88	2.9474	683.53	2.0700	396.53
TruckVan_LE3	1.8214	11.45	1.5368	291.02	0.6550	108.94
Van_Van	1.1554	3.96	1.4630	205.48	0.2596	31.43
SUV_SUV	1.0637	5.69	1.2296	217.61	0.3513	56.47
Truck_Truck	1.1689	5.73	1.4855	277.89	0.4907	78.05
HasNew	0.2396	1.64	-0.4597	-216.30	-1.2221	-347.23
TotalAge	-0.1057	-18.55	-0.1345	-705.25	-0.0891	-429.31
numTwoSeater	-0.5047	-3.00	-0.5420	-106.99	-0.3296	-97.82
numTwoSeater_GT3	-1.9169	-3.28	-1.7619	-97.55	-1.1255	-93.97
μ					1.5357	184.53

In contrast to the one vehicle model (which uses separate variables for, e.g., Subcompact, Midsize, etc.), this model's preference function specification relies primarily on the seven body-type size variables (Small Car, Midsize/Large Car, Pickup, Van, SUV). For example, the classes Two-seater, Subcompact and Compact have been combined into "Small" (but note that the model retains Two-seater dummy variables). The model includes many dummy variables to represent the interaction effect of different combinations of vehicle types, where the base alternative is the combination of a Small car and a Midsize/Large car. Note that the coefficients for Small-Small and MidL-MidL are both negative, and that most of the other interactions (e.g., Car-Truck, Car-Van, Car-SUV) are positive. As in previous results in the literature, multi-vehicle households reveal a preference for a more diverse set of body types. As in the one-vehicle model, we include some interactions with household characteristics. Higher income households (>$75K) have a positive interaction with "HasPrestigeCar", and lower income households (<=$75K) have a negative interaction. However, higher income households are less likely to hold a combination of Prestige vehicle and Truck. The number of two-seater vehicles (numTwoSeat) has a negative coefficient, with an additional large negative coefficient for households with more than 3 members. Two-seaters generally have a low market share, but larger households are even less likely to hold two-seaters. Coefficients for the Car-Van and Truck-Van interactions are larger for households with more than 3 members than they are for households with fewer than three members. This indicates that a two-vehicle household with more members prefers that one vehicle have a larger carrying capacity (e.g., a minivan).

MNL with Full Choice Sets (Two-Vehicle)

As has been discussed, estimating two-vehicle choice models using all possible vehicle pairs has been considered computationally intractable in the past, but we have developed expressions for doing so. Because many readers may not be interested in the details, we have put the technical material on this procedure into a later section, and devote this section to reviewing the model estimates themselves.

For numerical results using all possible pairs, see Table 8.23. Results for the sampled approach versus the full-choice-set approach exhibit a pattern similar to those for the one-vehicle case. The Price/Ln(Income) coefficient is more negative than in the sampled-alternative model, and at the same time the coefficient for OpCost gets slightly smaller in magnitude, yielding a smaller willingness-to-pay for fuel savings. As before there are essentially no sign changes, except for one notable case: HasNew. The HasNew coefficient is clearly negative in the full-choice-set case. This is perhaps to be expected, because there are many more used vehicles than there are new vehicles, and every possible combination of new and used vehicles is enumerated in this approach. The portfolios that include a new vehicle are greatly outnumbered by the remaining combinations, making each a relatively rare event, which yields a negative coefficient. More generally, the sampled approach has a specific structure associated with it, so that alternative specific constants related to vehicle pair types would be expected to be different for the two methods.

Nested Logit Extension with Full Choice Sets (Two-Vehicle)
As for the MNL case, the mathematical expressions for computing the choice probabilities are given in a later section, and we consider here the estimation results themselves. Similar to the one-vehicle case, it can be a bit difficult to compare estimates from MNL and NL models. The NL model has an estimated scale parameter μ of 1.54 versus a value of $\mu = 1$ for MNL. The value is greater than one, which is required by theory for a valid random utility model, and is larger than the 1.34 value obtained in the one-vehicle case. This is consistent with the idea that there is correlation in preference within the vehicle-pair type branches of the tree, and would be expected to have an effect on the price elasticities. As before, multiplying the coefficients of the generic attributes by the scale value 1.54 yields values that are generally similar to the MNL estimates. Most of the variation in the results occurs for the interaction terms, which could yield slightly different results in a market simulation.

d) Vehicle Quantity Choice Model

For CARBITS 3.0, we adopted the nested logit models estimated in the preceding section for one- and two-vehicle choice, respectively. These models were used to compute the inclusive values used as explanatory variables in the estimation of the vehicle quantity choice model. Additional explanatory variables for the quantity choice model are number of workers, log(household size), log (household income), and alternative-specific dummy variables for the choice of one or two vehicles, respectively. For log (household income), we used representative values for each household income category. As in other models in the literature, these variables were interacted with the one- and two-vehicle dummy variables.

When estimating these models, it became clear that there was a great deal of multicollinearity. To obtain stable estimates, we elected to use the inclusive value as an offset variable in the logit model, effectively assuming a coefficient of one. This is equivalent to assuming an MNL structure with respect to the choices in the lower level in the tree. In theory, the inclusive value is already in "utility units," so this was seen as a way to set the utility scale for the model and get stable estimates for the remaining coefficients. For estimation results obtained using Stata, see Table 8.24. Using this approach yielded a pseudo-R-square of 0.7, which is very high for a model of this type.

The coefficient values are generally what would be expected from theory and are also quite similar to those obtained in Train (1986). Specifically, the coefficients are larger for the two-vehicle interactions than for the one-vehicle interactions. The interpretation is that, if the number of workers increases, or if the household size increases, or if the household income increases, then the relative effect is for the household to shift in the direction of being a two-vehicle household versus a one- or zero-vehicle household.

Table 8.24 Vehicle Quantity Choice Model Estimate

```
Conditional (fixed-effects) logistic regression   Number of obs   =        516
                                                  Wald chi2(8)    =     507.32
                                                  Prob > chi2     =     0.0000
Log pseudolikelihood = -7300763.4                 Pseudo R2       =     0.7031

                                   (Std. Err. adjusted for clustering on csid)
------------------------------------------------------------------------------
             |               Robust
         yij |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     worker1 |   .4651225   .4215828     1.10   0.270    -.3611645     1.29141
     worker2 |   .7726623   .4506047     1.71   0.086    -.1105067    1.655831
   lnhhsize1 |  -.1242468   .6257556    -0.20   0.843    -1.350705    1.102212
   lnhhsize2 |   1.333451   .6102389     2.19   0.029     .1374045    2.529497
   logHHInc1 |   .6678058   .3999111     1.67   0.095    -.1160054    1.451617
   logHHinc2 |    1.51105   .4195262     3.60   0.000     .6887943    2.333307
 one vehicle |  -3.795556   1.484421    -2.56   0.011    -6.704967   -.8861447
two vehicles |  -12.47154   1.616541    -7.71   0.000     -15.6399   -9.303173
        incv |   (offset)
------------------------------------------------------------------------------
```

e) Efficient Computation of MNL and NL Choice Probabilities for All Vehicle Pairs

In this section, we develop notation and derive procedures for performing efficient computation of MNL and NL choice probabilities for all possible vehicle pairs. To begin, note that the preference functions used in the earlier section on estimation results is generally composed of two types of terms: terms based on sums of attributes, and terms based on interactions between vehicle types. It turns out that this specific type of structure can be exploited to develop expressions for efficient computation of choice probabilities for all possible vehicle pairs. This is most easily illustrated using a specific example; however, the notation and expressions developed for this example can be used more generally.

MNL Model with All Possible Pairs

Consider the case where there are two types (or groups) of vehicles: cars and trucks, denoted by C, and T, respectively. Let g denote a function that yields the set of all possible vehicles in a group, e.g., suppose there are two available vehicles that are cars (c_1 and c_2) so that $g(C) = \{c_1, c_2\}$. Assume that $|g|$ denotes the size of the set, so that $|g(C)| = 2$. In this example we will also assume that there are two trucks (t_1 and t_2), so that $|g(T)| = 2$. Finally, let G denote the set of *all* vehicles obtained by taking the union of $g(C)$ and $g(T)$, i.e., $g(G) = \{c_1, c_2, t_1, t_2\}$.

Next, let p denote a function that yields all possible (unique) pairs created from two groups of vehicles, so that: $p(CC) = \{c_1c_1, c_1c_2, c_2c_2\}$, $p(CT) = \{c_1t_1, c_2t_1, c_1t_2, c_2t_2\}$, and $p(TT) = \{t_1t_1, t_1t_2, t_2t_2\}$ in our example. As a check, note there are four vehicles in all (two cars and two trucks), and 4*5/2 = 10 possible pairs. Let P denote the set of all possible pairs by taking the union of $p(CC)$, $p(CT)$, and $p(TT)$ [or, equivalently, $p(GG)$].

To define preference functions, let V_{ij} denote the utility of the vehicle pair *ij*. For this example assume that there are two attributes: vehicle acquisition cost (*a*) in $, and fuel operating cost (*f*) in cents per mile. The linear-in-parameters utility function for the vehicle pair c_1t_1 is given by

$$V_{c_1t_1} = \beta_a(a_{c_1} + a_{t_1}) + \beta_f(f_{c_1} + f_{t_1}) + V^{CT}$$

where, b_a and b_f denote parameters for *a* and *f*, respectively, and V^{CT} denotes the interaction term associated with a vehicle pair consisting of one car and one truck. As in our earlier discussion, the preference function uses the sum of the attributes from the two vehicles. This special structure allows *V* to be re-written as

$$\begin{aligned} V_{c_1t_1} &= \beta_a(a_{c_1} + a_{t_1}) + \beta_f(f_{c_1} + f_{t_1}) + V^{CT} \\ &= (\beta_a a_{c_1} + \beta_f f_{c_1}) + (\beta_a a_{t_1} + \beta_f f_{t_1}) + V^{CT} \\ &= V_{c_1} + V_{t_1} + V^{CT} \end{aligned}$$

where V_i denotes the utility function expression for the one-vehicle case.

Using this notation, the MNL choice probability for the vehicle pair c_1t_1 is given by

$$P_{c_1t_1} = \frac{e^{V_{c_1t_1}}}{\sum_{p \in P} e^{V_p}}$$

where *p* denotes an individual vehicle pair, and computing the denominator requires the evaluation, exponentiation, and summation of V_{ij} terms over all possible pairs. In what follows, we show that this calculation can be made much more efficient.

First, consider the fact that the choice probability for P_{ij} can be written as

$P_{ij} = P[ij|g(i)g(j)]P[g(i)g(j)]$,

where *P[ij|g(i)g(j)]* is the conditional probability of choosing *ij*, given that a pair of the type *g(i)g(j)* has been chosen, and *P[g(i)g(j)]* is the unconditional probability that a pair of the type *g(i)g(j)* is chosen. For the pair c_1t_1 this can be written as

$$
\begin{aligned}
P_{c_1t_1} &= P(c_1t_1 \mid CT)P(CT) \\
&= \frac{e^{V_{c_1t_1}}}{\sum_{p\in p(CT)} e^{V_p}} P(CT) \\
&= \frac{e^{V_{c_1}+V_{t_1}+V^{CT}}}{\sum_{c\in g(C)}\sum_{t\in g(T)} e^{V_c+V_t+V^{CT}}} P(CT) \\
&= \frac{e^{V^{CT}} e^{V_{c_1}} e^{V_{t_1}}}{e^{V^{CT}} \sum_{c\in g(C)} e^{V_c} \sum_{t\in g(T)} e^{V_t}} P(CT) \\
&= \frac{e^{V_{c_1}}}{\sum_{c\in g(C)} e^{V_c}} \frac{e^{V_{t_1}}}{\sum_{t\in g(T)} e^{V_t}} P(CT) \\
&= P_{c_1} P_{t_1} P(CT)
\end{aligned}
$$

where P_i denotes the MNL probability expression for the one-vehicle case. Now, consider an expression for *P(CT)*:

$$
P(CT) = \frac{\sum_{p\in p(CT)} e^{V_p}}{\sum_{p\in p(CC)} e^{V_p} + \sum_{p\in p(CT)} e^{V_p} + \sum_{p\in p(TT)} e^{V_p}}.
$$

Let

$$
S_g = \sum_{j\in g} e^{V_j}
$$

for group g. We have already seen that

$$
\sum_{p\in p(CT)} e^{V_p} = e^{V^{CT}} \sum_{c\in g(C)} e^{V_c} \sum_{t\in g(T)} e^{V_t} = e^{V^{CT}} S_C S_T.
$$

Now consider the case where both vehicles are from the same group, e.g., two cars. It can be shown that

$$
\sum_{p\in p(CC)} e^{V_p} = e^{V^{CC}} \frac{1}{2}\left[\left(\sum_{c\in g(C)} e^{V_c} \right)^2 + \sum_{c\in g(C)} e^{2V_c} \right] = e^{V^{CC}} \frac{1}{2}\left[S_C^2 + \sum_{c\in g(C)} e^{2V_c} \right].
$$

Defining D_p by

$$D_{p(g_1 g_2)} = S_{g_1} S_{g_2}, \text{ if } g_1 \neq g_2$$
$$= \frac{1}{2}\left[S_g^{\ 2} + \sum_{j \in g} e^{2V_j} \right], \text{ if g} = g_1 = g_2$$

it is easy to show that, e.g., for the case of one car and one truck, the probability *P(CT)* is given by

$$P(CT) = \frac{e^{V_{CT}} D_{p(CT)}}{e^{V_{CC}} D_{p(CC)} + e^{V_{CT}} D_{p(CT)} + e^{V_{TT}} D_{p(TT)}}.$$

Essentially the same formula is used for the other body type combinations. Because the quantities S_g and D_p are easily computed, these probability expressions are computationally tractable even for a relatively large number of groups.

However, there is another aspect of the model to be exploited for computational efficiency purposes. Specifically, the preference functions consist of two types of terms: those with household interaction effects, and those without. The portions of the preference function values that do not involve household interactions can be computed one time and stored. Then, calculations can proceed on the basis of unique household types that have, e.g., the same income and household size. The incremental values for the interaction terms can be computed one time per unique household type and combined with the pre-stored values. For example, in the context of model estimation calculations would not be unnecessarily repeated for each household in a data set. Rather, calculations are performed one time for each unique combination of household characteristics in the data set and are applied to the appropriate households.

Nested Multinomial Model Extension for All Possible Pairs

The reader may have noted some similarities between the structure used for the efficient calculation of MNL probabilities and the structure of nested logit. In fact, the MNL expressions can be extended to the case of a simple nested logit for two-vehicle choice, similar to the NL model previously discussed for the one-vehicle case. Specifically, we consider the case where each node in the tree defined by a vehicle-pair type has a scale value *m* associated with it. It is important to note that, in this model, all nodes share the same scale value *m*. This represents a modeling assumption that vehicle portfolios *within* a vehicle-pair type have similar patterns of substitutability. It would be possible to consider the case where each node has a unique scale value, e.g., $m_{p(g1g2)}$; however, this yields a model that is more complex and requires more computation to implement.

Using the notation developed in the previous section, a choice probability expression for this nested logit model is

$$P_{ij} = \frac{e^{\mu(V_i + V_j + V^{g(i)g(j)})}}{\sum_{kl \in p[g(i)g(j)]} e^{\mu(V_k + V_l + V^{g(i)g(j)})}} \frac{\exp\left[\frac{1}{\mu} \ln e^{\mu V^{g(i)g(j)}} D_{p[g(i)g(j)]}\right]}{\sum_{p \in P} \exp\left[\frac{1}{\mu} \ln e^{\mu V^{p}} D_p\right]}$$

where the previous definitions of S_g and D_p and have been extended as follows:

$$S_g = \sum_{i \in g} e^{\mu V_i}$$

and

$$\begin{aligned} D_{p(g_1 g_2)} &= S_{g_1} S_{g_2}, \text{ for } g_1 \neq g_2 \\ &= \frac{1}{2}\left[S_g + \sum_{j \in g} e^{2\mu V_j} \right], \text{ for } g = g_1 = g_2. \end{aligned}$$

When performing model estimation, these expressions can be efficiently coded and used so as to avoid needless repetition, as previously discussed. However, we have not yet discussed the complicating factor that arises when performing market simulation: It is still prohibitive to explicitly compute individual choice probabilities for all possible pairs. The efficiency comes in noting that the researcher is not really interested in these probabilities per se', rather, the goal is to compute the total demand (a.k.a. total choice probability) for each individual vehicle configuration. Specifically, we are interested in computing

$$P(i) = \sum_{p \in p(i)} P(i \mid p) P(p)$$

where *p(i)* denotes the collection of group pairs where at least one of the groups contains *i*, *P(i|p)* is the probability that *i* is chosen given that group pair *p* is chosen, and *P(p)* is the probability that group pair *p* is chosen. Also, as a convention, we assume that the pairs enumerated in *p(i)* are ordered so that the first group (denoted g_1) always contains *i*. In other words,

$$p(i) = \{\forall g_1 g_2 \in P \ni i \in g_1\}.$$

To begin, note that the probability P_{ij} can be written as

$$P_{ij} = \frac{e^{\mu V_i} e^{\mu V_j}}{D_{p[g(i)g(j)]}} \frac{\exp\left[\frac{1}{\mu} \ln e^{\mu V^{g(i)g(j)}} D_{p[g(i)g(j)]}\right]}{D} = e^{\mu V_i} e^{\mu V_j} F_{p[g(i)g(j)]}$$

where

$$D = \sum_{p \in P} \exp\left[\frac{1}{\mu} \ln e^{\mu V^p} D_p\right]$$

and

$$F_p = \frac{\exp\left[\frac{1}{\mu} \ln e^{\mu V_p} D_p\right]}{D_p D}.$$

Using this notation, it can be shown that

$$P(i \mid p) = \sum_{j \in g_2(p)} \frac{e^{\mu V_i} e^{\mu V_j}}{D_p} = \frac{e^{\mu V_i} S_{g_{2(p)}}}{D_p}$$

and

$$P(i) = e^{\mu V_i} \sum_{p \in p(i)} S_{g_2(p)} F_p$$

where $g_2(p)$ denotes the second group in the pair p. This simple expression is quite efficient to compute, because values for S_g, D_p, D, and F_p can be computed one time and stored for repeated use. Moreover, the summation term in the expression immediately above only needs to be computed one time for each group g_1, and can be reused when computing *P(i)* for individual *i*'s.

8.2.6. Calibration Data

The models estimated in Section 8.2.4 are based on a specific sample of survey respondents, i.e., from the Caltrans 2000-2001 Travel Survey. These household-level data are useful for identifying important behavioral effects when individual households make vehicle purchases. However, the sample sizes and time-frames associated with survey data are not condusive to providing an accurate measure of *aggregate-level market statistics* (e.g., new vehicle sales of various vehicle types) that can be important when performing policy analysis. To address this issue, models estimated using survey data are typically *calibrated* so that they match aggregate-level statistics from other data sources. For example, in the case of CARBITS it would be desirable for the market demand model to "simulate" new vehicle sales in the base year that match actual vehicle sales at a particular point in time. Moreover, because CARBITS also models the used vehicle market, it would be desirable to match vehicle count distributions by model year as well.

The primary source of calibration data for CARBITS is DMV registrations data that have been processed by a group at the ARB for use in their EMFAC model. The DMV has been producing regular biannual data "dumps" of all registrations for quite a number of years. Each data dump can be thought of as a snapshot of vehicle registrations at a particular point in time. The snapshots generally occur in October and April of each year. These can be used in conjunction with each other to clean data records, e.g., to identify vehicles that have been temporarily unregistered. A complete discussion of the cleaning process for these data is beyond the scope of this document.

a) Total Vehicle Counts

In what follows, we look at registration data from October 2001. October is an attractive month to consider because, by this time of the year, most sales of new vehicles with the *model* year corresponding to the current *calendar* year have occurred. For example, by October 2001 most sales of new 2001 model year vehicles would have occurred. In addition, some sales of new model year 2002 vehicles will have also occurred. However, in the DMV data there are relatively few of these vehicles, and our current practice is to drop them. For an illustration using the October 2001 DMV/EMFAC snapshot see Figure 8.9, which also includes a vehicle profile from the Caltrans Survey data for comparison purposes.

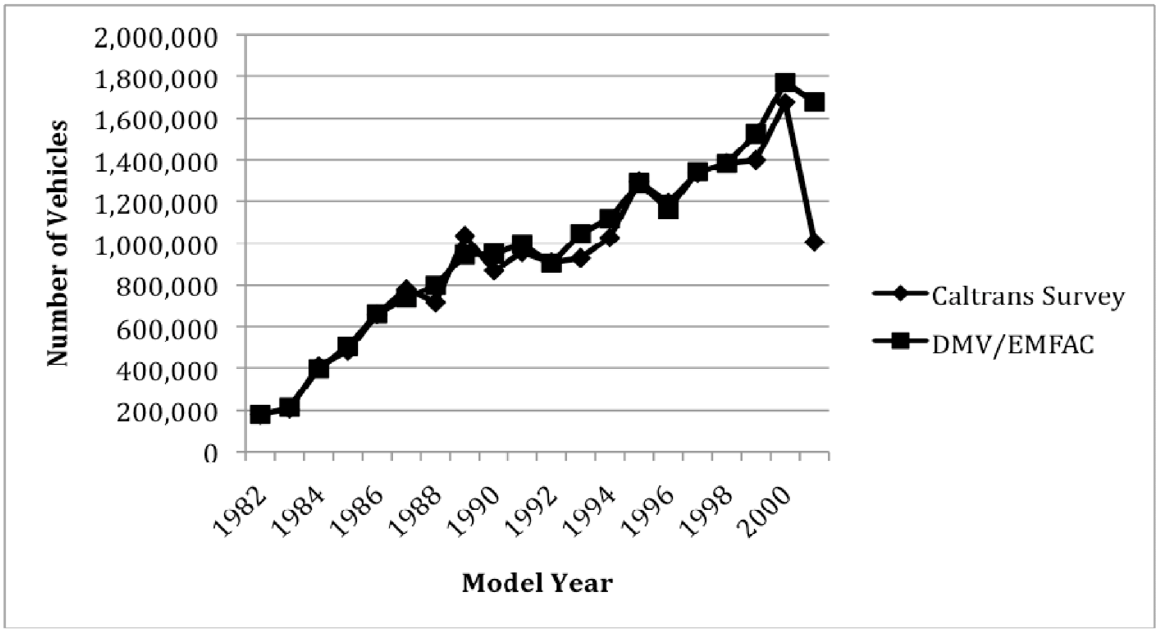

Figure 8.9 Model Year Distributions for DMV/EMFAC vs. Caltrans Travel Survey

First, consider the DMV/EMFAC profile. The data in Figure 8.9 are generally limited to light-duty vehicles, and the vehicle total for model years 1982-2001 is approximately 19.6 million. A few features of this figure are noteworthy. During this period there were economic recessions in 1980-1982, 1990-1991, and 2001-2003, with periods of steady growth in between. The downturns in Figure 8.9 generally correspond to these periods. Although the drop in vehicle registrations for 2001 could be due in part to the recession, we have determined there is a lag effect due to as-yet-unregistered 2001 model year vehicles that is also a factor (see discussion below).

For comparison, consider the profile computed from the Caltrans Travel Survey. These data were collected over the entire period from October 2000 to December 2001, and the sample was weighted to match Census data so that 21.4 million vehicles are "available to households". The number of light-duty vehicles with model years 1982-2001 using this weighted sample is estimated to be 18.5 M versus the 19.6M for the DMV/EMFAC snapshot. Based on our past experience in comparing such distributions across different data sources, these are reasonably close. However, the figure for DMV/EMFAC could be a bit larger due to the inclusion of non-personal LDV's.

The DMV/EMFAC curve is smoother than the Caltrans curve, as might be expected due to the issue of sample size. The main difference is that the vehicle counts for model year 2001 are substantially lower for the Caltrans data. This is easily explained: The Caltrans data were collected from households over an extended period of time starting in October 2000. Sales of model year 2001 vehicles accumulate over the entire calendar year and beyond into the following calendar year. The earlier a household was interviewed, the more likely it was that they could have purchased a 2001 model year vehicle *after* they were interviewed, leading to a diminished count of 2001 model year vehicles. Moreover, households interviewed very early in the survey process could have purchased a model year 2000 vehicle in the "new vehicle market". More generally, it can be difficult to determine "new vehicle sales" on the basis of either survey data or vehicle registrations, so we typically are concerned with model year vehicle counts. All these phenomena lead to the need for calibration of model constants for market simulation. In this case, the main need is to add a calibration constant to increase the purchase rate of model year 2001 vehicles.

b) Body Type Distributions and New Vehicle Sales

To further illustrate calibration-related issues, see Figure 8.10. The vehicle count profiles in this figure are obtained from two different data sets that have been merged. For the period 2000 to 2008, vehicle counts were obtained from the DMV/EMFAC data for those calendar years. The values plotted are vehicle counts where the model year is equal to the calendar year (in the October snapshot), which provides a crude estimate of new vehicle sales. For the period 2009-2025, the vehicle counts are obtained from new vehicle sales estimates produced by the MDM under the AEO reference scenario. The deep dip in 2009 due to the recent recession is clearly in evidence.

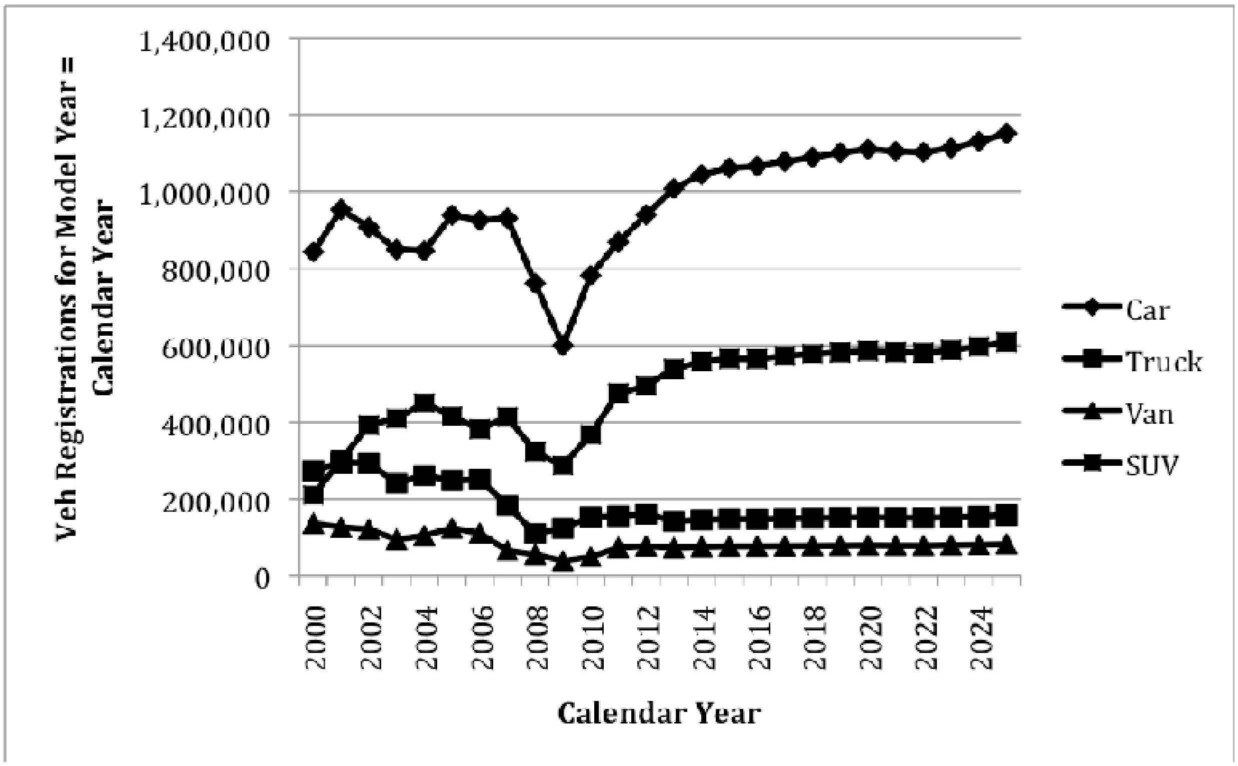

Figure 8.10 New Vehicle Sales Estimates from Two Merged Data Sources (DMV/EMFAC 2000-2008, MDM Estimates with AEO Scenario 2009-2025)

For the period 2000-2004 there is a noticeable shift in sales patterns involving the four major body types (Car, Truck, Van, SUV). The main shifts appear to involve Cars and SUVs, i.e., a drop in Cars and an increase in SUVs. The pattern reverses itself during 2005-2007 due to increases in fuel prices. Starting in 2006 the sales levels for Trucks and Vans decline (along with the other two body types); however, they are projected to stay at low levels in the future while sales of Cars and SUVs rebound. To accommodate these sales pattern shifts, calibration constants were added to CARBITS 3.0 for the period 2002-2006, and in 2013. As noted previously, sales counts for 2002-2006 were based on DMV data, and those for 2013 were based on MDM results calibrated to the AEO reference scenario.

8.2.7. Household Survey Data

In this section we review some information on the household database used by CARBITS 3.0, namely, the 2000-2001 California Statewide Travel Survey, which we also refer to as the "Caltrans Travel Survey," or the "Caltrans Survey." The survey is documented in a Final Report—see Caltrans (2002). For purposes of background, the following is an excerpt from the Executive Summary of the Final Report:

> The 2000-2001 **survey was conducted between October 2000 and December 2001** among households located in each of the 58 counties throughout the State. A total of **17,040 households** participated in the survey. Household socioeconomic data gathered in this survey includes information on **household size**, **income**, **vehicle ownership**, **employment status** of each household member, and housing unit type among other data. Travel information was also collected including trip times, mode, activity at location, origin and destination, and vehicle occupancy among other travel-related data. [Emphasis added.]

The Caltrans survey has a large sample size, follows careful data collection procedures, and provides weight factors that make it an attractive option for our purposes. The data items in bold above are the main elements required for vehicle choice modeling using "revealed preference" data. The survey methodology includes the development of household weights that, when applied, provide a way to compute statistics that represent the entire California population—see Table 8.25. Specifically, the weights are chosen so that certain statistics match those of the 2000 Census—see Chapter 6 of the Caltrans Survey Final Report. The following sections have been included to provide additional documentation for the interested reader.

Table 8.25 Key Household Statistics from 2000-2001 California Statewide Household Travel Survey

Household Vehicles Available	21,448,770
Vehicles in Use on Average Weekday (71%)	15,252,463
Full-time Employees	10,130,359
Licensed Drivers	19,696,497
Occupied Housing Units	11,502,870
Single Housing Units	68%
Multiple and Other Housing Units	31%
Median Household Income	$54,946
Persons Per Household	2.8
Vehicles Per Household	1.9
No Vehicles	9.3%
One Vehicle	29.7%
Two Vehicles	37.7%
Three or More Vehicles	23.4%
Licensed Drivers Per Household	1.7

a) Caltrans Household Income Distributions

Household income distributions from the Caltrans Survey are presented in Table 8.26. The first columns of the table report distributions based on the un-weighted sample of 17,040 households. The final three columns show the same figures computed using the weights developed to match Census data to represent the 11.5 million households in California at that time. The table illustrates some common features of this type of survey work: Households at the lowest and highest income levels are frequently under-sampled, and many households (12-13% in this case) refuse to provide income information.

Table 8.26 Household Income Distributions in the Caltrans Travel Survey

	Unweighted			Weighted		
	Freq	Percent	Valid Percent	Freq	Percent	Valid Percent
<$10,000	732	4.3	4.9	984705	8.6	9.7
$10,000-$24,999	2419	14.2	16.3	2003837	17.4	19.7
$25,000-$34,999	2244	13.2	15.1	1113007	9.7	11
$35,000-$49,999	2369	13.9	15.9	1297487	11.3	12.8
$50,000-$74,999	3389	19.9	22.8	1774103	15.4	17.5
$75,000-$99,999	1850	10.9	12.5	1103269	9.6	10.9
$100,000-$149,999	1268	7.4	8.5	1103019	9.6	10.9
$150,000+	583	3.4	3.9	775768	6.7	7.6
Total Known	14854	87.2	100	10155194	88.3	100
Don't Know/Refused	2186	12.8		1347671	11.7	
Total	17040	100		11502866	100	

b) Vehicle Holdings

Another distribution of interest is the level of vehicle holdings by households. Despite the reference to "vehicle ownership" in the Executive Summary of the Caltrans Final Report, note that the survey generally relies a related measure termed "vehicle availability." Using this variable in conjunction with weights yields the statistics in Table 8.25. An expanded distribution is given in Table 8.27. By this measure, fewer than 10% of California households have no motorized vehicles available (3.5 % of the sample). About 68% of households (73% of the sample) hold one or two vehicles. The mode in California is two-vehicle households.

Table 8.27 "Vehicle Availability" Distribution for Caltrans Survey Households

	Unweighted		Weighted
No. of Vehicles	Frequency	Percent	Percent
0	601	3.5	9.3
1	5123	30.1	29.7
2	7343	43.1	37.7
3	2742	16.1	16
4	861	5.1	4.9
5	237	1.4	1.5
6	81	0.5	0.6
7	32	0.2	0.2
8	13	0.1	0.1
9	7	0	0
Total	17040	100	100

One potential issue for this project is that "availability of motorized vehicles" is not necessarily equivalent to the choice of "vehicle holdings" that we are concerned with, i.e., the household's light-duty vehicles. At the same time, the Caltrans Survey apparently assumes that "vehicle availability" is equivalent to the Census definition of "vehicles kept at home." These could include leased, borrowed, or employer-provided vehicles as well as vehicles owned by the household. In our work, we have taken the practical approach of treating vehicle availability as equivalent to vehicle ownership.

Another issue we faced in working with the Caltrans data was our discovery that the vehicle data were "dirty" in a number of ways, as can happen in surveys of this type. Relevant vehicle variables used for this project include body type, year, make, model, and fuel type of household vehicles. Problems we encountered included:

1. Item non-response, i.e., missing items (Don't Know or Refused) in variables for Year, Make, or Model of vehicle.
2. Limited information in Model variable (e.g., "Car" rather than the actual model name).
3. Errors in data entry, as evidenced by:
    a. Miss-matches between Make and Model (e.g., Nissan Camry).
    b. Miss-matches between stated body type and other variables. (For example, the body type could be listed as "Moped" for a 1999 Toyota Camry.)
    c. Miss-spelled model names, creating difficulties in vehicle matching.
    d. Miss-matches between year and model (e.g., a 1985 Toyota Prius does not exist, so there is a miss-match between year and make/model).

In addition, there were a relatively large number of very old vehicles in the data set (e.g., more than 40 years old). This can happen in a survey of this type due to sample response bias, e.g., individuals with a strong interest in cars might be "collectors," and would also be more likely to respond to the survey. For our work, we limited the "window" for vehicles to the period 1985-2001 for purposes of choice modeling (see Section 8.2.4). This was primarily for practical reasons, in that it is quite difficult to get vehicle data for model years prior to 1985.

Constructing a data set to be used for choice model estimation for this project was quite challenging, because it requires that vehicles in the Caltrans Survey be 'identified' in enough detail to assign or match them to the vehicle configurations at the level of detail discussed previously. Note that the best that can be achieved is to match vehicles at the Year-Make-Model level, i.e., the Caltrans Survey does not have information on, e.g., engine size, transmission, etc. We established procedures for matching vehicles at the Year-Make-Model level, and a procedure for probabilistically assigning vehicle configurations to households based on weights established using DMV data. DMV data allow calculation of vehicle counts at this level of detail, and can therefore be used as a source of weights for probabilistic assignment.

8.2.8. Vehicle Technology and Prices

The data requirements for developing CARBITS are extensive. In addition to the household survey data, we required detailed vehicle data and prices for the period 1985-2001. A complicating factor is that no single vehicle database will necessarily have all the required data elements, requiring datasets to be merged. For this project, it was necessary to use data from the following databases: Chrome VINMatch, Chrome New Vehicle Data (NVD), National Automobile Dealer Association (NADA) VIN Prefix Solution, EPA Fuel Economy Guide, DMV registrations, and California BAR smog check data. With the exception of the EPA and Chrome NVD, these data sets are keyed on Vehicle Identification Numbers (VINs), which facilitate matching. The Chrome data have another database key (Chrome Style ID) that can be linked to VINs through their VINMatch data. We provide additional background in the next sections.

a) Vehicle Technology

Two main sources of vehicle technology data come from the Chrome company. Chrome offers a number of vehicle data-related products. As noted, we used two: Chrome VINMatch data, and Chrome New Vehicle Data (NVD). These datasets provide information on vehicles at a relatively high level of detail. The Chrome data are attractive because they have been implemented using modern relational database management (RDBM) techniques. Each data set has a table that uses a numeric variable called a Chrome StyleID that is the index variable to a database record containing a high level of detail for a particular vehicle type called a Chrome "Style."

In the NVD, the Style table is the central table in the database. In VINMatch, there are two "parallel universes" of vehicle definitions, one based on Chrome Style, and one based on VIN prefix (the first 9 characters of a VIN). A summary of the variable names, types (N=numeric, S=string), and space allocations are given Table 8.28. Each table uses the same key variable (although they have slightly different names). The VINMatch table provides vehicle model and style information in a more user-friendly character string format. The NVD has more vehicle-attribute information directly included in the table, including MSRP, MktClassID (related to EPA vehicle classification), Consumer Friendly (CF) body type, Passenger Capacity, and information on whether certain transmission and drive train equipment are Standard, Optional, or not available. There is an indicator in the VINMatch table of whether the corresponding Chrome style exists in the NVD.

Table 8.28 Variables contained in Chrome NVD and VINMatch "Style Tables"

Style (NVD)	Type	Width		YearMakeModelStyle (VINMatch)	Type	Width
StyleID	N	4		ChromeStyleID	N	4
HistStyleID	N	10		Country	S	2
ModelID	N	4		Year	N	4
ModelYear	N	4		DivisionName	S	13
Sequence	N	2		SubdivisionName	S	21
StyleCode	S	8		ModelName	S	18
FullStyleCode	S	9		StyleName	S	35
StyleName	S	35		TrimName	S	25
TrueBasePrice	S	1		MfrStyleCode	S	7
Invoice	N	8		FleetOnly	S	1
MSRP	N	8		AvailableInNVD	S	1
Destination	N	6		DivisionID	N	2
StyleCVCList	S	71		SubdivisionID	N	4
MktClassID	N	2		ModelID	N	4
StyleNameWOTrim	S	35		AutoBuilderStyleID	S	14
Trim	S	24		HistoricalStyleID	N	10
PassengerCapacity	N	2				
PassengerDoors	N	1				
ManualTrans	S	1		**Common variables**		
AutoTrans	S	1		(Chrome)StyleID		
FrontWD	S	1		(Model)Year		
RearWD	S	1		StyleName		
AllWD	S	1		ModelID		
FourWD	S	1		AutoBuilderStyleID		
StepSide	S	1		Trim(Name)		
Caption	N	1				
AutoBuilderStyleID	S	14				
PriceState	S	9				
CFModelName	S	28				
CFStyleName	S	40				
CFDriveTrain	S	17				
CFBodyType	S	31				

It is important to note the type of detail that Chrome Style is oriented toward: It is primarily defined on the basis of Year-Make-Model-Style information. In this sense, Chrome Style is the natural entry point to provide linkages to survey vehicles, which generally have this same type of information. At the same time, Chrome Style is generally much more detailed than the vehicle identifiers in survey data. The Caltrans Travel Survey vehicles were linked to vehicle technology data by first matching them to Chrome Styles.

However, as detailed as this information is, for our purposes a vehicle configuration requires additional information on variables such as engine, transmission, drive train, and curbweight. We emphasize this because two critical vehicle attributes are a direct function of these vehicle characteristics: *fuel economy* and *performance*. During the course of this project, we developed a detailed vehicle technology database on the basis of a construct called a "Chrome Vehicle," which can be uniquely identified on the basis of the following key variables:

Chrome StyleID [=> Year-Make-Model-Body Type]

VINPrefix

FuelSystem

EngineCategory (e.g., 4 cylinder, V6, Straight 6)

ForcedInduction (e.g., turbo charged)

TransmissionType

TransmissionSpeed

DriveTrain

In other words, taken together, these variables constitute a "composite key" that uniquely defines a "complete Chrome vehicle" at the level of detail required to determine key characteristics related to fuel economy and performance. Two important ones are horsepower and curbweight. In some cases the Chrome data were incomplete (particularly prior to 1989) and required augmentation from other sources, including the EPA Fuel Economy data, and the NADA Prefix Solution data (which was a major source of curbweight data). Once vehicle technology data are developed at this level of detail, they can be used to meet various modeling requirements. By way of review, we note that the vehicle technology data described here were used for vehicles for model years 1985-2006. Starting in 2007 the source of vehicle technology data was the Manufacturer Decision Model.

b) Prices

The Chrome NVD contains information on MSRP for vehicles sold new. However, we also needed price data for used vehicles. The NADA Prefix Solution was the source of used vehicle data. These data were used to provide used vehicle prices for the California region during the base year of 2001, using prices from December. The NADA data for model years 1982 to 2001 were used to estimate a price depreciation model. The form of the model was exponential, but the model was estimated using ordinary least squares regression with ln(Price) as the dependent variable.

The primary factors that affect the (log of) current price of a vehicle are: ln(MSRP) when sold new (in 2001 dollars), and Age. In addition, we included dummy variables for body configuration (two-seater, truck, van, SUV, with car used as the base level) and prestige, as well as interactions between age and these factors. Finally, after some investigation we discovered that the data were fit best by using two depreciation models: one for vehicles less than seven years old, and one for vehicles 7 years old and older. In the latter model, age squared became a statistically significant variable. Estimation results for these two models are provided in Tables 8.29 and 8.30, respectively.

Note that in each of these models, the coefficient estimate of ln(MSRP) is very close to one. This means that the basic form of the model is approximately: $Price = MSRP * \exp(b_0 + b'X)$, so that the second term represents a multiplicative depreciation factor relative to the original MSRP. The Age coefficients are negative (as expected) and very significant. The coefficients on the interaction terms between Age and body configuration are all positive, showing that prices depreciate more slowly for Trucks, Vans, and SUVS versus Cars.

Table 8.29 Coefficients for Price Depreciation Model (Vehicle Age < 7 Years)

	Coefficient	Std. Error	t	Sig.
(Constant)	0.0809904	0.054	1.489	0.137
ln_MSRP	0.9886832	0.005	183.539	0
Prestige	0.0539690	0.006	8.863	0
TwoSeat	-0.0734471	0.006	-13.241	0
Pickup	0.0247440	0.008	3.049	0.002
Van	-0.1337035	0.01	-13.94	0
SUV	-0.1581399	0.01	-16.183	0
Age	-0.1641528	0.001	-149.347	0
Age_Pickup	0.0588658	0.002	33.495	0
Age_Van	0.0375608	0.002	16.945	0
Age_SUV	0.0233136	0.003	9.097	0

Table 8.30 Coefficients for Price Depreciation Model (Vehicle Age >= 7 Years)

	Coefficient	Std. Error	t	Sig.
(Constant)	0.8904553	0.063	14.11	0
ln_MSRP	0.9187795	0.006	156.26	0
Prestige	0.2648907	0.021	12.761	0
TwoSeat	-0.1107070	0.006	-20.11	0
Pickup	0.3803445	0.013	28.18	0
Van	0.1280204	0.006	19.797	0
SUV	-0.0770385	0.023	-3.329	0.001
Age	-0.2057623	0.003	-63.95	0
Age_Pickup	0.0144675	0.001	15.597	0
Age_SUV	0.0279581	0.002	16.99	0
AgeSqr	0.0036041	0	29.757	0
Age_Prestige	-0.0167809	0.002	-10.413	0

9. POLICY ANALYSIS

9.1. Manufacturer Decision Model (MDM) Scenario Results

The impact of a feebate system on the GHG emission rates of new light-duty vehicles will depend on a variety of factors: 1) the nature and scope of the feebate system, 2) the "state of the world", including fuel prices, costs and effectiveness of advanced technologies and, 3) other relevant policies, especially fuel economy and emissions regulations. The usefulness of this analysis of feebates will depend not only on the validity of our models but also on assumptions made about critical issues, such as how the market values fuel economy. The 56 feebate cases described in section 7 "Policy Formulations" were designed to explore how the impacts of feebates vary under changes in all these factors. Insights from these modeling experiments are presented in this section. A complete set of modeling results, embedded in a graphical display tool, is available on the ARB's website.

After reviewing the premises of the Reference case and its emissions rates, fuel economy and vehicle sales, the Base California Feebate case is presented. This case assumes that only California adopts a feebate system, and that the system is designed using the CAFE footprint functions as benchmarks with a $20/g/mi linear feebate rate. The CAFE footprint function makes each vehicle's emissions benchmark a function of its footprint, i.e., its wheelbase (distance from rear to front axle) multiplied by its track width (distance from one wheel to another along the same axle). This is the (approximately) rectangular area delineated by the vehicle's four tires. As a consequence, smaller vehicles have lower emissions benchmarks than larger vehicles. How emissions rates will change if the Opt-in states or the rest of the US adopt an identical feebate system is investigated next. Following that, the impacts of alternative feebate rates of $10 and $30/g/mi are tested. The investigation of alternative feebate systems concludes by considering alternative structures: a single benchmark for all vehicles, individual benchmarks for cars and light trucks, and a single step function as an alternative to the linear feebate used in all other cases.

Robust policies perform well under a wide range of conditions. The impacts of feebates are investigated under different assumptions about fuel prices, the costs of emission-reducing technologies, especially hybrid vehicles, the value consumers attach to increased fuel economy, and the sensitivity of consumers' choices to vehicle prices. The stringency of emissions regulations can also influence the effect of feebates on new vehicle emissions rates. Both more and less aggressive emissions regulations are tested. The effects of other more technical assumptions, such as whether emissions regulations allow banking of fuel economy credits, are also explored.

9.1.1. Reference Scenario: Continuation of New Vehicle Emissions Reductions at 2%/Year

The Reference case incorporates the national emissions standards through 2016, and assumes a continued constant (linear) reduction of 2% of the 2016 level thereafter.[41] It was necessary to

[41] This is somewhat more stringent than a 2% per year compounded reduction. The standard is set by lowering the DOT/EPA footprint function, which relates vehicle emissions in grams per mile to a vehicle's footprint (wheelbase multiplied by track width). The footprint is the area delimited by a vehicle's wheels. This rate was chosen prior to federal or state rulemakings as a plausible guess of what future requirements might be. Alternative rates were tested in sensitivity analyses.

consider two emissions rates: unadjusted and adjusted. Compliance with the standards is based on an adjusted emissions rate that includes credits earned by selling flex-fuel vehicles (FFV) and by improving the efficiency of automotive air conditioners and reducing the global warming potential of the refrigerants used in them. Unadjusted emissions rates do not include credits for FFVs or improvements that reduce the impacts of air conditioning on GHG emissions. In the Reference case, new light-duty vehicle unadjusted emissions rates for California and nationwide decline from just over 300 g/mi in 2011 to about 220 g/mi in 2025 (Figure 9.1). Adjusted emissions rates for vehicles sold in California decrease from just under 300 g/mi in 2011 to about 200 g/mi in 2025. Initially, California's adjusted emissions rates are below the national standard (Target) but, over time, as the standards become stricter, the California adjusted rates and the nationwide target converge. However, the California adjusted emissions estimates shown in Figure 9.1 do not include the effects of California's ZEV mandate. If the assumed ZEV scenarios were realized, it would firmly place California's emissions below the assumed national standard.

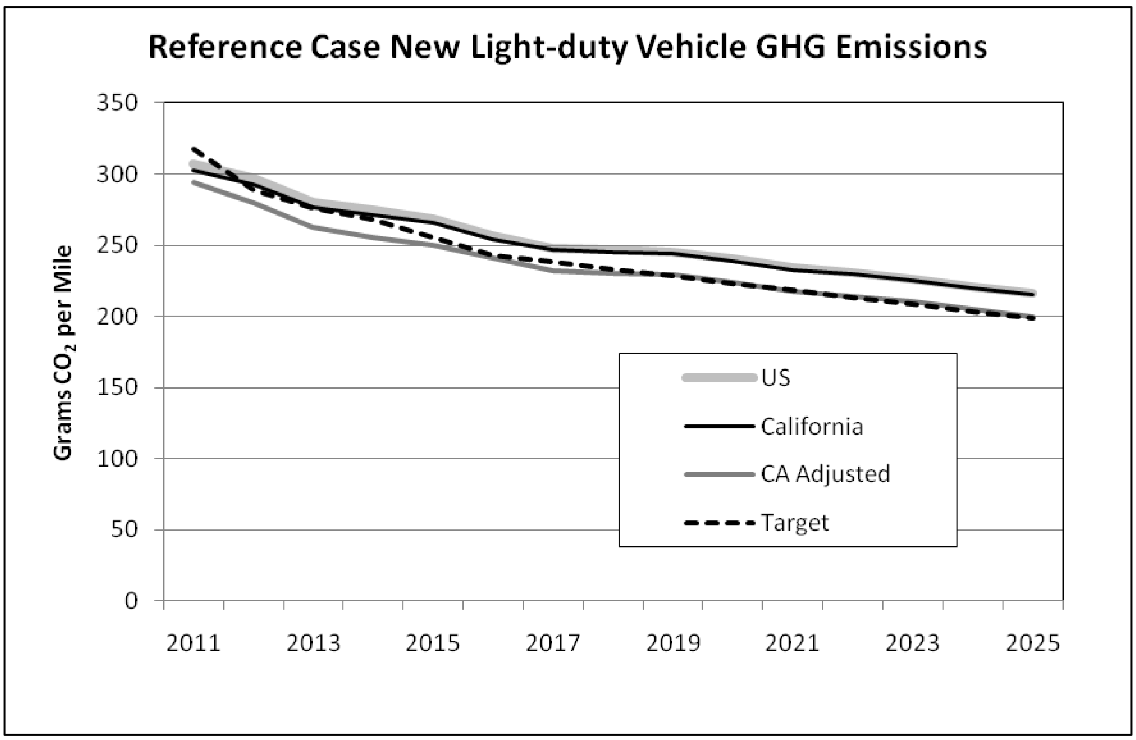

Figure 9.1 Reference Case New Light-duty Vehicle GHG Emissions

The average fuel economy of new passenger cars and light trucks nationwide reaches almost 45 miles per gallon (MPG) by 2025 (Figure 9.2). Similar to Figure 9.1, new vehicle fuel economy in California, adjusted for flex-fuel vehicle (FFV) and air conditioner credits, is initially above the national standard but converges toward the standard in later years. Including ZEVs would put California adjusted fuel economy above the target levels even in later years.[42]

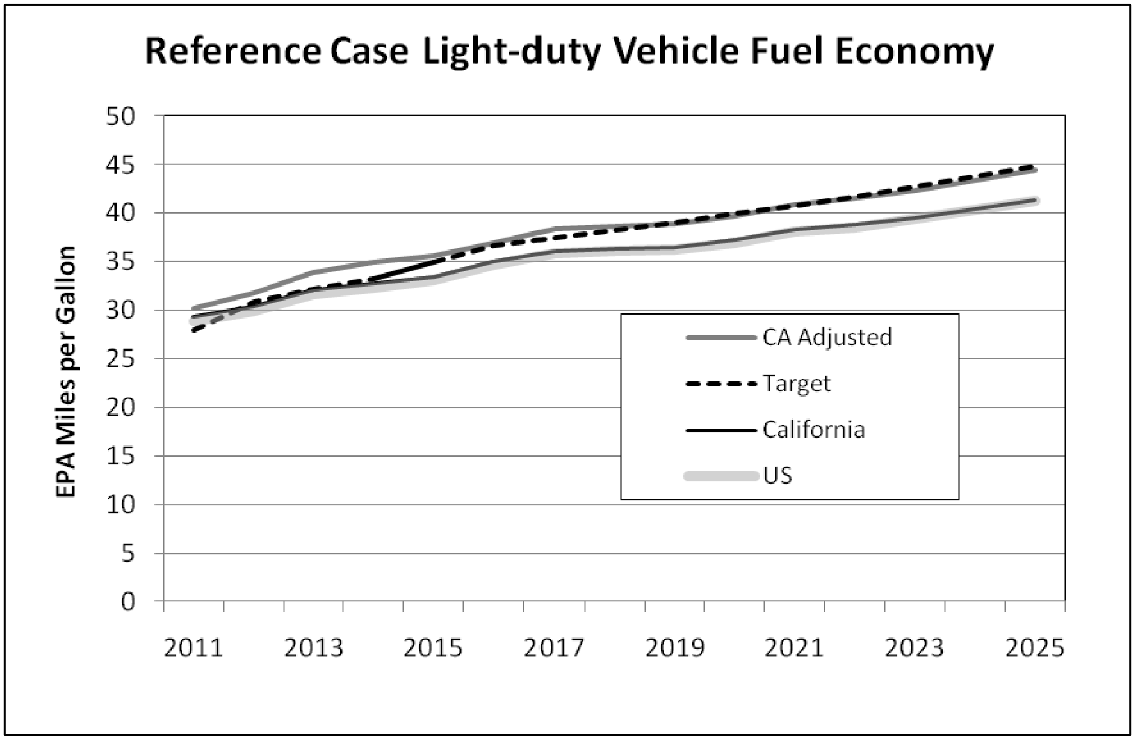

Figure 9.2 Reference Case New Light-duty Vehicle Fuel Economy

In both graphs there are slight inflections in 2017 and 2021.[43] These are due to the fact that the Manufacturer Decision Model allows only about one-fifth of all makes and models to be redesigned in each year according to their existing product cycles. Depending on the popularity of the models redesigned in a given year and the stringency of future emissions standards, it can be an optimal strategy for a manufacturer to overdesign emissions reductions in one year so that the high-selling models redesigned in that year help meet future standards.

[42] Standards are specified in grams per mile (g/mi) CO_2 rather than miles per gallon. This will cause the target in miles per gallon to increase more than linearly. Although the target is lowered at a linear rate post-2016, the target is a footprint function. Thus, trends in the sizes of vehicles sold could cause the time path of the overall fuel economy target to deviate from a simple linear path.

[43] In general, we find that allowing banking of fuel economy credits (discussed in section 9.1.9 of this chapter) eliminates inflection points such as seen in Figures 9.1 and 9.2, and also reduces the use of pricing strategies by manufacturers to meet emissions standards.

Vehicle sales in California in the Reference case increase from just below 1.6 million units in 2011 to 2.1 million units in 2025 (Figure 9.3). Sales of passenger cars increase from 1.1 to 1.5 million units, with light trucks making up the remainder.[44] Hybrid vehicle sales remain low despite the increasingly stringent emissions standards, increasing from 4% of light-duty vehicles in 2011 to 6% in 2025. Hybrid sales do not take off because the assumed cost of hybridization (discussed in section 8.1) remains relatively high compared with other technological options for reducing emissions. Of course, the costs of hybrids through 2025 are uncertain; the implications of lower costs are explored in section 9.1.5.

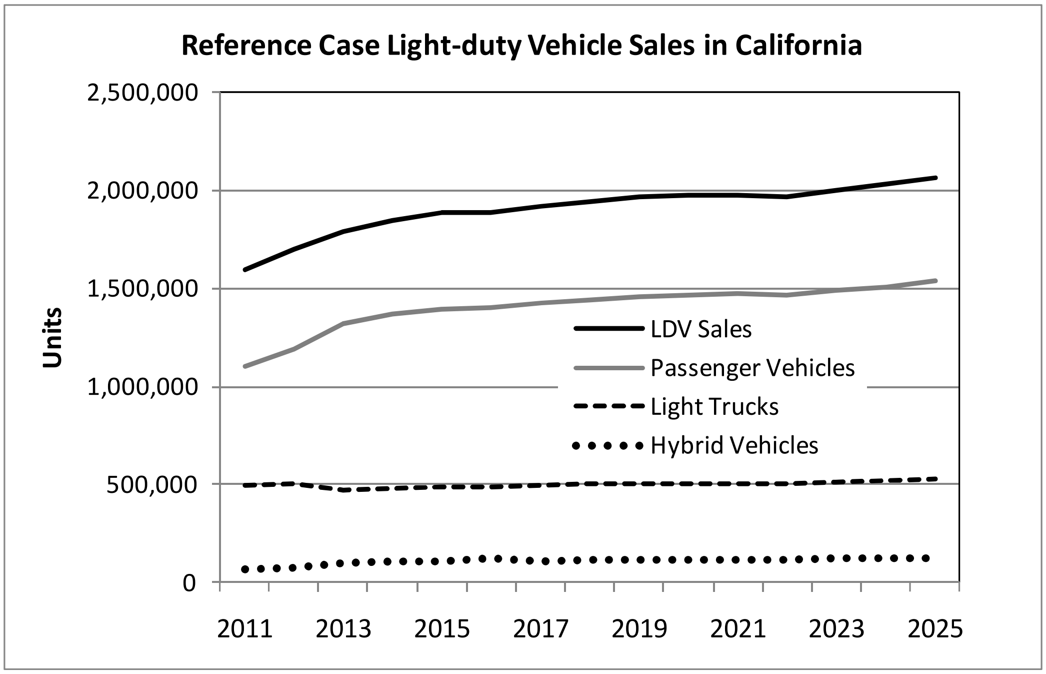

Figure 9.3 Reference Case Light-duty Vehicle Sales in California

Adding the Base Feebate ($20/g/mi, California only, beginning in 2011, linear, benchmarked to two separate footprint functions for passenger cars and light trucks), causes an immediate reduction of about 12 g/mi in the average emissions rates of new light-duty vehicles in California (Figure 9.4). Please note that emissions reductions in Figure 9.4 and all other figures are shown as negative numbers (i.e., -12 g/mi). A reduction of this size is comparable to the impacts observed in France and other EU countries with similar feebate systems. The impact of feebates remains at that level through 2015, decreases to 8 g/mi in 2016 and decreases gradually to just below 5 g/mi in 2025. The decreasing impact of the feebate system is chiefly due to the increasing stringency of emissions regulations and the resulting increasing cost of technologies to reduce emissions. If it turns out that our technology cost functions underestimate the progress of emissions-reducing technology in the future, feebates could have a larger impact than shown in Figure 9.4. The reverse would be true if the cost functions are too optimistic. These possibilities are tested in sensitivity analyses described below.

[44] Consistent with the definition used for the new federal emissions standards, passenger cars include both minivans and SUVs not equipped with 4-wheel drive.

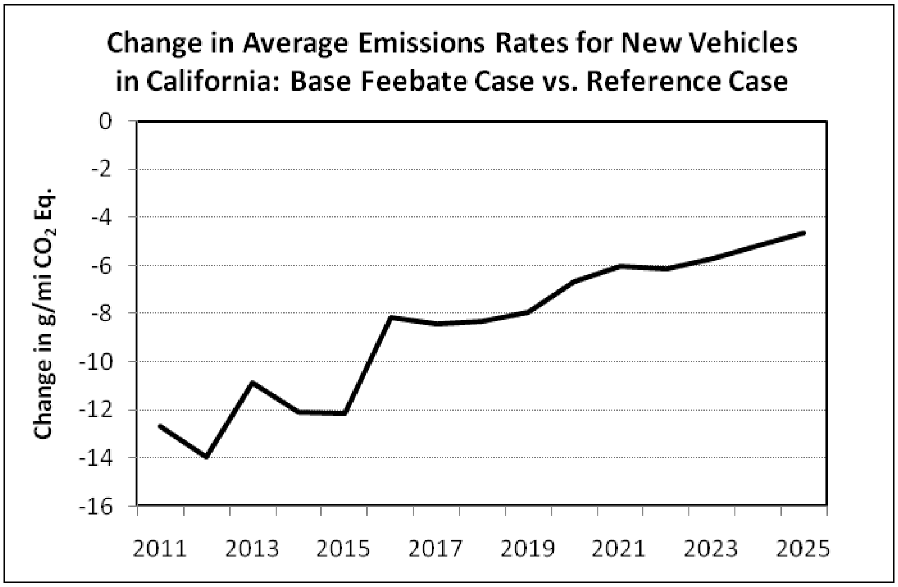

Figure 9.4 Change in Average Emissions Rate of New Vehicles in California: Base Feebate Case vs. Reference Case Case
(Negative values indicate reductions in the average emissions rate.)

The reduction in average new LDV emissions rates in California from this feebate program design and scenario is mostly due to shifts in vehicle sales, rather than an increased uptake of technology. There is some increase in the application of technology, however, at a cost of about $50 more per vehicle through 2015. The adoption of additional technology to reduce emissions diminishes over time and eventually slightly less emission-reducing technology is added (-$10 to -$20 per vehicle) from 2020 to 2025. Because the model does not allow special vehicle designs solely for the California market, the changes in application of emission-reducing technology are nationwide. The sales mix shifts induced by the California feebates eventually allow manufacturers to meet the emissions standards with slightly less emissions-reducing technology per vehicle. As a result, in early years the California feebate system has a small spillover effect, slightly reducing emissions in the rest of the U.S. below what would be accomplished by the standards alone. As the standards become tighter over time and emissions reducing technologies become more expensive, the small spillover effect becomes an even smaller leakage effect. From 2011 to 2015, emissions rates outside California are 2 to 2.5 g/mi lower in the Base Feebates case than in the Reference Case. However, in 2020 and afterward, rates outside California are 0.5 g/mi to 1.0 g/mi higher with feebates. Moreover, the vehicle market outside California is approximately an order of magnitude larger than the California market so the impact on total greenhouse gas emissions is proportionately greater. In general, when the standards are not a binding constraint on manufacturers (i.e., when there is sufficient cost-effective technology to comply with the standards), there is a small spillover benefit from the California Base feebate program. When the standards become a binding constraint there is a small leakage effect.

The positive spillover effect of California feebates through 2015 is due to the fact that the national emissions regulations are not binding on manufacturers until 2016.[45] The combination of relatively high fuel prices and the availability of cost-effective technologies make this possible, even though we assume consumers value only the first three years of (undiscounted) fuel savings. Whether or not consumers undervalue fuel economy in their car buying decisions is controversial. A recent literature review (Greene, 2010a) found that half of 28 recent econometric studies supported undervaluing fuel economy while the other half supported equal or over-valuing by new car buyers. The assumption that consumers consider the full present value of lifetime discounted fuel savings when making vehicle purchases is considered in section 9.1.6 of this chapter.

In the MDM, manufacturers can use a pricing strategy as well as technology to help meet emissions standards. A pricing strategy consists of manufacturers charging more for vehicles whose emissions are above the target level and subsidizing vehicles whose emissions are below it. Just like feebates, the charges are proportional to a vehicle's deviation from the (footprint-based) emissions standard. Thus, manufacturers' internal pricing strategies can have the same kinds of impacts as a feebate system. In our results, 2016 is the first year in which manufacturers use pricing in addition to technology to help meet the emissions standards in the Reference Case. Pricing is used in later years in both the Reference and Base Feebate Case. The main reason manufacturers use pricing in 2016 is because emissions credits for producing flexible fuel vehicles (FFVs) are assumed to expire in 2016. This requires an unusually large decrease in greenhouse gas emissions in that year. From 2001 to 2016 the emissions standard is tightening at the rate of 4-5% per year. In 2016, the loss of FFV credits effectively requires an additional 5 percentage point improvement (i.e., a 9-10% emissions reduction is required in that year). After 2016, the emissions standards are assumed to lower at the rate of only 2% per year. Thus, in 2016, manufacturers temporarily use pricing as a means of meeting the abruptly more stringent 2016 standard. In 2017, this is no longer necessary and the pricing strategy is discarded in favor of adding emissions reducing technologies. A sensitivity case was run that allowed banking of credits, and this eliminated the use of pricing in 2016. Manufacturers preferred to use credits banked in prior years instead of pricing to make up for the loss of the FFV credits.[46]

The actual emissions standards allow not only banking of past credits but borrowing against future credits. Including both banking and pricing increased the model's solution time by substantially expanding the options available to manufacturers. In addition, permitting banking creates the problem of valuing banked credits held at the end of the optimization period. Since there is no exact rule for valuing end-of-period credits, it is necessary to run the model for several years

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[45] The MDM is a constrained optimization model in which manufacturers seek to maximize consumers' satisfaction with the vehicles offered for sale, subject to emissions constraints and the cost of reducing emissions and improving fuel economy. When the emissions constraints can be met by technology that consumers are willing to pay for based on the perceived present value of fuel savings, the emissions constraints are not binding. Our base assumption is that consumers count only the first three years of fuel savings, meaning that they count only about one-half of the expected present value of fuel savings over the full lifetime of the vehicle. Even so, there appears to be a sufficient amount of technology for which consumers are willing to pay to meet the emissions standards through 2015.

[46] Of course, it is the logic of the optimization model and the data supplied to it that determine what "manufacturers prefer" to do in this analysis.

beyond the 2025, further increasing the size of the problem. Instead, banking was omitted and pricing was retained. This should underestimate the impacts of feebates whenever banking would reduce the shadow price of meeting the fuel economy constraint, likely a common situation. It enables modeling the interaction between feebates and pricing strategies internal to the firm, which in theory is potentially an important phenomenon. Whenever standards are strict enough to induce firms to price vehicles to induce shifts in sales toward lower emission vehicles, the addition of feebates will replace or moderate firms' pricing strategies. On the one hand, this relieves firms of the necessity of imposing emissions-based pricing, but on the other it mitigates the impact of the feebate system on emissions rates.

The estimated impact of the feebate system on new light-duty vehicle sales in California is a loss of approximately 10,000 units per year, with some variation from year to year, approximately 0.5% of annual sales. This result is a consequence of the assumption that consumers value only the first three years of fuel savings at time of purchase and will therefore suffer a loss of consumers' surplus if induced by the feebate system to purchase lower-emission, higher-fuel economy vehicles. However, even if consumers fully valued future fuel savings, feebates would still induce an additional shift in sales toward lower emission vehicles that would cause some loss of consumers' surplus. On the other hand, if, as suggested by Greene (2010b), consumers undervalue fuel savings when purchasing a new vehicle but fully value the savings as the vehicle is used there might not be a loss of consumers' surplus. How consumers value fuel savings is uncertain and the evidence from recent economic analyses is conflicting.

To evaluate the overall effectiveness of a feebate system, we calculate the total societal cost and benefit from the program (Table 9.1). The societal cost per ton of CO_2 mitigated is negative and in most years represents a savings of over \$100 per ton of CO_2 emissions avoided (Table 9.1). This calculation is based on the full lifetime present value of future fuel savings (tax excluded) versus the economic cost of the feebate system. The cost is the loss of consumers' surplus caused by shifting the mix of vehicles sold toward lower emission vehicles. The result is a net societal gain because although the fuel economy standards cause manufacturers to produce more fuel-efficient vehicles, consumers are still assumed to undervalue fuel economy when they choose among those vehicles. By encouraging consumers to purchase more fuel-efficient vehicles, feebates can induce a sales mix

Table 9.1 Summary Comparison of Reference Case and Standard California Feebate Case

		2015		2020		2025	
	Units	Reference (Case1)	Feebate (Case2)	Reference (Case1)	Feebate (Case2)	Reference (Case1)	Feebate (Case2)
Average emissions (adjusted)-US	g/mi	253.0	249.6	225.7	225.6	200.9	200.9
Average emissions (adjusted)-California	g/mi	250.0	237.9	224.1	217.4	200.0	195.4
Average Fuel economy (adjusted)-US	MPG	35.2	35.7	39.4	39.5	44.3	44.3
New car sales-US	units	11,296,744	11,295,293	11,798,362	11,799,060	12,147,391	12,147,177
New car sales-California	units	1,392,939	1,391,472	1,469,108	1,468,837	1,537,897	1,536,726
New car sales-Rest of the US	units	9,903,806	9,903,822	10,329,254	10,330,223	10,609,494	10,610,451
Light truck sales-US	units	4,079,873	4,072,098	4,167,296	4,156,973	4,267,455	4,260,726
Light truck sales-California	units	491,776	483,209	507,830	496,661	528,213	519,307
Light truck sales-Rest of the US	units	3,588,097	3,588,888	3,659,467	3,660,312	3,739,242	3,741,420
Consumers' surplus per veh-California	\$/veh	\$390	\$202	\$412	\$207	\$378	\$206
Consumers' surplus per veh-Rest of the US	\$/veh	\$26	\$28	-\$76	-\$71	-\$510	-\$503
Societal cost or benefit (-/+) per veh-California	\$/veh	\$0	\$264	\$0	\$169	\$0	\$114
Societal cost or benefit (-/+) per veh-Rest of the US	\$/veh	\$0	\$65	\$0	-\$22	\$0	-\$13
Average cost per ton of CO2 reduced-California	\$/tCO$_2$	\$0	-\$111	\$0	-\$126	\$0	-\$123
Average cost per ton of CO2 reduced-Rest of the US	\$/tCO$_2$	\$0	-\$146	\$0	-\$138	\$0	-\$108
Hybrid market share-US	%	4.1%	4.4%	4.3%	4.5%	4.4%	4.6%

closer to the societal optimum based on full lifetime fuel savings. In this way, feebates are a mechanism for correcting the assumed market imperfection, i.e., consumers' considering only the first three years of fuel savings. A sensitivity case described below tests the impact of assuming that consumers fully value discounted lifetime fuel savings (see section 9.1.6).

9.1.2. California, Opt-In States and National Feebate Systems

Our results indicate that a feebate system implemented in California alone would have less leverage on manufacturers' decisions about vehicle technology and design than if the same system were adopted in all states opting into the California standards, or nationwide. Additional scenarios were run to test the impacts of the Base Feebate system if it were adopted by more states. In the "Opt-in" scenario, the MDM was recalibrated so that its two regions corresponded to the fourteen "Opt-in states" and the rest of the US. This produces projections of vehicle emissions for the Opt-in/Rest-of-US regions that are slightly different (generally a few tenths of a g/mi) from the California/rest-of-US regions (because the markets in the two regions are different), and so a separate "Opt-in" Reference Case was run and is the basis for all comparisons in this section. In the "Nationwide" scenario, the entire US adopts feebates. This case can be directly compared with the Reference case.

As the scope of the feebate program expands, its impact on vehicle emission rates increases. When the other Opt-In states adopt the feebate system the reduction in new LDV emissions in those states increases to 15 to 20 g/mi through 2015 (Figure 9.5). Again, emissions reductions are shown as negative numbers in all figures. When the entire US adopts the Base Feebate system, the impact increases to about 30 g/mi throughout the US. In both cases the reduction diminishes over time such that the emissions reduction in the Opt-in case is only 5 g/mi by 2025 and 10 g/mi in the national case by 2025. Like the Base feebate case, this result is dependent on the rate of technological progress implied by our technology cost curves and the stringency of future emissions standards. If technological progress were more rapid than assumed in our cost functions, feebates would have a larger impact and vice versa for slower progress. The implications of slower and faster technological progress are explored below.

As the geographic scope of the feebate system expands, manufacturers are increasingly induced to adopt additional technologies to reduce emissions. In the California-only-"Base"-feebate case, shifts in vehicle sales toward lower emission vehicles generally account for more than 70% of the total feebate impact (Figure 9.6). The adoption of low emission technologies by manufacturers accounts for only 11% of the feebate's impact in 2011. As the design cycle proceeds, more vehicles become eligible to adopt new technologies and technology's share of the feebate impact increases to 30%. This shrinks in the later years as the standards become more stringent.

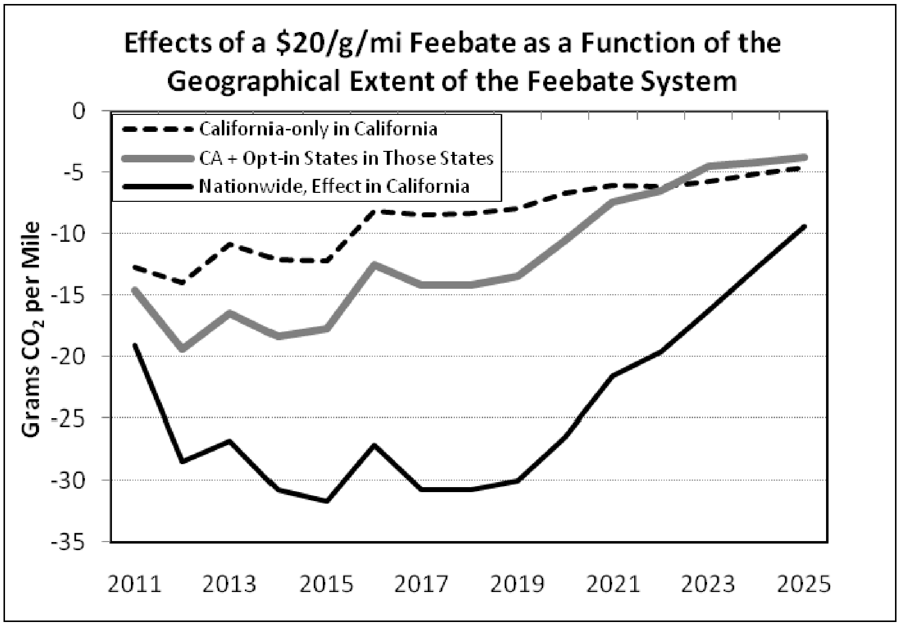

Figure 9.5 Change in New Light-duty Vehicle Adjusted Emissions Rates in California with Geographical Expansion of Feebate Scope.

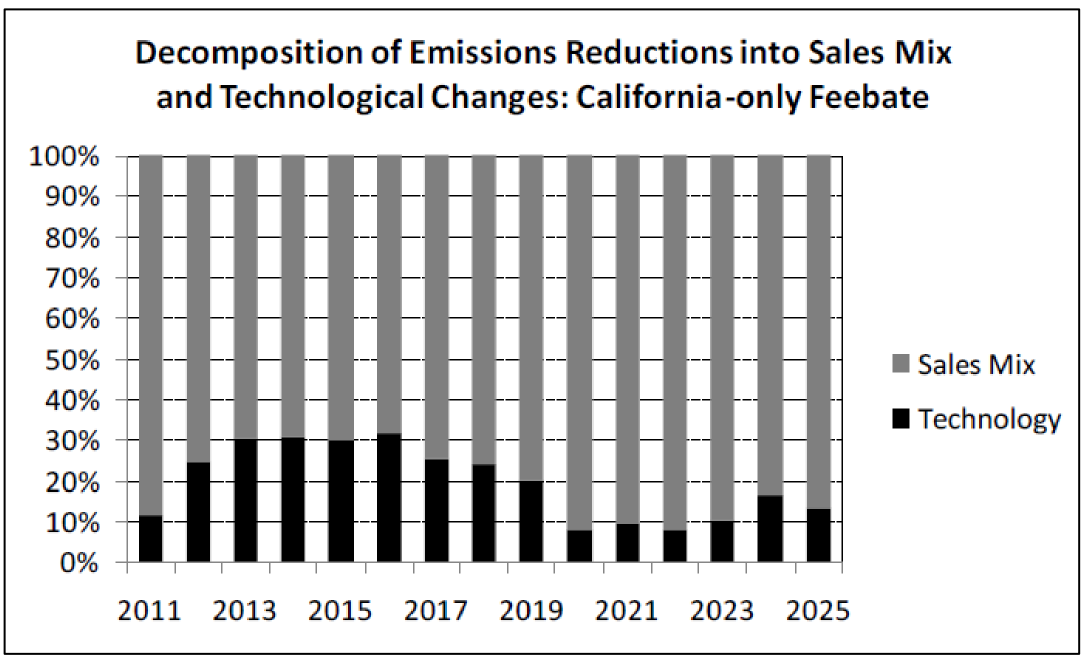

Figure 9.6 Decomposition of Emissions Reductions into Sales Mix and Technological Changes: California-only Feebate.

The roles played by technology and sales mix shifts are almost reversed in the Nationwide Feebate case. Technology's share starts at 38% and increases to 75% by 2015 as the design cycle is completed (Figure 9.7). However, in the long run as the standards become stricter and, in the absence of feebates, manufacturers themselves make greater use of differential pricing based on emissions rates to meet the standards, technology's share of the feebate impact declines to 58%. This result may be compared with prior studies of nationwide feebate systems by Davis et al. (1994) and Greene et al. (2005). Those studies found that 90% or more of the fuel economy improvements stimulated by feebates would be due to increased adoption of fuel economy technologies by manufacturers. However, those analyses did not assume base cases with continually increasing fuel economy standards. With increasingly stringent standards a greater proportion of the impact of feebates comes about through shifting the sales distribution toward lower emission vehicles. In the early years when the standards are not binding, technology's share is over 70%. In the later years as the standards become a binding constraint, technology's share remains above 50%. Note that the sales mix shifts in the cases considered here are predominantly not from larger to smaller vehicles (because the benchmarks are a function of each vehicle's footprint) but from higher to lower emission vehicles of the same size.

The greater role of technology when a feebate system applies nationwide is due to the greater market demand for lower emission vehicles. As explained in the MDM description in Section 5.1.2, manufacturers are assumed to design one configuration to sell nationwide. When only the California market has feebates, the demand for low emission vehicle designs is not nearly as strong as when the entire nation experiences the feebate incentives. Similarly, if the Opt-in states were to adopt feebate systems but the rest of the US did not, the roles of technology and changes in the mix of vehicles sold would fall between the California-only and Nationwide feebate cases.

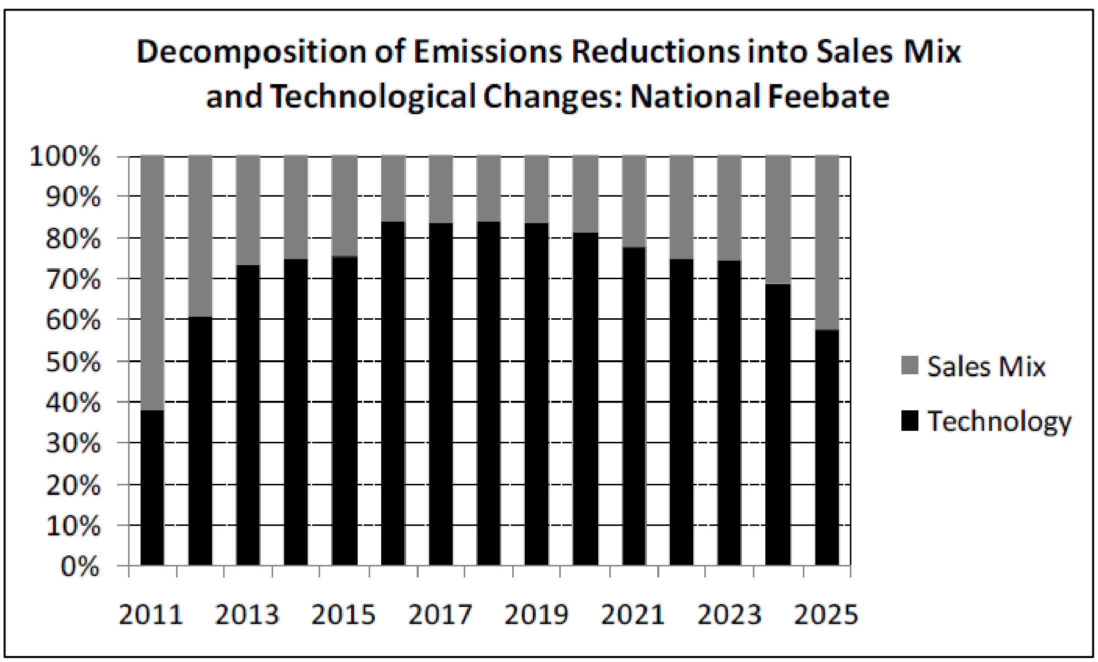

Figure 9.7 Decomposition of Emissions Reductions into Sales Mix and Technological Changes: National Feebate.

Table 9.2 Summary Comparison of Impacts of Different Regional Scales of a Feebate Program

		2015				2020				2025			
	Units	Reference (Case1)	California (Case2)	*Opt-in (Case3b)*	National (Case4)	Reference (Case1)	California (Case2)	*Opt-in (Case3b)*	National (Case4)	Reference (Case1)	California (Case2)	*Opt-in (Case3b)*	National (Case4)
Average emissions (adjusted)	g/mi	253.0	249.6	*241.4*	221.5	225.7	225.6	*219.7*	199.0	200.9	200.9	*200.7*	191.8
Average emissions (adjusted) Opt-in states(or CA)	g/mi	250.0	237.9	*232.0*	218.3	224.1	217.4	*213.8*	197.6	200.0	195.4	*196.1*	190.6
Average Fuel economy (adjusted)	MPG	35.2	35.7	*36.9*	40.2	39.4	39.5	*40.5*	44.7	44.3	44.3	*46.4*	46.4
New car sales	units	11,296,744	11,295,293	*11,293,838*	11,199,306	11,798,362	11,799,060	*11,810,963*	11,716,408	12,147,391	12,147,177	*12,205,592*	12,129,133
Light truck sales	units	4,079,873	4,072,098	*4,068,129*	4,054,466	4,167,296	4,156,973	*4,148,547*	4,087,032	4,267,455	4,260,726	*4,271,727*	4,202,579
Consumers' surplus per veh Opt-in states (or CA)	$/veh	$390	$202	*$48*	$152	$412	$207	*$52*	$71	$378	$206	*$80*	$205
Consumers' surplus per veh Non-Opt-in states	$/veh	$26	$28	*$43*	-$251	-$76	-$71	*-$62*	-$423	-$510	-$503	*-$456*	-$684
Societal cost or benefit (-/+) per veh Opt-in (or CA)	$/veh	$0	$264	*$407*	$976	$0	$169	*$273*	$955	$0	$114	*$96*	$530
Societal cost or benefit (-/+) per veh Non-Opt-in	$/veh	$0	$65	*$217*	$603	$0	-$22	*$98*	$537	$0	-$13	*-$42*	$129
Average cost per ton of CO2 reduced Opt-in (or CA	$/t$CO_2$	$0	-$111	*-$117*	-$156	$0	-$126	*-$130*	-$180	$0	-$123	*-$126*	-$281
Average cost per ton of CO2 reduced Non-Opt-in	$/t$CO_2$	$0	-$146	*-$134*	-$97	$0	-$138	*-$140*	-$100	$0	-$108	*-$111*	-$72
Hybrid market share	%	4.1%	4.4%	*4.9%*	5.7%	4.3%	4.5%	*5.0%*	5.7%	4.4%	4.6%	*4.9%*	5.6%

For rows labeled Opt-in states or CA, numbers are for California except in the columns labeled Opt-in (Case 3b), in which the numbers apply to the Opt-in states plus California.

9.1.3. Alternative Feebate Rates and Structures

The Base Feebate system incorporates a feebate rate of $20/g/mi. Whether this is high or low depends on how it is interpreted. If it is interpreted solely as a reflection of a price for carbon, it might be considered a high price for carbon. According to the National Highway Traffic Safety Administration, the expected lifetime miles for a new vehicle are 152,000 for a passenger car and 180,000 for a light truck (NHTSA, 2006). Thus, $20/g/mi is equivalent to $132/undiscounted-ton-$CO_2$ for passenger cars and $111/undiscounted-ton-$CO_2$ for light trucks. As noted above, if the feebate is interpreted as correcting for consumers' undervaluing of fuel economy in their new vehicle purchase decisions, the cost per ton is on the order of -$100.

Two alternative feebate rates were tested, $10/g/mi and $30/g/mi, once again assuming feebates are implemented only in California. The response to the feebate rate is very nearly linear. The $10/g/mi rate reduces average vehicle emissions by about 6 g/mi from 2011 to 2015, the $20 rate produces roughly a 12 g/mi reduction while the $30 rate reduces emissions by about 18 g/mi over the same period (Figure 9.8).

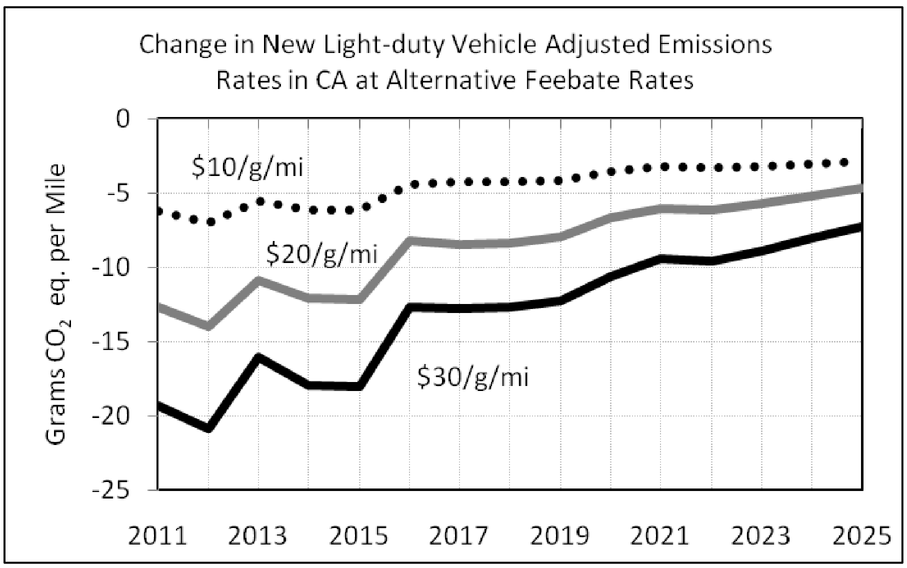

Figure 9.8 Estimated Reductions in CO_2 Emissions per Vehicle in California for Feebate Rates from $10 to $30 per Gram per Mile

The $10/g/mi feebate rate results in an estimated societal cost per ton beginning at -$80 in 2011 and declining to -$140 after 2015. Even the $30/g/mi feebate rate has a negative societal cost, starting at about -$40/ton CO_2 in 2011 and decreasing over time to about -$100/ton CO_2 (Figure 9.9). These results suggest that there is substantial scope for feebate rates higher than $20 per mile to be cost-effective from a societal perspective, provided that the assumption that the new vehicle market undervalues fuel economy is correct.

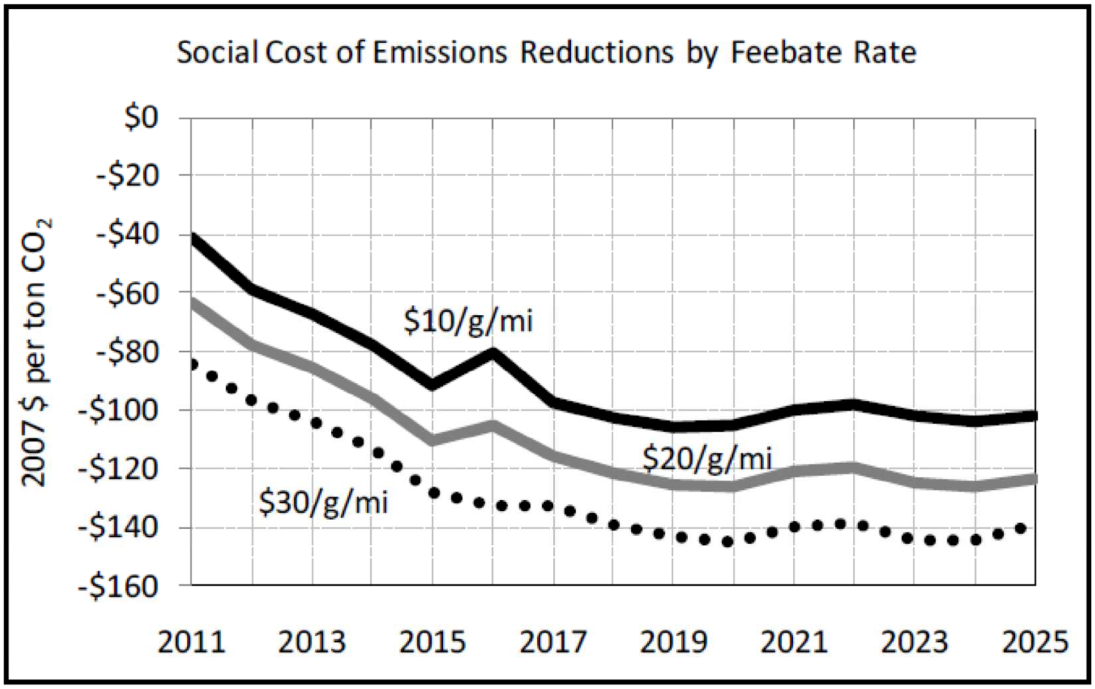

Figure 9.9 Estimated Societal Cost per Ton of CO_2 Reduction for Feebate Rates from $10 to $30 per Gram per Mile.

Table 9.3 Summary Comparison of Effects of Feebate Rate.

		2015				2020				2025			
	Units	Reference (Case1)	$20 feebate rate (Case2)	$10 feebate rate (Case5)	$30 feebate rate (Case6)	Reference (Case1)	$20 feebate rate (Case2)	$10 feebate rate (Case5)	$30 feebate rate (Case6)	Reference (Case1)	$20 feebate rate (Case2)	$10 feebate rate (Case5)	$30 feebate rate (Case6)
Average emissions (adjusted) - US	g/mi	253.0	249.6	251.3	248.3	225.7	225.6	225.4	225.3	200.9	200.9	200.4	200.8
Average emissions (adjusted) - California	g/mi	250.0	237.9	243.9	232.0	224.1	217.4	220.6	213.5	200.0	195.4	197.2	192.8
Average Fuel economy (adjusted) - US	MPG	35.2	35.7	35.4	35.9	39.4	39.5	39.5	39.5	44.3	44.3	44.3	44.3
New car sales - US	units	11,296,744	11,295,293	11,297,341	11,291,842	11,798,362	11,799,060	11,799,129	11,797,437	12,147,391	12,147,177	12,152,133	12,147,589
Light truck sales - US	units	4,079,873	4,072,098	4,076,413	4,067,207	4,167,296	4,156,973	4,162,142	4,150,403	4,267,455	4,260,726	4,257,743	4,254,939
Consumers' surplus per veh - California	$/veh	$390	$202	$323	$47	$412	$207	$328	$61	$378	$206	$304	$90
Consumers' surplus per vehicle - Rest of US	$/veh	$26	$28	$27	$27	-$76	-$71	-$75	-$72	-$510	-$503	-$512	-$500
Societal cost or benefit (-/+) per veh - California	$/veh	$0	$264	$153	$324	$0	$169	$104	$223	$0	$114	$79	$148
Societal cost or benefit (-/+) per veh - Rest of US	$/veh	$0	$65	$35	$82	$0	-$22	-$1	-$28	$0	-$13	$3	-$21
Average cost per ton of CO2 reduced - California	$/t$CO_2$	$0	-$111	-$128	-$92	$0	-$126	-$145	-$105	$0	-$123	-$139	-$102
Average cost per ton of CO2 reduced - Rest of US	$/t$CO_2$	$0	-$146	-$150	-$145	$0	-$138	-$107	-$144	$0	-$108	-$113	-$112
Hybrid market share	%	4.1%	4.4%	4.2%	4.6%	4.3%	4.5%	4.4%	4.7%	4.4%	4.6%	4.6%	4.7%

The feebate analysis above and nearly all of the cases analyzed assume that the feebate system is benchmarked to the CAFE footprint function. Each vehicle's feebate schedule is thereby a function of its footprint (wheelbase multiplied by track width). Use of the footprint metric in regulating GHG emissions and fuel economy is unique to the United States. Alternatives include the use of a single benchmark for all vehicles, or separate benchmarks for passenger cars and light trucks, or other ways of classifying vehicles. The footprint-based feebate program encourages consumers to purchase lower emission vehicles of any given size but does not encourage consumers to choose smaller, lower-emitting vehicles, as a single benchmark system would do. Because the single benchmark and car/truck benchmark systems encourage downsizing as well as choosing lower emission vehicles of a given size, they should have a greater impact on overall new LDV emissions than the footprint systems.

The single benchmark feebate system produces an initial reduction of 19 g/mi in average new LDV emission rates, compared with 13 g/mi for the footprint system (Figure 9.10). As expected, the car/truck benchmark system falls between the two. The impacts of the three systems evolve in a similar manner over time since they are influenced by the same basic forces of increasing stringency of emissions standards, and the rate of technological progress.

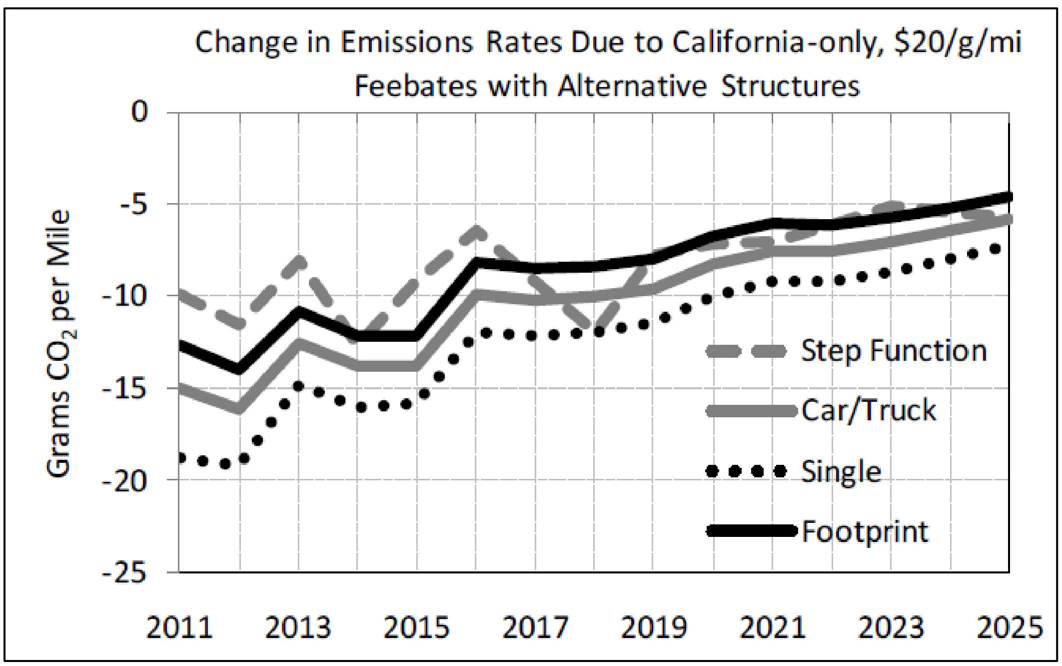

Figure 9.10 Change in New LDV Emissions Rates: $20 California-only Feebate: Alternative Structures.

The $20/g/mi footprint-benchmarked feebate has modest impacts on the market shares of different vehicle size classes. The footprint benchmark system tends to increase the market share of small cars (2-seaters, subcompacts and compacts), for example, by only 1 to 1.5 percentage points (i.e., from 27.0% of the market to 28.5%). As expected, the car/truck and single benchmark systems have larger impacts but the changes are still small, on the order of 2 and 3 percentage points, respectively (Figure 9.11). The effects of the step function are somewhat more erratic as a consequence of the discontinuities in the feebate function. Impacts on national market shares are approximately an order of magnitude smaller.

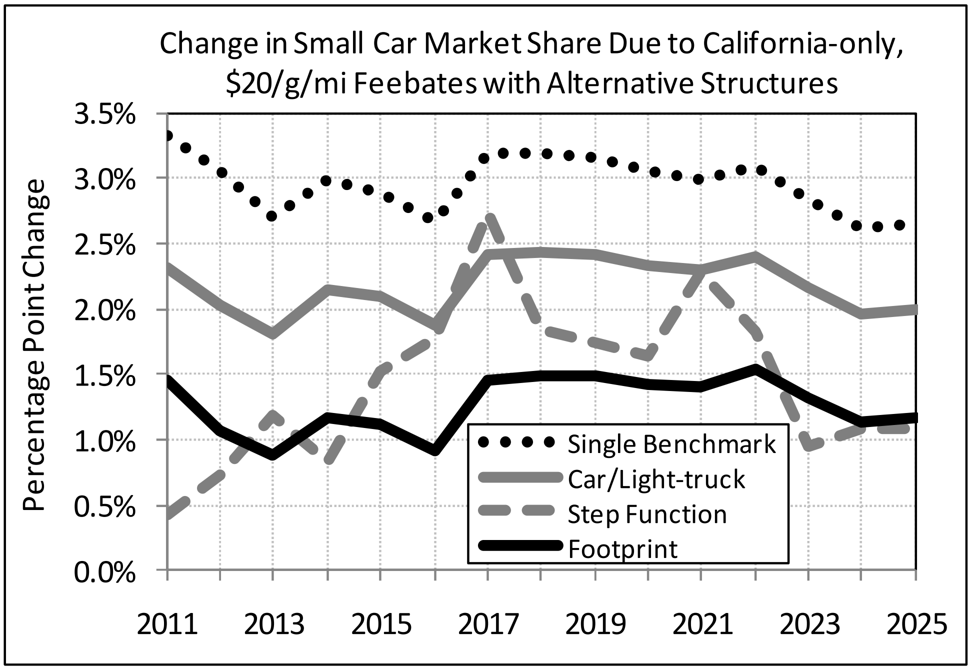

Figure 9.11 Changes in the Market Share of Small Cars: $20 California-only Feebate, Alternative Structures.

The sales mix shifts induced by the single benchmark and car/truck systems increase the cost of the feebate system via increased consumer surplus losses. These losses measure reduced consumer satisfaction as a consequence of the feebates moving some consumers away from the vehicle choices they would have preferred in the absence of feebates. The effect is to increase the (negative) cost per ton of CO_2 reduced by about $6 to $7 per ton in the case of the car/truck benchmarks and $7 to $8 per ton in the case of the single benchmark system. Still the societal costs per ton are negative and generally less than -$110 per ton of CO_2 avoided. Again, the negative mitigation costs depend on the assumption that the market undervalues fuel economy in new vehicle purchase decisions.

The final alternative structure considered was a step function feebate instead of a continuous linear function. The step function, however, is a single benchmark function similar to the French "Bonus/Malus" feebate system. The main reason the French chose a step function rather than a linear feebate function was their belief that car buyers would find a step function easier to understand. Their view was that grouping vehicles into classes with a fixed feebate for each class would be more comprehensible. While benchmarking a step function to the car and truck footprint functions is possible, doing so would result in a very complex feebate structure, defeating the purpose of the step function. The step function used here has an average slope of $20/g/mi but is comprised of five discrete steps: 1) 0-200 g/mi ,$4,000 rebate, 2) 201-265 g/mi, $1350 rebate, 3) 266-335 g/mi, $0, 4) 336-400 g/mi, -$1,350 fee, 5) >400 g/mi, -$4,000 fee. These points represent the step function in the first year of implementation, 2011. For an illustration of the step function, see Figure 8.4. In succeeding years the function is shifted toward lower emissions (fee and rebate levels are not changed) in an attempt to maintain revenue neutrality for the feebate system.

As Figures 9.10 and 9.11 show, the impact of the step function on vehicle emissions is similar to that of the linear footprint feebate. Although the step function is a single pivot point system it does not achieve emissions reductions as large as the linear single benchmark system. This is a consequence of the step function structure. From the manufacturer's perspective, the incentive to jump to the next better step is strong but once that step has been reached there is no incentive to continue reducing emissions. For some vehicles the jump to the next step will be too large to justify, and there will be no incentive to reduce emissions at all. A similar phenomenon occurs from the consumers' perspective. If a switch to a similar vehicle can be made that crosses the step boundary, there is a strong incentive to do so, but no incentive to choose an even lower emission vehicle. If moving to the next step requires too great a compromise in vehicle attributes, there is once again no incentive to make a smaller compromise.

A key difference between the step function and the linear function is the greater difficulty in anticipating net revenues from the feebate system because of the discontinuities in the step feebate structure. The problems encountered by the French government in achieving revenue neutrality for their Bonus/Malus system are described in the Lessons Learned chapter. The MDM includes a revenue neutrality algorithm that adjusts the feebate benchmark to achieve revenue neutrality. Given a linear feebate structure the algorithm was easily able to achieve revenue neutrality. The continuity and linearity of the system makes it easier to predict what will happen if the benchmark is changed. The step function poses a more complex problem and the algorithm struggled to find revenue neutral solutions (Figure 9.12). Not only is "step jumping" more difficult to predict but the impacts on revenue flows can be abrupt and large. Our algorithm successfully kept net revenues below $1,000 per year for the linear systems but produced fluctuations of hundreds of millions of dollars annually for the step function. While it would be difficult in the real world to match the performance of the computer algorithm (which has perfect foresight), the greater difficulty in achieving revenue neutrality with a step function is a real problem. Shifting the entire step structure *in toto* cannot be done in such a way as to guarantee revenue neutrality, even in theory. That would require shifting the relative positions of the steps. It is not clear how this could be done while preserving transparency to consumers and stability for manufacturers.

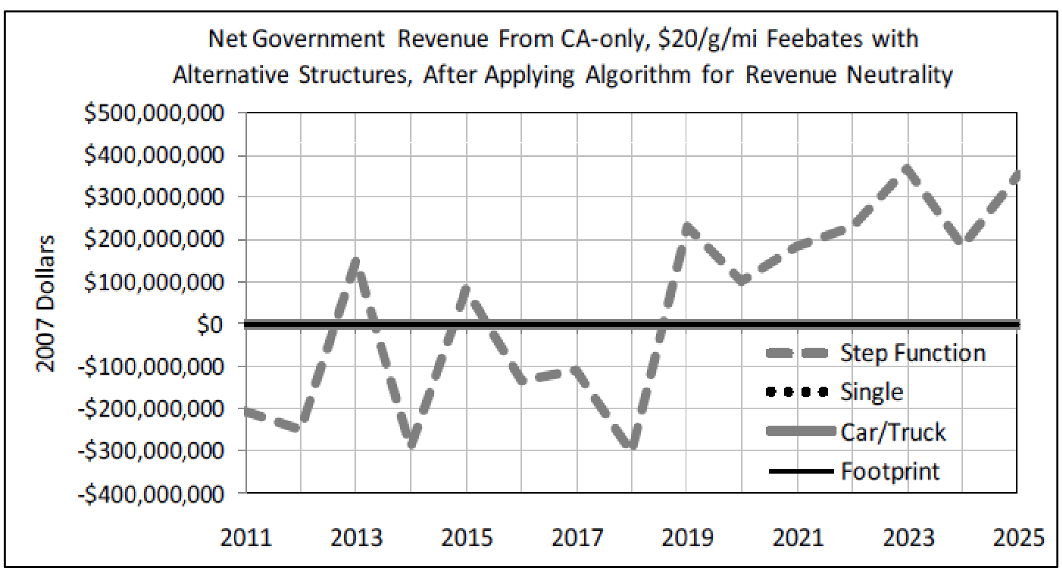

Figure 9.12 Net Government Revenue from $20 California-only Feebate Under Alternative Structures After Applying Algorithm to Achieve Revenue Neutrality.

9.1.4. The Effect of Fuel Prices

As discussed in Section 7, the Reference case uses the fuel price assumptions of the 2009 Annual Energy Outlook (AEO) ARRA projections (DOE/EIA, 2009)[47]. The two alternative price cases are based on the AEO 2009 Low and High Oil Price projections. In the Reference Case the price of gasoline drops from $3.17/gallon in 2008 to $1.90 in 2009 and then rises to over $3.00/gallon again by 2015 (Figure 9.13). The Low Oil Price projection remains at approximately $2.00/gallon through the end of the forecast period, while the High Oil Price Case is already above $3.00/gallon in 2011 and increases to over $5/gallon by 2020.

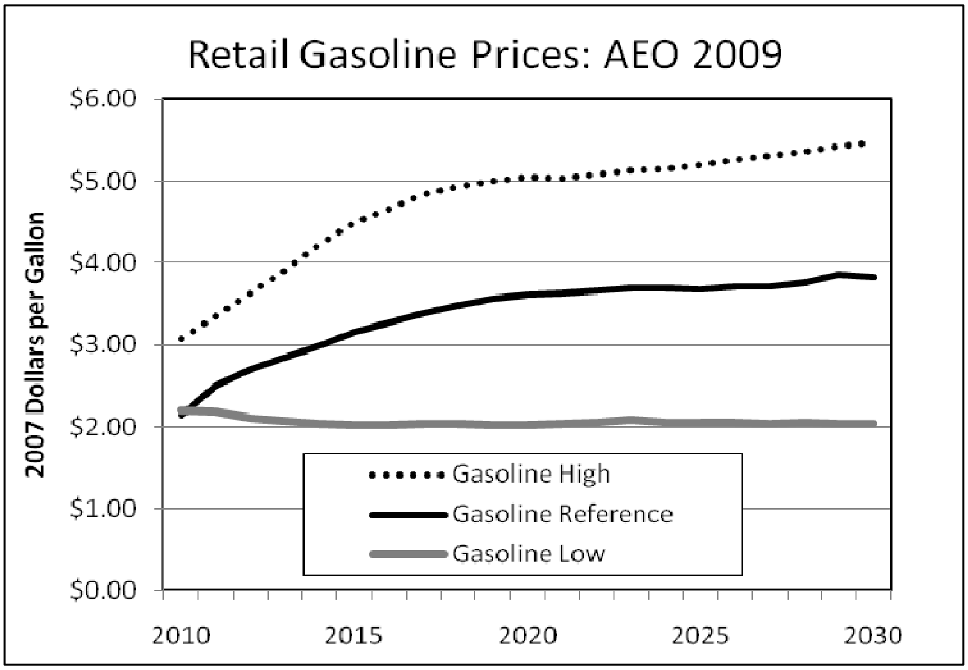

Figure 9.13 Retail Gasoline Prices in the 2009 AEO High, Reference and Low Oil Price Cases.

The price of gasoline, however, appears to have only a small impact on the effect of feebates on LDV GHG emissions. For both the High and Low price cases a new Reference case was run using the respective gasoline prices. Comparing the impact of a $20/g/mi California-only feebate across the oil price cases shows only minor differences in new vehicle emissions rates (Figure 9.14). In the High Price case, the emissions reduction is around 12 g/mi through 2015, gradually decreasing to 5 g/mi in 2025. In the Low Oil Price case the emissions reduction also begins at about 12 g/mi but begins to decline one year before the Reference Case and two years earlier than the High Oil Price case. The High Oil Price case remains 2-3 grams per mile below the other two cases over most of the time period. Nonetheless, all three cases end up at about 5 g/mi in 2025.

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[47] In 2009 the Energy Information Administration produced two versions of its Annual Energy Outlook projections. The first did not include the impacts of the stimulus packaged enacted later in the year. A second set of projections were developed to reflect the expected impacts of the stimulus package. It is the second run that we use as a Reference Case for this analysis.

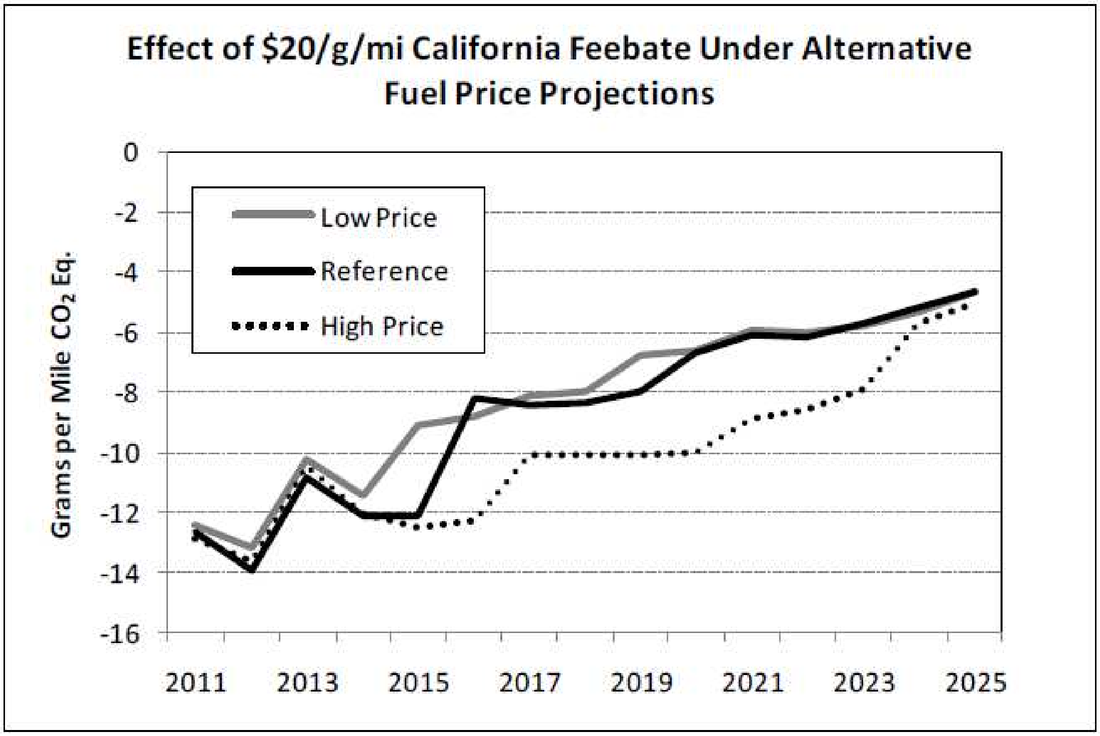


Figure 9.14 Effect of $20/g/mi California Feebate Under Alternative Fuel Price Projections

On the other hand, fuel prices have a large effect on the societal costs of the feebate system. In the High Oil Price Case, the societal cost per ton of CO_2 avoided begins at -$100/ton CO_2 in 2001 and decreases to -$200/ton before 2020. This compares with costs of -$60 to -$120 in the Reference Case. Again, this result is attributable to the assumption that fuel economy is undervalued in the new vehicle market.

9.1.5. The Costs of Emissions-Reducing Technologies

The Low, Middle and High technology cost curves developed for this study by ICF, International (see Section 5.1.2) were used to test the sensitivity of the Base Feebate system to the costs of emissions-reducing technologies. This sensitivity analysis applies only to technologies applicable to gasoline and diesel internal combustion engine vehicles and not to hybrids. A test of the sensitivity to hybrid costs follows immediately after in this section. There is relatively little difference between the impacts of the feebate system on new LDV GHG emissions per mile in the High Cost and Reference Cost cases (Figure 9.15). In the Low Cost case, the impact of the feebate system is greater than in the High or Reference Cost cases, especially in the years 2017 to 2023. Lower technology costs make it less likely that manufacturers would need to employ pricing strategies in order to meet emissions standards. In the Reference and High Cost cases, manufacturers do use pricing strategies after 2020. Pricing strategies have an effect on vehicle sales and emissions rates that is very similar to feebates. When manufacturers are already using pricing strategies to meet emissions standards, adding feebates allows manufacturers to reduce or eliminate their own pricing strategies and let the feebates do the work for them. The convergence of the three technology cost scenarios in 2025 reflects the fact that in that year manufacturers were using pricing strategies of a similar magnitude to the $20 feebate in all three scenarios.

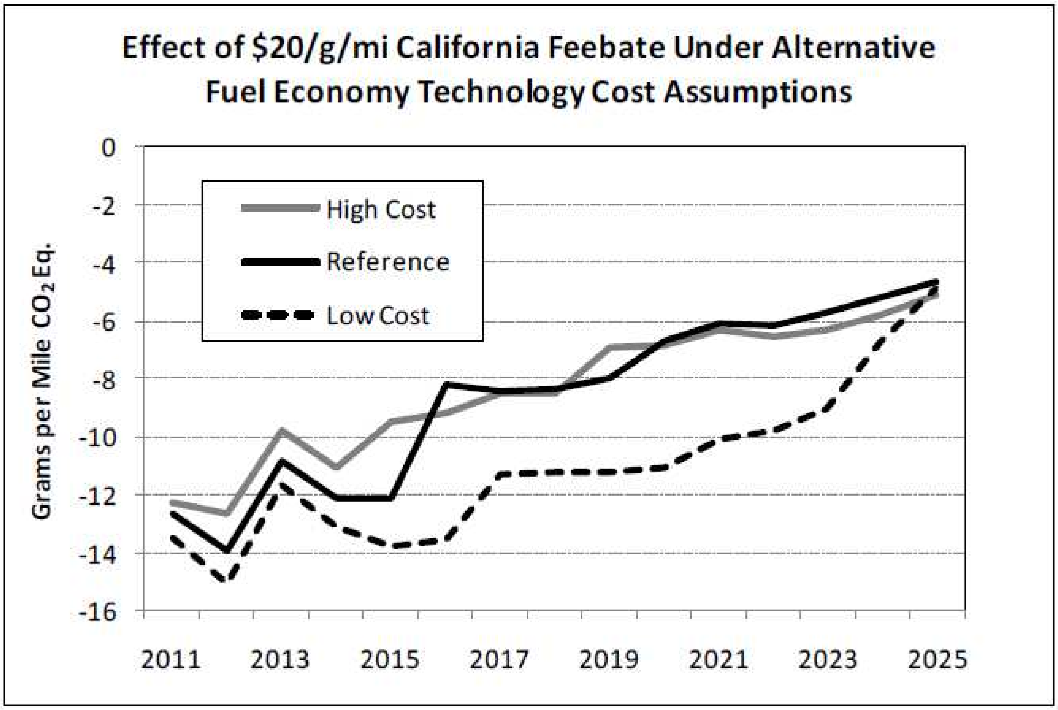


Figure 9.15 Effect of $20/g/mi California Feebate Under Alternative Fuel Economy Technology Cost Assumptions.

Estimating the impact of feebates on hybrid vehicle sales is considerably more difficult than estimating the impact of feebates on the emissions rates of conventional gasoline vehicles. The technologies for reducing GHG emissions included in our technology cost curves add cost to a vehicle but are otherwise almost invisible to the consumer. To predict the impact of feebates on hybrid vehicles, one must predict their impact on the availability of hybrid makes and models, as well as consumers' choices among makes and models. This introduction of an additional hybrid make/model/configuration is represented in the MDM as the decision by a manufacturer to convert an existing make/model/configuration to a hybrid powertrain. This transforms the nonlinear, dynamic optimization problem into a mixed integer/nonlinear dynamic optimization problem, an inherently much more difficult problem to solve. Experiments confirmed that, as is typical with such models, the solution found by the optimization software is highly dependent on initial conditions. In particular, which vehicles were assumed to be converted to hybrids in the future strongly influenced the outcome. Because of this, we first performed a side calculation to determine which vehicles had a greater net value as hybrids than as non-hybrids (see section 8.1.2 [Introducing Advanced Technologies] for details). This required calculating the net value for each vehicle as either a hybrid or a non-hybrid, considering the cost of conversion, the value to the consumer of fuel saved, the feebate if any, and the reduction in the shadow price[48] of the emissions

[48] In a constrained optimization model, the shadow price of a constraint is the value of relaxing the constraint by one unit, in this case by 1 g/mi. Thus, like a feebate, the shadow price is measured in $/g/mi.

constraint. This would give a precise optimum if we knew in advance the shadow price of the emissions constraint for the optimal solution. The shadow price of the constraint in a scenario in which no vehicles are converted to hybrids is a reasonable starting point but as soon as vehicles begin to be converted to hybrids the shadow price changes. Iteratively resolving using an updated shadow price suggests (but does not prove) that one iteration gives a solution very close to what would be obtained after many iterations. At a minimum, the method insures that hybrid conversions are responsive to the underlying economics. Nonetheless, it remains only a heuristic method, since it does not eliminate the dependence of the final outcome on the initial conditions.

The MDM estimates that, given our Reference assumptions of future hybrid costs, the market share of hybrid vehicles in California will respond to a California feebate but that the California feebate alone will not be sufficient to transform the California or US markets. Note that these estimates do not assume additional hybrid vehicle incentives, such as federal or state tax credits. The market shares shown in Figure 9.16 are based on the Reference hybrid cost assumptions provided by ICF, International. These assume that a typical midsize, 3,000 lb. passenger car would cost $5,100 more as a full hybrid until 2014, $4,500 more between 2015 and 2022, and $3,900 more in 2023 and later.[49] The $30/g/mi feebate nearly doubles the hybrid's market share in California in the early years relative to the Reference Case, and increases it by about 50% in later years. As non-hybrid vehicles become more fuel efficient over time they become more competitive with hybrids and the hybrid's market share decreases slightly.

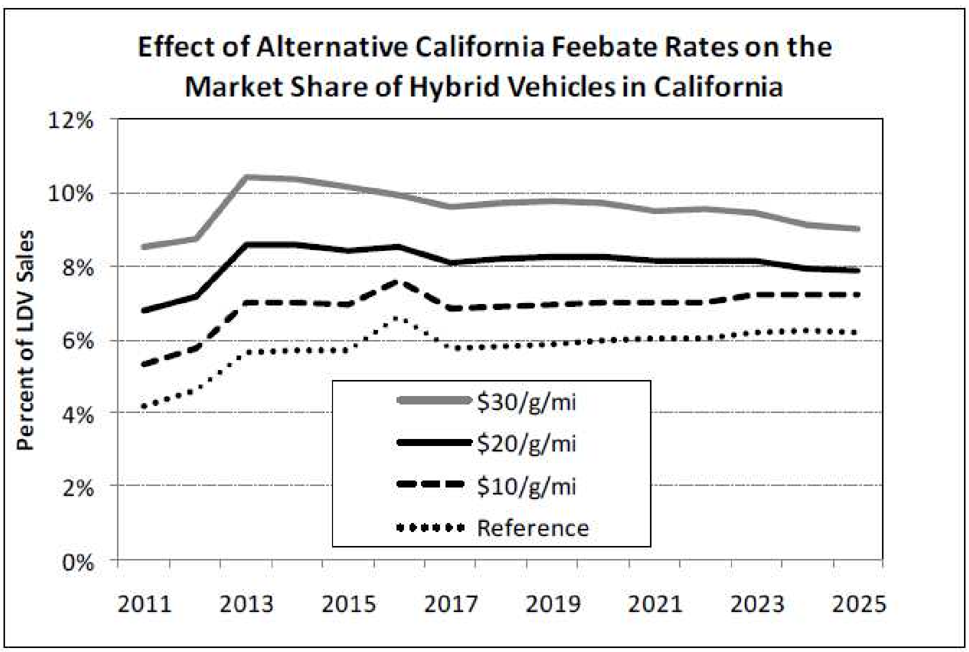


Figure 9.16 Effect of Alternative California Feebate Rates on the Market Share of Hybrid Vehicles in California.

[49] Only conversion to a full hybrid, similar to Toyota's power-split hybrid was considered. In reality, hybridization is a matter of degree. Honda's IMA system delivers a smaller increase in fuel economy but is also cheaper and more cost-effective. Considering a range of hybridization would likely have led to a greater impact of feebates on the market share of hybrids.

Other knowledgeable sources propose that future hybrid costs could be substantially lower than our reference assumptions (Bandividekar et al., 2009). Three alternative cases were run assuming that the costs of a 3,000 lb. full hybrid could be $4,260 from now to 2014, $3,200 over the period 2015-2022, and $2,160 after 2022 (a reduction of 45% from the Reference hybrid assumptions described above). Even with these lower costs there is very little difference between the $20/g/mi feebate cases shown in Figures 9.16 and 9.17. Only in the presence of a nationwide feebate system are manufacturers persuaded to convert a large number of make/model/configurations to hybrid power trains. In the California-only feebate cases the number of make/model/configurations offered as hybrids fluctuates between 78 and 82. In the US feebate case the number of make/model/configurations increases to 329 out of 985. In that case, the hybrid's market share begins to take off in 2020 and rises to nearly 30% in California by 2025 (assuming other assumptions remain constant).

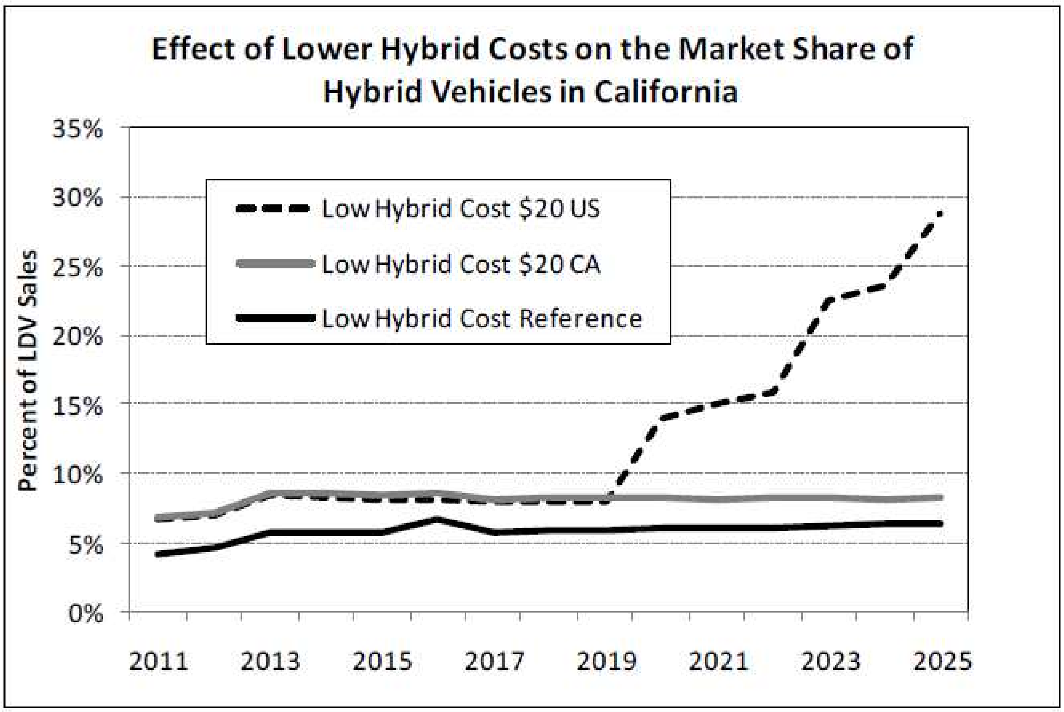


Figure 9.17 Effect of Lower Hybrid Costs on the Market Share of Hybrid Vehicles in California

9.1.6. How Consumers Value Fuel Economy

At the present time, it is not clear whether or not the market under- or over-values fuel economy relative to its expected present value.[50] Econometric studies are evenly divided between those that find evidence for under-valuing and those that conclude the market either accurately or over-values fuel economy relative to its expected present value (Greene, 2010a). The theory of rational

[50] We say "expected" present value because many of the factors that determine lifetime fuel savings are uncertain, notably the price of fuel and the fuel economy a vehicle will achieve in actual use. For a discussion of the many sources of uncertainty, see Delucchi, 2007.

economic behavior implies that markets should value fuel economy at its expected present value, unless consumers are risk averse. Prospect theory, on the other hand, implies that markets will undervalue fuel economy relative to its expected value by half or less, due to consumers' loss aversion (Greene, 2010b). In the MDM, we have assumed that consumers undervalue fuel economy, a view held by many automobile manufacturers. In this section the implications of valuing fuel economy at its full lifetime discounted present value are explored.

If the market valued the fuel savings due to fuel economy improvements brought about by reducing CO_2 emissions at their expected present value, discounting over the full lifetime of a new vehicle, emissions would be 5 to 30 g/mi lower than in the Reference Case (Figure 9.18). In addition, the emissions standards of the Reference case would not be a binding constraint on manufacturers. The incremental reduction brought about by a $20 feebate would be almost the same, however, whether or not the market fully value fuel economy or undervalues it. The reduction due to the feebate under the full lifetime value assumption (the difference between the two curves shown in figure 9.18) is initially 14 g/mi, falls to 8 g/mi for the period from 2012 to 2016 and then drops to 6 g/mi where it remains through 2025. Because the feebate affects the net price of a new vehicle, and because most of the effect of a California feebate is on the mix of vehicles sold, the feebate system has very nearly the same effect on GHG emissions rates whether the market undervalues fuel economy or not. This would not be the case for a national feebate system because a national program would have a much greater impact on the adoption of emissions reducing technologies than a California only program.

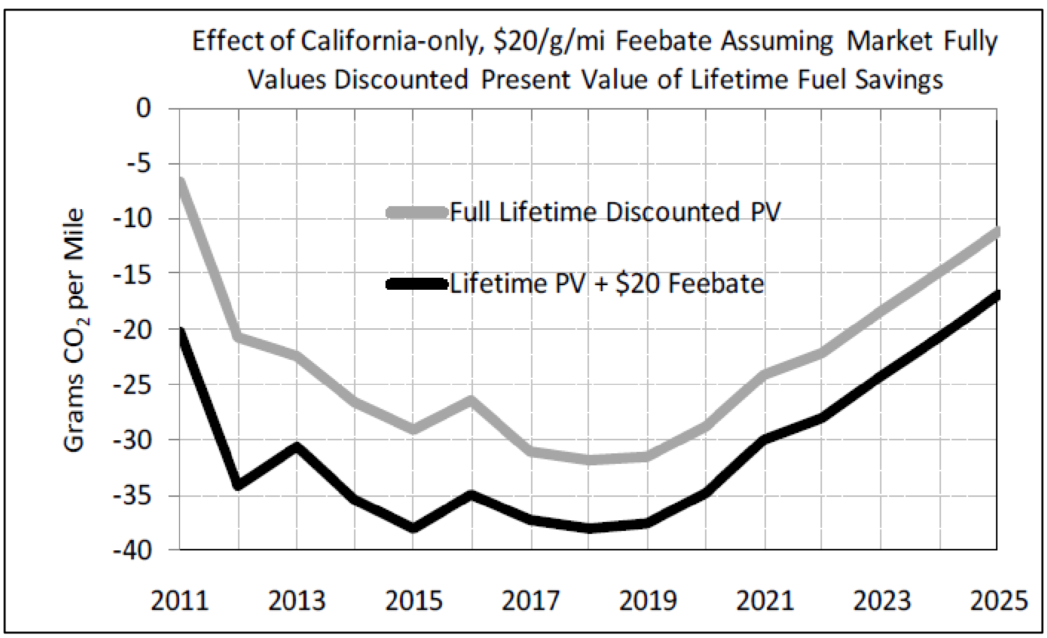


Figure 9.18 Change in New Light-duty Vehicle CO_2 Average Emissions Rates in CA Assuming the Market Fully Values Lifetime Fuel Savings.

9.1.7. The Sensitivity of Vehicle Choices to Vehicle Prices

The MDM was calibrated to 2007 vehicle sales data using a set of price elasticities for different vehicle types that is generally consistent with the existing literature on consumers' new vehicle choices. Since the effects of California-only feebates depends to a great extent on changes in the mix of vehicles sold, this section explores the effect of alternative assumptions about consumers' sensitivity to vehicle prices. In the High Price Elasticity case, the Reference Case price elasticities were multiplied by 1.25, implying that consumers would be more responsive to changes in vehicle prices. The Low Elasticity case is more complex. It first attempts to match the elasticities reported for a model built by NERA et al. (2007) and then reduces those elasticities by 20%. The NERA elasticities are already somewhat lower than the Reference elasticities, further reducing them provides a more extreme test of the sensitivity of estimated feebate effects to price elasticity assumptions. The result is an average reduction in elasticities at the level of makes and models of about 30%, a reduction at the level of vehicle class choice of about 45%, and a reduction at the level of choice between passenger and cargo vehicles of 50%.

The resulting estimations show that uniformly increasing the price elasticity of vehicle choice changes the impact of the feebate system very little (Figure 9.19). The lower price elasticities have a greater effect, reducing the impact of the feebate system on emissions rates by about one-third. Due to the complex change in the patterns of elasticity in the Low elasticity case it is difficult to interpret these results. It is clear, however, that the impact of a California-only feebate program will depend on consumers' sensitivity to vehicle prices. If, for example, price sensitivity decreased over time as consumers' incomes rose, the impact of a feebate program would decrease. This would be less true of a national feebate program in which a greater proportion of the impact would be due to increased adoption of emission reducing technologies.

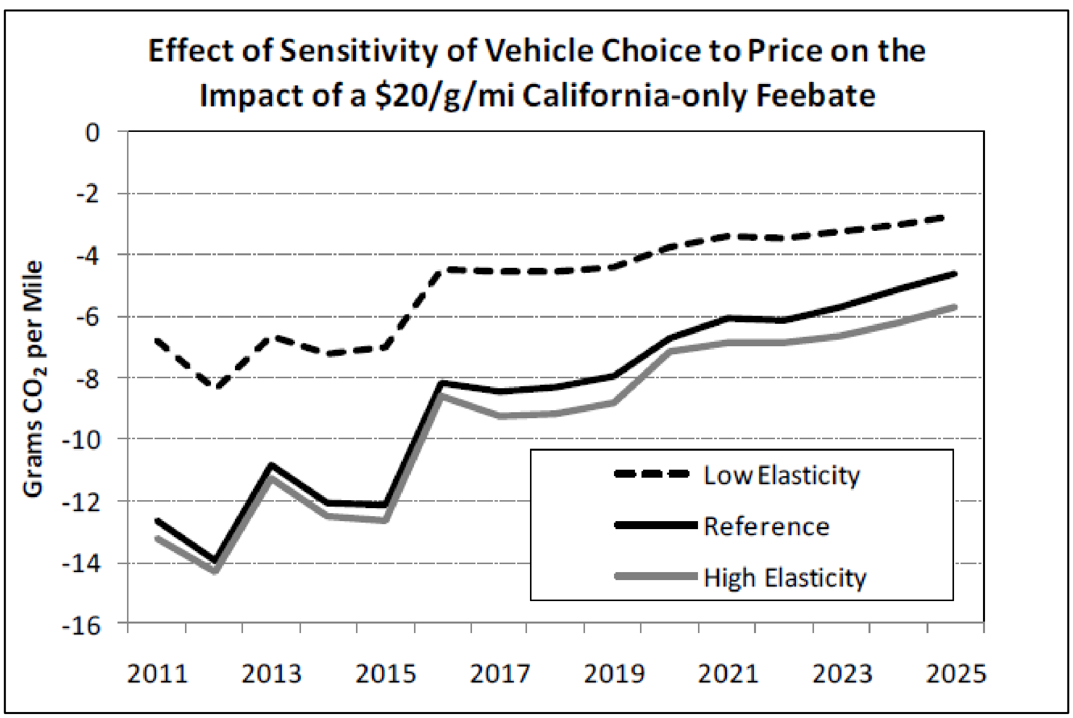


Figure 9.19 Effect of Sensitivity of Vehicle Choice to Price on the Impact of a $20/g/mi California-only Feebate.

9.1.8. Emissions Standards After 2016

How stringent GHG emissions standards are after 2016 could have a large influence on the impact of a California feebate system on vehicle emissions rates. As pointed out previously, the stringency of emissions standards and the rate of technological progress jointly influence the impact of feebates through the degree to which the emissions standards are a binding constraint on manufacturers. After emissions standards become a binding constraint, manufacturers may begin to use pricing strategies to steer customers toward lower-emission vehicles to help meet the emissions standards. Because manufacturers' pricing strategies function like feebate systems internal to the manufacturer, they dilute the impact of the feebate system on average emission rates.

The implementation of a feebate system relieves the manufacturer of the need to use internal pricing; the feebate system accomplishes the same result. Manufacturers reduce or abandon their pricing strategies and let the feebate system do the work. This is illustrated in Figure 9.20, which shows the impacts of the same feebate program under three different assumptions about the stringency of future emissions standards. All cases are based on the current emissions standards through 2016. After 2016, in the Reference Case emissions standards are lowered at the rate of 2% of the initial 2011 emissions level per year. If there is no further lowering of emissions standards after 2016 (the 0% case), the impacts of the $20/g/mi California-only feebate system stabilizes at about a 12 g/mi reduction. If the standards are lowered at only 1% per year, the impact of the feebate system begins to decline in 2020, decreasing to about a 7 g/mi reduction by 2025. A 4% per year reduction in emissions requirements after 2016 has an immediate impact on the efficacy of the feebate system, and by 2025 feebates reduce emissions relative to a 4% per year Reference case by only 4 g/mi. Of course, this reduction comes off of a much lower emission rate since the 4% standard requires the emission rate in 2025 to be about 20% lower than the 2% standard even in the absence of feebates.

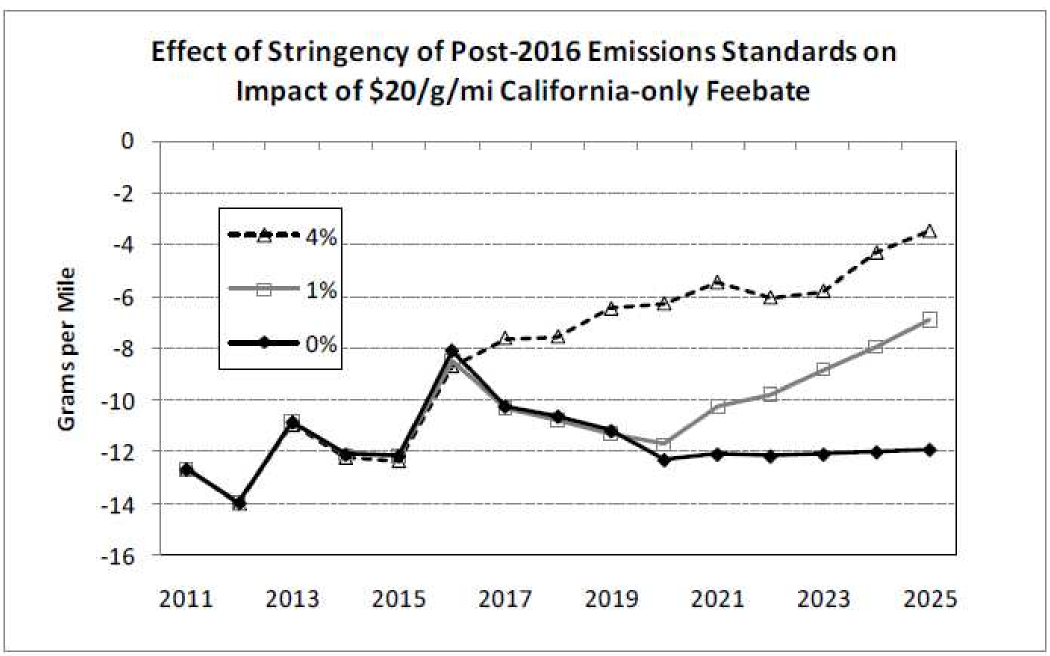


Figure 9.20 Effect of Stringency of Post-2016 Emissions Standards on Impact of $20/g/mi California-only Feebate.

9.1.9. Additional Sensitivity Cases

A variety of cases was run to test the sensitivity of the MDM's predictions to assumptions about the emissions standards' stringency, coverage and rules. The additional cases described here test the effects of allowing banking of credits earned by doing better than the standards in the past, the impacts of different assumptions about the costs of administering the feebate program, cases assuming that California standards are stricter than federal standards after 2016, and a calculation of what feebate rates would be required to achieve the same reduction in emissions as a California standard requiring a 4% per year reduction in greenhouse gas emissions, given no further tightening of the federal standards after 2016.

Banking Emissions Credits

The 2011 to 2016 emissions standards allow not only credit trading among manufacturers but also both banking of credits earned in the past five years and borrowing of credits from future years. In testing of the MDM, we found that implementing all of these features and internal pricing of vehicles by manufacturers proved to be too much complexity for a nonlinear optimization model intended to analyze on the order of 50 scenarios. We elected to implement the capability for manufacturers to price vehicles according to their deviation from the emissions standard in order to help meet the standard in any given year. We found that in 2016, the year in which FFV credits expire, the model did elect to use pricing to help meet the standard. Otherwise, pricing was relatively common only after 2020, when standards became more stringent and reducing emission via our technology cost curves became more expensive.

We ran two cases that allowed banking but not pricing: the reference case with banking and the base feebate case with banking. With banking but without pricing, the reduction in average new vehicle emissions with feebates was 1 g/mi greater than in the cases with pricing but without banking. The (unweighted) average reduction across all years from 2011 to 2025 was 9.5 g/mi with credit banking allowed but no pricing and 8.5 g/mi with pricing but not banking. In addition, with banking allowed, the 2016 emissions constraint was not binding since adequate credits could be earned in previous years. Without banking, the emissions constraint is binding in 2016 and manufacturers make use of pricing in 2016 to shift sales to lower emission vehicles. Given the option to bank credits earned by exceeding standards in prior years, the 2016 standard can be met without use of pricing. This result suggests that omitting the banking option from our standard runs is not likely to have a large effect on our emission rates impact estimates; we are more likely to be underestimating the impacts of feebates than overestimating them by omitting the banking option because banking allows manufacturers to avoid the use of pricing and pricing reduces the impacts of feebates. Including banking but not pricing slightly increases both spillover and leakage effects: the average net effect is -0.5 g/mi (net spillover) without banking but with pricing and -1.5 g/mi with banking but without pricing.

Impacts of Administrative Costs

Three cases were run to test the impacts of administrative costs for the feebate program. Administrative costs are assumed to be $3 per vehicle in the Base Feebate case. Administrative costs must be recouped by lowering the feebate pivot point to generate sufficient net revenue to pay for the costs of running the program. With approximately 1.5 million vehicles sold in California, the total revenue generated must be on the order of $4.5 million. A high cost case assumed administrative costs of $10/veh, a low case $1/veh and a third case assumed no administrative costs. The loss of consumers' surplus per vehicle, in comparison to no administrative costs passed on via feebates, is just slightly lower than the administrative cost per vehicle (e.g., in the $10 administrative cost case the average annual surplus loss per vehicle relative to the Base Feebate case is $9.75). The impact on vehicle sales in California is correspondingly small, 500 vehicles per year in the High Administrative cost case and 50 vehicles per year in the Low cost case, compared with no administrative costs. The impact on vehicle emissions rates is very small, on the order of thousandths of a gram per mile.

Note that the MDM does not predict market shares of ZEVs, which are based on a fixed scenario.

California Standards More Stringent than Federal Post 2016

If the federal government does not tighten emissions standards after 2016 (a possibility that seems highly unlikely at the present time since the EPA and DOT are currently preparing a rulemaking for post-2016 standards) there is little difference in the impact of feebates until the emissions standards in the Reference case become binding after 2015. Figure 9.21 compares the impacts of the $20 footprint feebate system in a case in which only California requires a 2% per year reduction in emissions, to the impact of the same feebate system under the Reference case assumptions, in which the entire US requires a 2% per year reduction. Initially, the impacts are similar to the Reference feebate case but after 2020 the feebate impact becomes very small (about 1 g/mi) in the California goes it alone case. This is because if California is the only state requiring emissions reductions post 2016, manufacturers are already using pricing as a major strategy for achieving the California standards. Adding feebates under these conditions allows manufacturers to reduce their internal pricing but has little impact on emissions rates. If the Opt-In states join California in setting post-2016 standards but the rest of the US does not, the initial impact of feebates is greater because more states are participating. As the standards become binding after 2020, the impacts of feebates diminish rapidly. This is once again because feebates increasingly substitute for internal manufacturing pricing strategies as standards become a more strongly binding constraint.

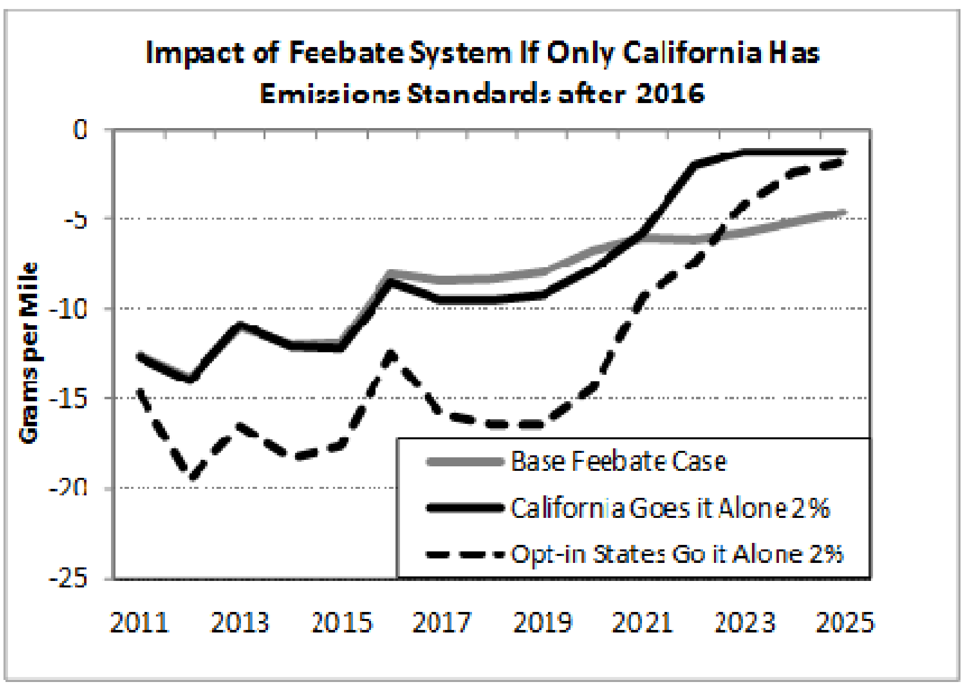


Figure 9.21 Impact of $20/g/mi Feebate System in California given varying scope of Emissions Standards After 2016.

A second set of cases considered the impacts of feebates should federal standards require a 2% per year reduction in emissions while California required a more challenging 4% per year reduction. Two feebate levels for California were tested: $20/g/mi and $30/g/mi. The impact of the feebates through 2015 is approximately -12g/mi for the $20 feebate and -18g/mi for the $30 feebate. After 2015, the impacts of both levels of feebate decrease to nearly zero, by 2019 in the case of the $20 feebate and by 2020 for the $30 feebate. This is again due to the feebate substituting for increasingly intense pricing strategies by manufacturers. To achieve the stricter California standards in the absence of a California feebate system, manufacturers implement an internal, feebate-like pricing system that begins at $25/g/mi in 2019 and increases to $125/g/mi by 2025. With a $20 California feebate, the internal pricing begins at $2.50/g/mi in 2019 and increases to $100/g/mi in 2025. With a $30 feebate, the manufacturers' internal pricing begins at $10/g/mi in 2020 and increases to $90/g/mi in 2025.[51]

A "LEV-III replacement" case considered how large feebate rates would have to be to achieve the same reductions in emissions as a 2% per year California standard in the absence of any tightening of federal standards after 2016. The results are considered in section 10.1.2.

9.2. California Vehicle Market Simulation Model (CARBITS) Results

Much of the analysis required for evaluating feebate policies can be done using the MDM. As described in Sections 5 and 8, the California Vehicle Market Simulation Model (CARBITS) is a totally separate model that takes the vehicle configurations from the MDM and uses them as input. It is true that CARBITS and the MDM both simulate new vehicle sales within California; however, they use completely different modeling approaches, and were not intended to be part of an internally consistent integrated system, so therefore the expectation is that they would almost certainly produce different numerical projections for the same outcome measures they share in common (e.g., new vehicle sales, average new vehicle emission rates, average new vehicle mpg, etc.). This intentional feature of our research design provides redundancy and allows for comparison of results from multiple methodological approaches. Of course, as also discussed, CARBITS has features that allow for more detailed analyses of the California market than the MDM. Two main features are the inclusion of the used vehicle market, and the capability to compute statistics for different household types to examine issues related to equity.

This section summarizes the results of various scenario analyses using CARBITS. It begins by giving an overview of how CARBITS behaves as a model, and why, including comparisons with the MDM.

[51] In theory, the sum of the feebate and internal price should exactly equal the internal price in the absence of the feebate system. The small differences seen here (e.g., $20 + $100 ≈ $125) are due to the particular way in which the internal pricing and the objective function were implemented in the feebate model. In subsequent experimentation we have developed a formulation that leads to exact equality. The practical differences between the two formulations are negligible, however. Those interested in the mathematical details may contact the authors.

9.2.1. New Vehicle Sales and the Effect of the Used Vehicle Market in CARBITS

Because they use different methodologies, CARBITS and the MDM exhibit different types of behavior when simulating new vehicle sales. Although some of these differences are due to different assumptions about how California consumers respond to vehicle prices and how they value fuel economy, a major structural difference is that CARBITS takes into account the existence of the used vehicle market.

To begin, we compare results from CARBITS and the MDM on two reference scenarios (EIA-Reference, and the 2%National Standard, or "Reference")—see Figure 9.22. The Reference scenario imposes an emissions standard with increasing stringency starting in 2017 whereas the EIA-Reference scenario does not. The MDM, which uses an aggregate approach and models the new vehicle market only, shows a steady increase in new vehicle sales over time. It can be seen that new vehicle sales for the Reference scenario versus the EIA scenario begin to separate for the MDM starting in 2017.

The new sales profiles for CARBITS in Figure 9.22 are qualitatively different. First, although CARBITS forecasts lower sales levels than the MDM in 2011, it has a steeper increase in new vehicle sales during the period 2011-2013 than does the MDM. New vehicle sales then level off for the period 2014-2016, experience an uptick in 2017, and actually begin to *decline* in 2018. The basic reason for the overall sales pattern in CARBITS is the inclusion of the used vehicle market. Because of the new vehicle emissions standards, there is a rapid improvement in fuel economy of new vehicles available for purchase during the initial period, and the new vehicles coming on line are much more attractive than the existing used vehicles in the fleet. However, this is a dynamic process. Once new vehicles enter the market, they then become available as used vehicles in later years. The relative advantage of new vehicles begins to wane as the used vehicle fleet "fills up" with higher fuel economy vehicles created during a period of dramatically improved standards.

Note also the inflections that occur in 2017 and 2021. These were discussed in section 9.1 for the MDM results, and the effect occurs for the same reason: Manufacturers offer improved fuel economy for some popular makes and models during these two years. The relatively larger size of this uptick in sales illustrates that CARBITS consumers place a higher relative value on fuel economy than MDM consumers.

Next, consider the differences between the EIA and Reference results for CARBITS versus the MDM. CARBITS and the MDM exhibit similar behavior for the period 2011-2020, in that EIA sales levels are higher than Reference sales levels. However, there are two differences over the period 2011-2025: (i) the gap between the two sales levels is larger for CARBITS over most of the period, and (ii) the lines cross in the year 2021, so that Reference case sales exceed EIA sales. Because emissions standards are more stringent in the Reference case, Manufacturers are generally offering more fuel-efficient vehicles but at higher prices than in the EIA case. The higher prices would explain the sales differences for both CARBITS and MDM over most of the period, with the effect being larger for CARBITS. At the same time, the gap in fuel economy gets larger and larger between the two scenarios after 2016 (because the emissions standard goes flat after 2016 in the EIA case). CARBITS' greater sensitivity to fuel economy would explain the crossover in 2021.

It may be that the CARBITS pattern of declining sales in later years might be considered "unrealistic" given historical patterns in vehicle sales. However, note that in this modeling scenario vehicles are only allowed to improve along one dimension: fuel economy. The improvements and innovations that are also likely to occur to support increased sales over time are not occurring in these scenarios, and the behavior of CARBITS is easily understandable. In contrast, the MDM has been calibrated to match a pre-determined increase in new vehicle sales projected by an outside source, so its sales will increase almost by definition.

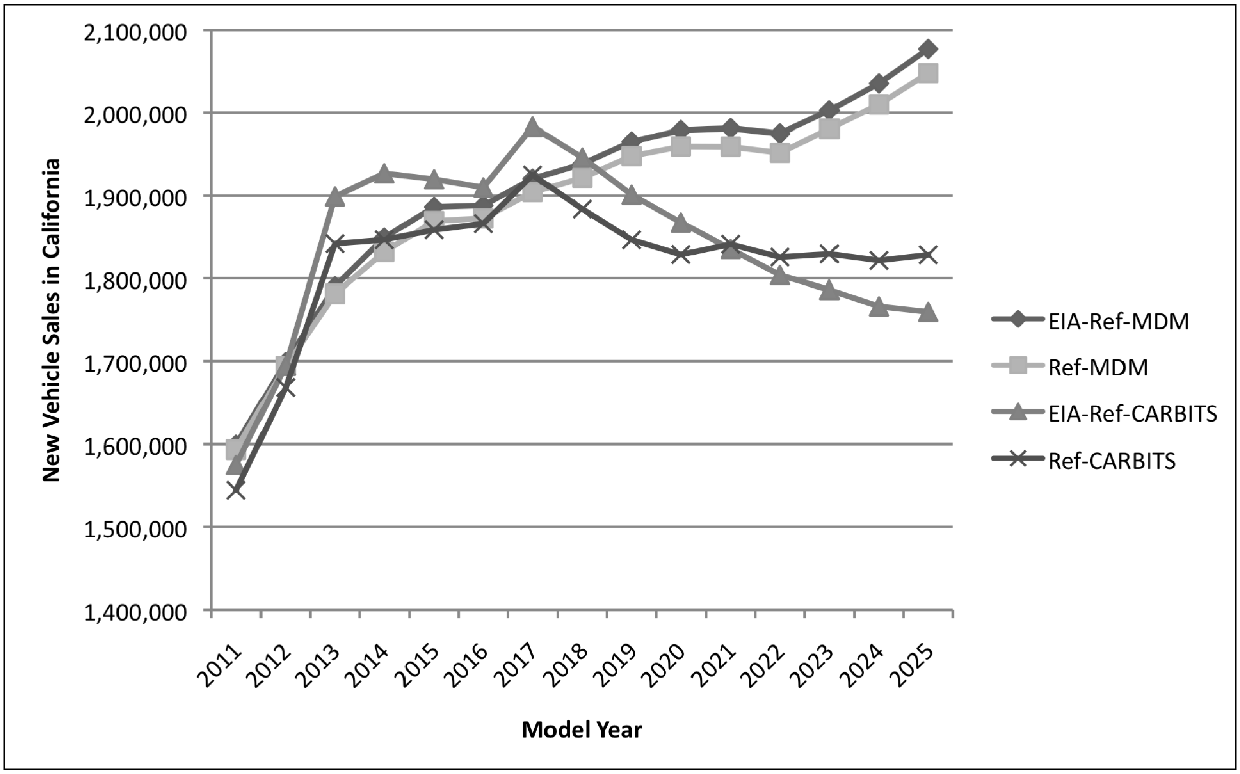


Figure 9.22 New Vehicle Sales from CARBITS and the MDM for Two Reference Scenarios

9.2.2. The Effect of Feebate Programs in CARBITS

The overall effect of California-based feebate programs in CARBITS can be very simply stated: *These programs have a relatively small effect on vehicle market behavior in California*. This is in contrast to the MDM, which shows larger improvements in new vehicle emissions due to feebates. Differences between CARBITS and the MDM for the Reference and Base Case (footprint with $20/g/mi rate) are shown in Figure 9.23. For the MDM, there is a clear improvement in average new vehicle emissions when going from the Reference to the Base Case, as has been discussed in previous sections. There is also an improvement for CARBITS, but it is much smaller. The CARBITS and MDM Base Case results in Figure 9.23 are virtually identical; however, the CARBITS Reference Case numbers in Figure 9.23 are smaller than those from the MDM. The reasons for this simply stated: Because the CARBITS consumer response model is less sensitive to vehicle price and more sensitive to fuel savings than the MDM, California households react strongly to the design changes required by emissions standards, but are then less influenced by feebates once this effect has been taken into account.[52] This is related to an important finding from the MDM: A California-only feebate

52 The consumer demand model in CARBITS is based on a completely different methodology than the MDM demand model. To review, CARBITS is based on household-level discrete choice models estimated from the Caltrans Travel Survey, whereas the MDM model is an aggregate demand model based on elasticities from the literature and assumptions on how consumers value fuel savings.

generates very small design changes relative to those induced by emissions standards. Most of the improvements due to feebates in the MDM are due to sales mix shifting. In contrast, CARBITS demonstrates very little sales mix shifting.

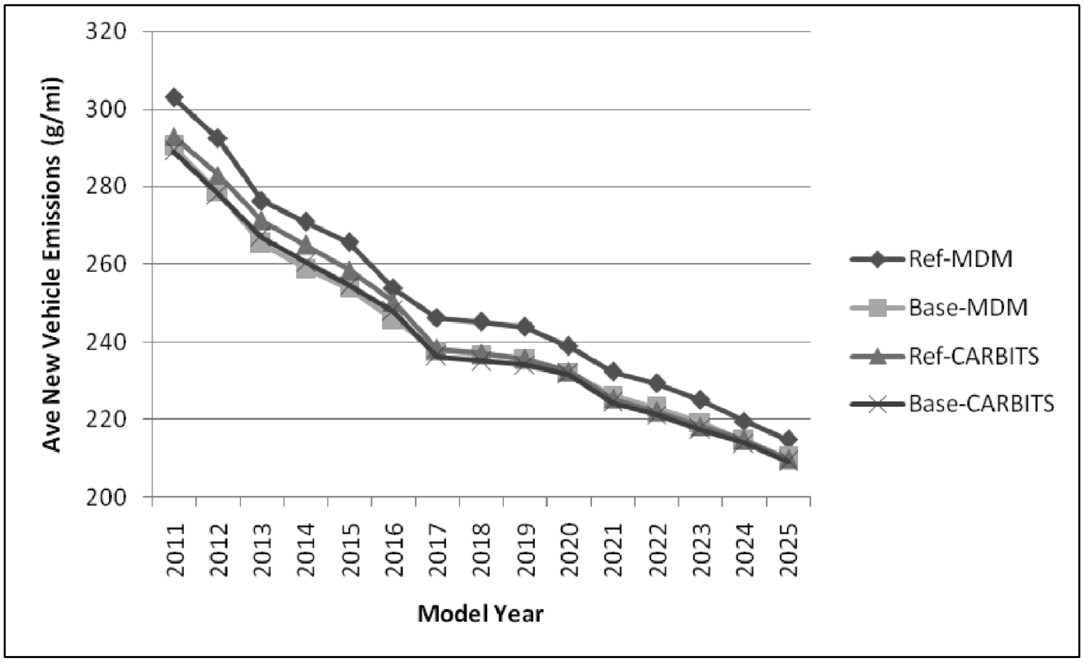


Figure 9.23 Comparison of Emissions for Reference and Base Case Scenarios

This point is further illustrated in Figure 9.24, which includes results under a National feebate system (footprint with $20/g/mi rate). In these results, the feebate shifts *both* the MDM and CARBITS results to *about the same location*. This is because, in the case of the National feebate, there is a much larger impact of the feebate on vehicle redesign, and less reliance on sales-mix shifting in the MDM.

For a comparison of the three different benchmark systems (Footprint, Single, and Car/Truck, all with a $20/g/mi feebate rate) see Figure 9.25. These results are qualitatively similar to those from the MDM, but are smaller in magnitude. Specifically, the Footprint yields the smallest reduction, the Single benchmark yields the largest reduction, and Car/Truck falls in between.

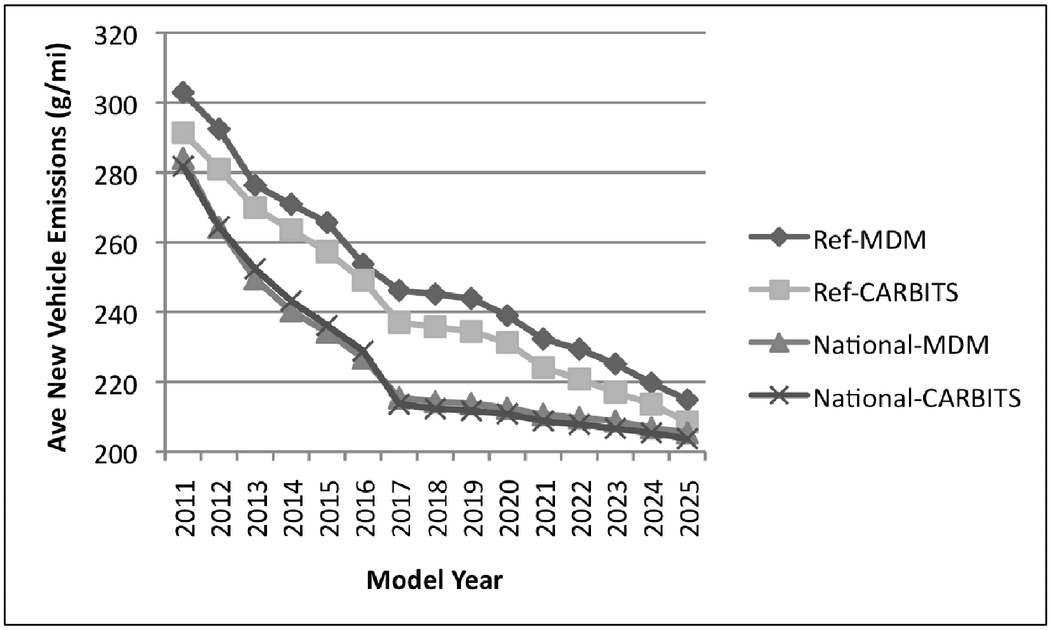


Figure 9.24 Comparison of Emissions for Reference and National Feebate Scenarios

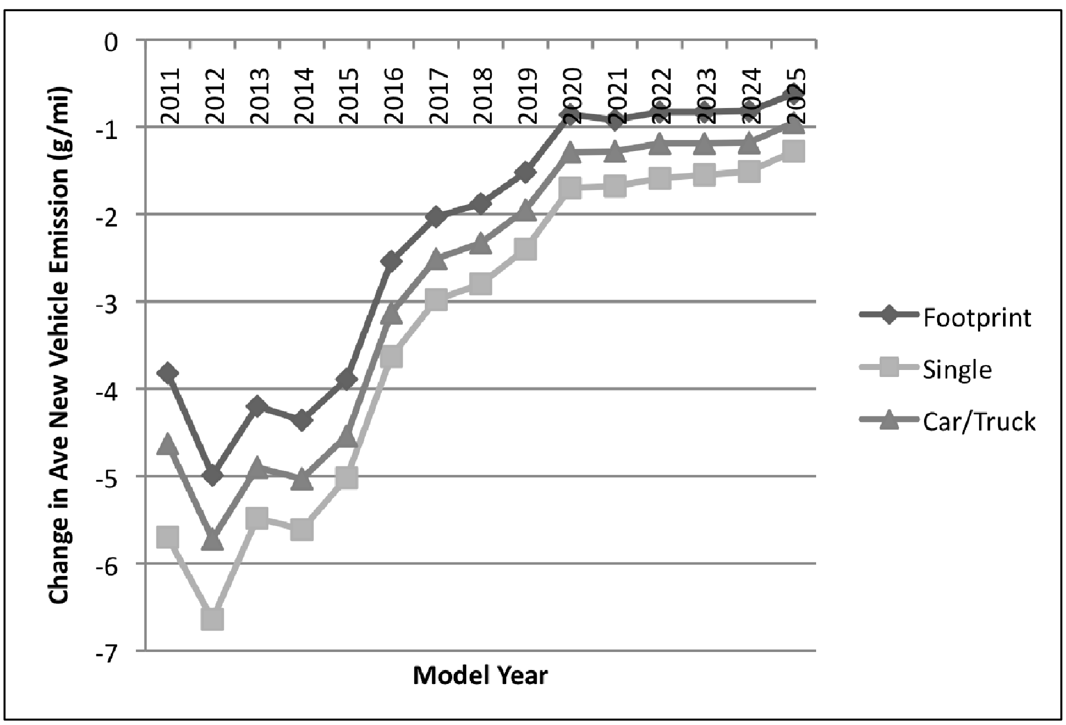


Figure 9.25 Comparison of Emissions Changes for Three Benchmark Systems

9.2.3. Comparison of CARBITS and MDM Consumer Response Models

Descriptions of the CARBITS and MDM consumer response models are provided in Chapters 5 and 8. Briefly, the MDM uses a top-down aggregate approach with a nested multinomial logit model consumer demand model, and CARBITS uses a bottom-up disaggregate approach that models household-level behavior using a nested multinomial logit structure. An important difference between these two models is that CARBITS captures differences in household behavior due to factors such as income and household size. Because the consumer behavior models are so different, it can be difficult to make comparisons. However, we provide two types of calculations that can be used to help make comparisons: Lifetime valuation of fuel savings, and price elasticities.

Lifetime valuation of fuel savings.

Equation (1) in Section 7 shows how the lifetime value of fuel savings can be computed. Using a variant of that equation, it can be shown that the full lifecycle costs (*LC*) of a new vehicle (in dollars) can be evaluated as

$$LC = P + \frac{1-e^{(\delta+\rho)L}}{\delta+\rho} M_0 \bullet \frac{OpCost}{100}$$

where *P* is the purchase price of the vehicle (*$*), M_0 is the miles driven in the first year, *OpCost* is the fuel operating cost of the vehicle (cents/mi), δ is rate of decline in vehicle use with age, ρ is a discount rate, and L is the expected vehicle lifetime. CARBITS uses utility function coefficients β_P and β_{OC} for *P* and *OpCost*, respectively, so that the utility associated with these values is given by $\beta_P P + \beta_{OC} OpCost$. Dividing the utility by β_p yields an expression for lifecycle costs from CARBITS. Equating the lifecycle costs from the two expressions

$$P + \frac{\beta_{OC}}{\beta_P} OpCost = P + \frac{1-e^{(\delta+\rho)L}}{\delta+\rho} M_0 \bullet \frac{OpCost}{100}$$

implies that the first year annual miles must satisfy

$$M_0 = 100 \frac{\beta_{OC}}{\beta_P} \frac{\delta+\rho}{1-e^{(\delta+\rho)L}}.$$

CARBITS has two sets of coefficients for its vehicle choice sub-models: One set for one-vehicle households, and one set for two-vehicle households—see Section 8.2.4. Moreover, the coefficients vary by household income. Table 9.4 uses the above equation to compute the implied first year annual miles (per vehicle) for one and two-vehicle households under the following assumptions: δ =0.02, ρ = 0.02, and L = 16 years. These annual first year miles are perhaps a bit high but not entirely unrealistic, and are generally consistent with assumptions whereby households make their vehicle choices on the basis of fully valuing (or perhaps slightly over-valuing) fuel savings associated with vehicle fuel economy. In other words, CARBITS households behave as though they place a very high value on fuel savings. This is in contrast to the MDM, which assumes that consumers only value the first three years of fuel savings. This illustrates how CARBITS is more sensitive to fuel efficiency changes than is the MDM.

Table 9.4 Estimated Annual First Year Miles for CARBITS Households

Income	One-Vehicle HH	Two-Vehicle HH
<$10K	8,713	11,492
$10-25K	12,377	16,324
$25-50K	15,614	20,595
$50-75K	17,881	23,584
>= $75K	21,048	27,762

Assumptions are: δ =0.02, ρ = 0.02, and L = 16 years

Elasticities

Own- and cross-price elasticities of demand were computed for new vehicles during the year 2010, which is the same for all scenarios. The average values within each of the twenty vehicle classes are reported in Table 9.5. The own-price elasticities are similar to some that have been reported in the literature, but are generally on the low end of these estimates. The elasticities for prestige-type vehicles tend to be noticeably larger than for their non-prestige counterparts. For light-duty trucks, elasticities tend to increase with size.

Also reported is the average of the within-class cross-elasticities. We do not reproduce here the full 20 x 20 matrix of cross-elasticities; however, these values are actually similar in value to cross-elasticities for vehicles *outside* the class that might be regarded as close substitutes. For example, midsize SUVs and large SUVs have larger cross-elasticities than do, e.g., small cars and large SUVs. This observed pattern is consistent with the fact that this version of CARBITS incorporates a nested logit structure for vehicle classes (in the case of the one-vehicle household model), and pairs of vehicle classes (for the two-vehicle household model). However, the pattern is not as strong as that exhibited by the MDM, which uses a nested logit structure with a very high degree of substitutability (larger elasticities) within a vehicle class.

The elasticities in Table 9.5 may be compared to the elasticities reported in Table 8.4 for the MDM. The MDM elasticities are much larger, with the implication that CARBITS is much less sensitive to price changes than is the MDM. This is consistent with our earlier interpretation of numerical results for CARBITS versus the MDM.

To review, CARBITS and the MDM are based on very different modeling approaches that give rise to differences in their behavior. The relative merits of alternative modeling approaches can be the subject of endless debate that will never reach a consensus conclusion. Our view is that it is important to understand the similarities and differences of alternative modeling approaches, and to take these into consideration when interpreting the analyses and developing policy implications.

Table 9.5 Average of Own- and Cross-Price Elasticity of Demands by Vehicle Class

Vehicle Class	Ave Own-Price Elasticity	Ave Cross-Price Elasticity (within Class)
Prestige Two-Seater	-2.72	0.00329
Prestige Subcompact	-2.63	0.00436
Prestige Compact and Small Station Wagon	-2.17	0.00601
Prestige Midsize Car and Station Wagon	-2.58	0.00872
Prestige Large	-3.83	0.00496
Two-Seater	-1.89	0.00144
Subcompact	-1.40	0.00341
Compact and Small Station Wagon	-1.35	0.00403
Midsize Car and Station Wagon	-1.48	0.00520
Large Car	-1.84	0.00375
Prestige Small SUV	-2.19	0.00122
Prestige Midsize SUV	-2.22	0.00123
Prestige Large SUV	-2.34	0.00086
Small SUV	-1.19	0.00207
Midsize SUV	-1.60	0.00189
Large SUV	-1.83	0.00190
Minivan	-1.33	0.02449
LargeVan	-1.38	0.01634
Pickup Small	-1.40	0.00588
Pickup Standard	-1.77	0.00314

9.2.4. Effects of Policies on Different Income Groups

One of the stated features of CARBITS is its ability to analyze the effect of feebate policies on income groups. As noted previously, CARBITS has a very small response to feebate policies compared to the MDM. However, CARBITS does respond to feebate policies, and does so in a manner that is qualitatively similar to the MDM. The primary difference is its lower degree of sensitivity.

Rebates and Fees

To begin, we consider what the pattern of rebates and fees looks like by income category. Table 9.6 provides a summary of rebates and fees per vehicle for two feebate policies: Footprint and Single Benchmark (both with a $20/g/mi rate). These figures are computed as the average per new vehicle sold in that category, over the entire analysis period (2011-2025). The average net feebate is also computed.

As in the MDM, fees outweigh rebates on a per vehicle basis. However, in contrast to the MDM, the overall average rebate and fee for the Footprint system is a bit lower. At the same time, the net feebate for CARBITS is about the same. This is generally consistent with our previous discussion in which it was established that CARBITS is less sensitive to feebates than the MDM, with less sales mix shifting, but otherwise behaving similarly. Also, as with the MDM, the levels of rebates, fees, and feebates are larger under the Single Benchmark than under the Footprint system. This would be expected due to the properties of the benchmark, regardless of any sales-mix shifting.

Under both systems the average fee and average net feebate per vehicle increases (gets more negative) with increasing income. This is consistent with the fact that price sensitivity decreases as income increases. Under the Footprint, the average rebate increases with increasing income (although the increase is modest). However, under the Single benchmark, the average rebate decreases with increasing income. Based on this pattern of fees and rebates, it could be said that both feebate systems are non-regressive with regard to income. Although the overall average net feebates are similar under the two systems, it appears that the Single benchmark system is more "progressive" on the basis of net feebates. Having said this, it is important to remember that these figures are computed on a per vehicle basis, and the number of new vehicles purchased per household decreases dramatically with decreasing income.

Table 9.6 Rebates and Fees by Income Group for Two Feebate Policies

Total HH Income	Footprint			Single		
	Rebate per Veh	Fee per Veh	Feebate per Veh	Rebate per Veh	Fee per Veh	Feebate per Veh
<$10K	528	-512	93	773	-739	272
$10-25K	532	-577	-7	750	-843	57
$25-50K	533	-617	-68	739	-901	-70
$50-75K	533	-641	-107	730	-939	-156
>= $75K	538	-739	-245	709	-946	-291
Total	534	-639	-99	734	-894	-91

Consumer Surplus

As in previous sections, one useful measure for evaluating the impact of policies is consumer surplus (CS). CARBITS was set up to compute this measure at the level of household type in order to facilitate comparisons. First, recall that it is not generally possible to consider absolute measures of CS; rather, one computes consumer surplus *changes* in order to make comparisons.

As an initial exploration, we computed a weighted average of consumer surplus across all households in each year for each policy option. In addition to the Reference scenario, we consider three benchmark systems (Footprint, Single, Car/Truck). The change in average consumer surplus from their 2010 levels was then computed for each year—see Figure 9.26. For all policy options, average consumer surplus decline increases in magnitude each year until 2017, and then decreases in magnitude until the end of the simulation period in 2025. This pattern is likely to be due to a combination of effects. Early in the period there are increased new vehicle prices associated with dramatic improvements in vehicle efficiency through 2017. Thereafter, improvements occur at a slower pace; however, at the same time, technology improvements should be bringing down the cost per vehicle associated with a given level of efficiency. Finally, recall that new vehicle sales levels begin dropping in 2018—see Figure 9.22.

Aside from the overall shape of the curves, one main finding is that there is very little difference in the average change in consumer surplus *between* the policy options from a longitudinal perspective; similar to earlier findings, this suggests that the addition of a feebate policy has a relatively small impact on consumer surplus after the change due to national fuel economy standards has been taken into account.

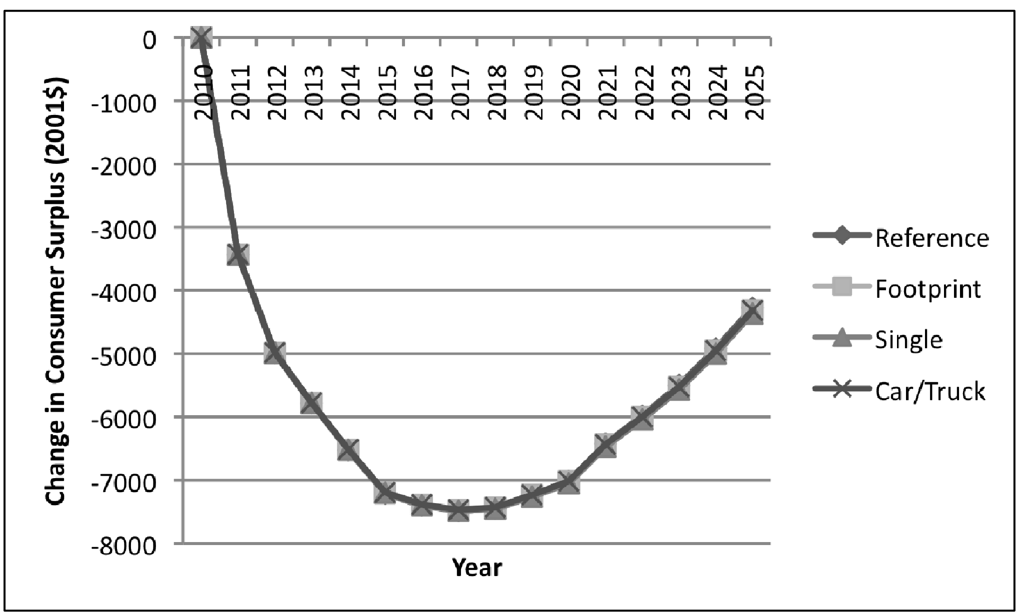


Figure 9.26 Change in Average Consumer Surplus from the 2010 Base Year Level Under Various Policies

However, there are some measurable differences among the three benchmarks in terms of change in consumer surplus versus the Reference case. See Figure 9.27. The pattern in this figure is different from the MDM, e.g., see Figure 1.8. First, the values are smaller in magnitude. Second, the

MDM values are negative over the entire range of years, whereas in the CARBITS results there are areas where the change in average CS *increases*. The change in CS is positive (or close to zero) for both the Footprint and Car/Truck systems until 2020, and negative thereafter. The crossover point is 2018 for the Single benchmark. The change in CS is similar for the Footprint and Car/Truck systems after 2020; the change in CS is more negative for the Single benchmark than for the other two systems starting in 2018. This pattern is similar to the MDM, in the sense that, for the MDM, the change in CS is more negative post 2018 versus prior to 2018—see Figure 1.8.

The pattern in Figure 9.27 is due to differences between the MDM and CARBITS that have already been discussed. Specifically, the CARBITS consumer model places a greater value on fuel savings and is less price-sensitive than the MDM consumer model. In the early years, small improvements in fuel economy due to feebates appear to outweigh the disutility associated with effect on vehicle prices. In later years, when price levels for vehicles are higher due to more expensive technology, the feebate systems yield a net negative change in consumer surplus similar to that seen in the MDM. There is one qualitative difference with the MDM: The Car/Truck benchmark appears to out-perform the Footprint system on this measure (although the differences are small).

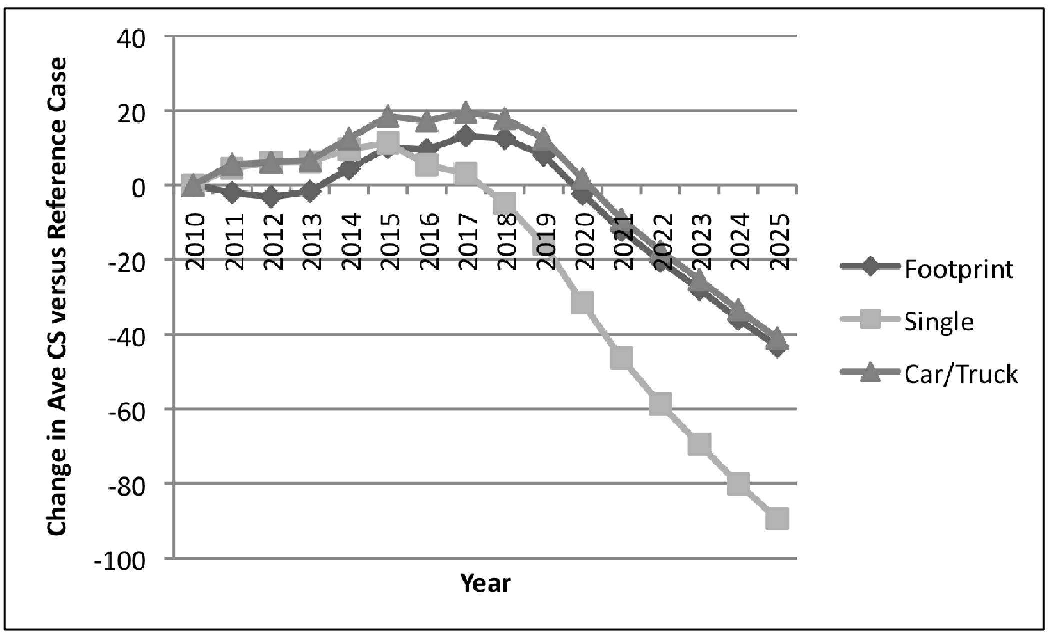


Figure 9.27 Change in Consumer Surplus for Three Benchmark Systems (versus the Reference Case)

In the remaining analyses, we continue to compare changes in CS for feebate policies versus the Reference scenario. For these comparisons we compute average CS for individual household segments defined by Total Household Income category as in, e.g., Table 9.6. Weighted averages are computed by using household weights available for each year of the simulation from 2011-2025.

The first finding is that *the change in average consumer surplus depends on income level*. See Figure 9.28. The change in average CS is positive for the two lowest income categories, and negative for the two highest income categories, in all three benchmark systems. For the Footprint and Single benchmark systems, the trends are monotonic in income. Moreover the Single benchmark has a much steeper slope than the Footprint. Note that these results are entirely consistent with earlier results in Table 9.6 on average rebates, fees, and feebates per vehicle. The pattern of fees and rebates paid and received would be expected to have a direct effect on consumer surplus. The Car/Truck system has an anomaly versus the other two systems: The pattern reverses itself for the highest income group. It may be that having two separate benchmarks creates a more favorable pricing structure for sale of larger light-duty trucks, many of which are held by high-income households.

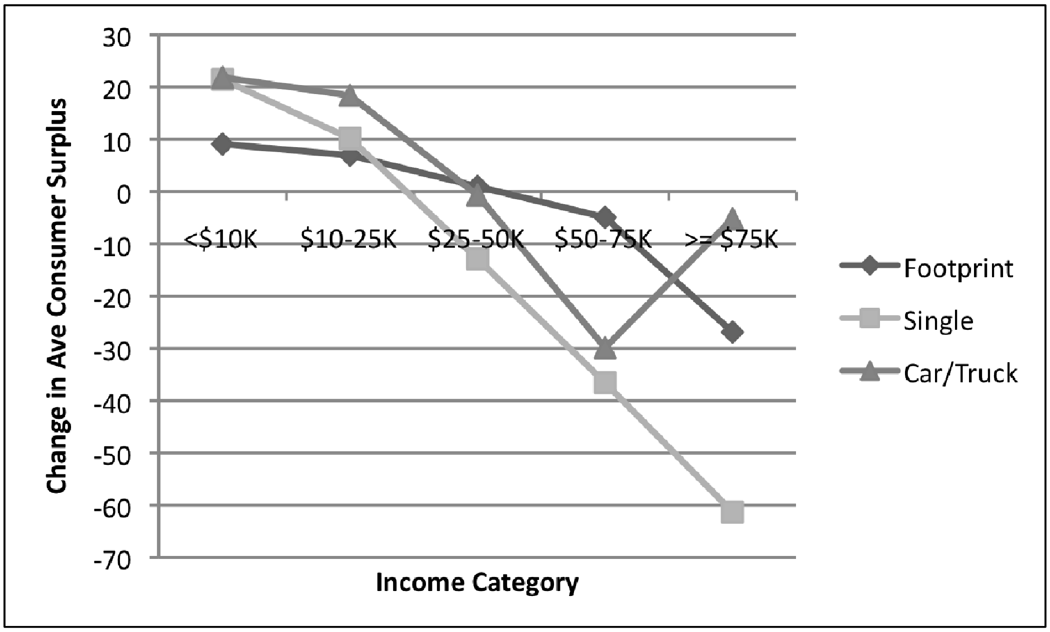


Figure 9.28 Change in Average Consumer Surplus by Income Category

Figure 9.28 (together with Table 9.6) would suggest that the effect of feebates is non-regressive with respect to relative impact on income groups. In fact, it would appear that higher income groups are "harmed" more than lower income groups are "helped" by these policies. However, consider that a change in CS essentially represents a change in income measured in absolute dollars. A one-dollar change may mean more to a low-income household than a one-dollar change does to a high-income household. An alternative comparison would be to consider change in average CS on a percent-of-income basis. We provide this comparison, using representative incomes for the categories are as follows:

1. < $10,000 = **$7,500**
2. $10,000 - $25,000 = **$17,500**
3. $25,000 - $50,000 = **$37,500**
4. $50,000 - $75,000 = **$62,500**
5. > $75000 = **$100,000**

See Figure 9.29. When adjusted to a percent-of-income basis, all three curves take on a non-linear shape that illustrates the diminishing impact of CS changes as income increases. According to this measure, lower income groups continue to see a positive benefit associated with feebates. However, the "harm" accorded to higher income groups decreases quickly. Having said this, it is helpful to keep in mind that all of these numbers are in actuality rather small.

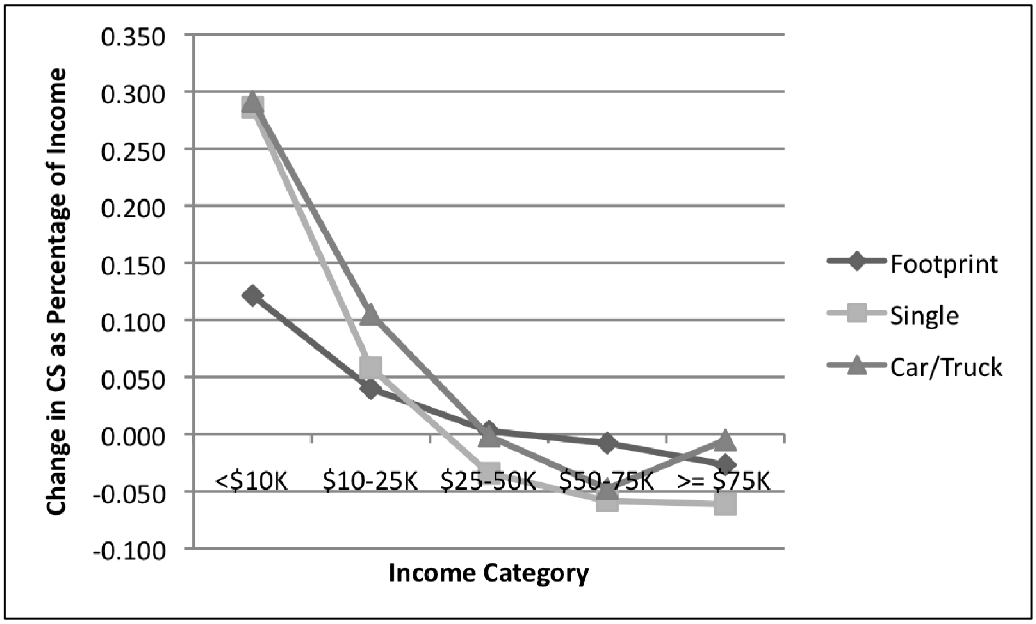


Figure 9.29 Change in Consumer Surplus as a Percentage of Income

To gain a greater understanding of what is causing these changes, we compute the CS changes on a year-by-year basis. See Figures 9.30 through 9.32 for each of the three benchmark systems. The year-by-year results for the changes in consumer surplus as a percentage of income are consistent with the previous results, as expected. However, these figures give additional information on the pattern of CS changes over time. Generally speaking, the profiles in all figures tend to increase in the earlier years, reach a peak somewhere in the middle, and then come back down. However, there are important differences by income group. The lower income groups see much larger increases, and the curves are separated from those of the higher income groups. For most years, the change in CS is positive for the two lowest income groups. (In the case of Car/Truck, it is positive in *all* years.) . Overall, our interpretation of the dynamics in these figures is: *As more efficient vehicles penetrate the used vehicle market and find their way into the hands of lower income groups, there is a notable effect on average consumer surplus for these groups*. This is the type of effect that can occur using a model like CARBITS.

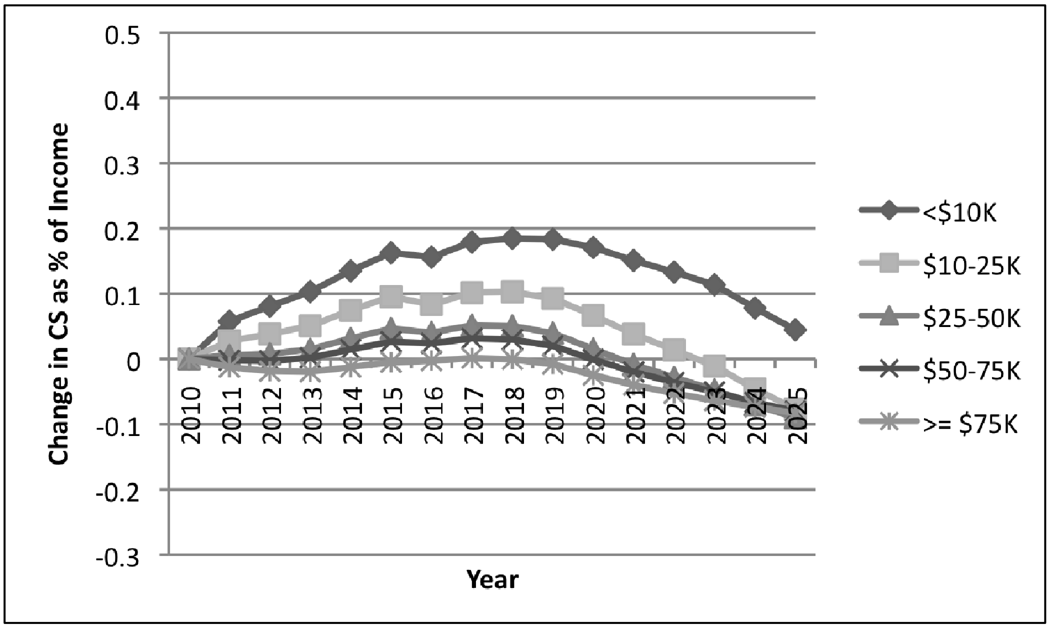


Figure 9.30 Change in CS for Footprint by Year and Income

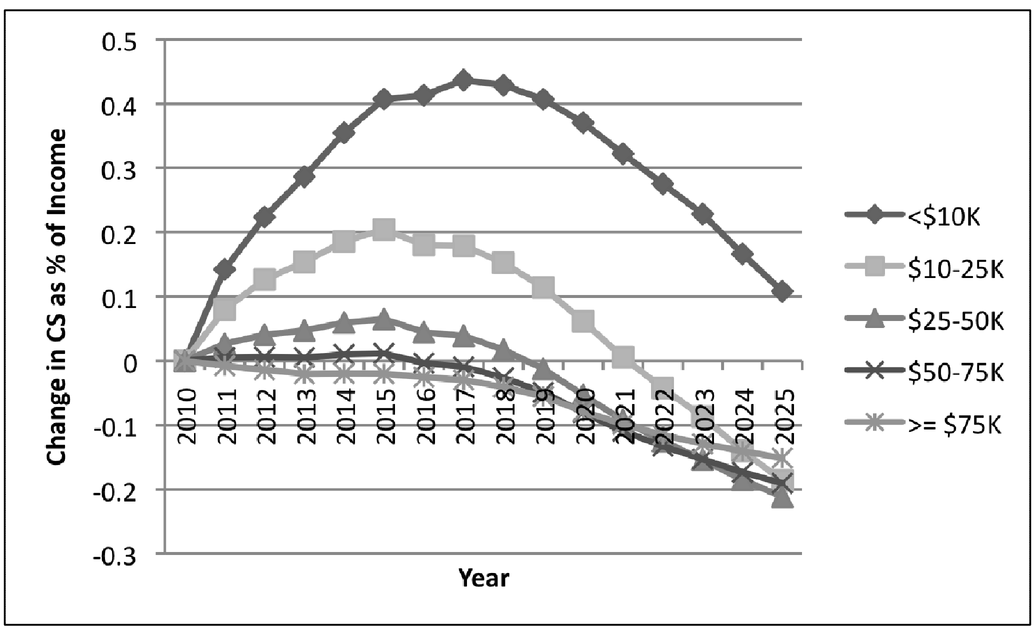


Figure 9.31 Change in CS for Single Benchmark by Year and Income

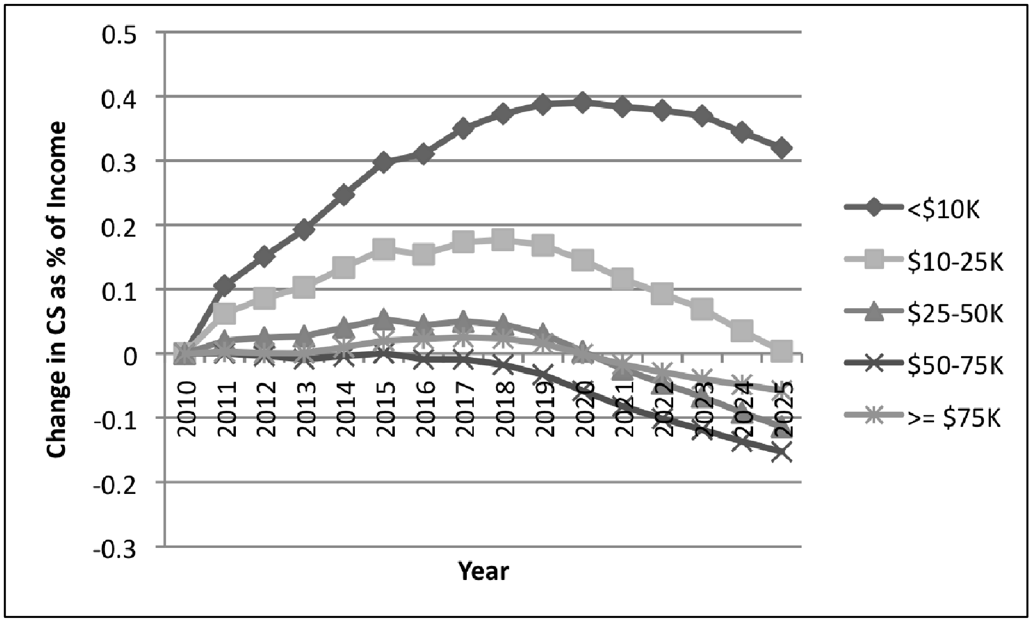


Figure 9.32 Change in CS for Car/Truck Benchmark by Year and Income

Fuel Economy

One question that frequently arises is: What does average fuel economy look like for households of different income levels? Using CARBITS results, we computed the weighted average mpg of vehicle holdings (new or used vehicles) for each household income segment over the entire period. For average mpg of held vehicles, see Figure 9.33. First, note that the differences across income groups are relatively small (range of 1 mpg). The income group with the lowest average mpg is the highest income group (>= $75k), and mpg generally increases with decreasing income. This is perhaps to be expected. As income increases, households can afford to hold more high prestige and high performance vehicles, and can afford to live with lower fuel economy. They might also hold more vehicles in their fleet with some being, e.g., lower mpg light-duty trucks. However, note that there is also a reversal in this trend for the lowest income group. It may be that the lowest-income households hold older vehicles, and in many cases are one-vehicle households with larger vehicles to accommodate their mobility needs. Note that all three feebate systems produce overall higher fuel economy compared to the Reference case, although the differences are not large. Also, the rank orders are as expected: Footprint has the lowest mpg, and Single is the highest, with Car/Truck in the middle.

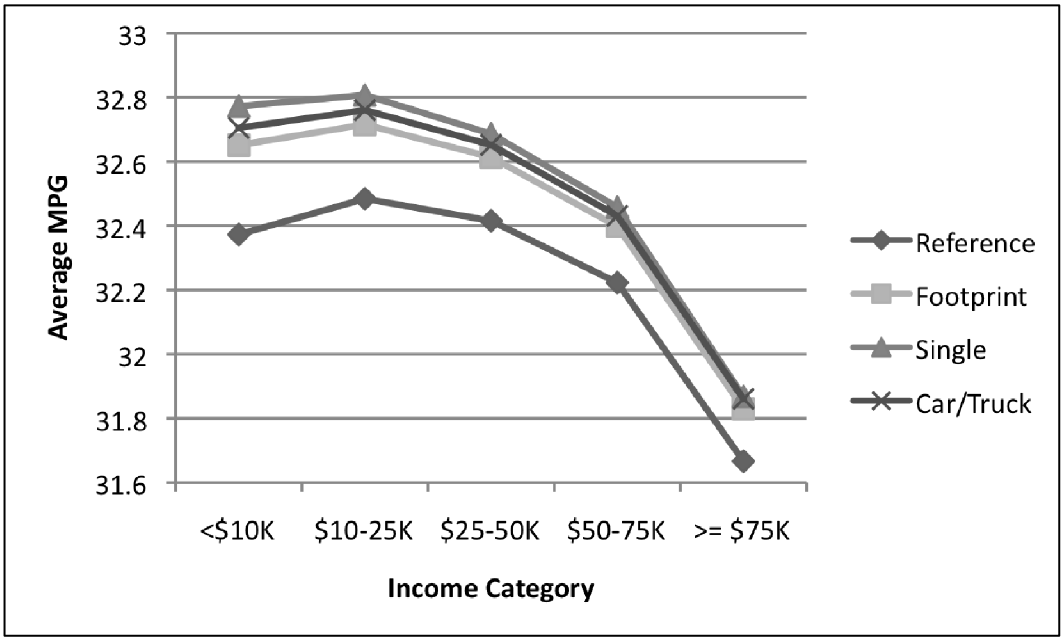


Figure 9.33 Average MPG of Held Vehicles by Income Category (2011-2025)

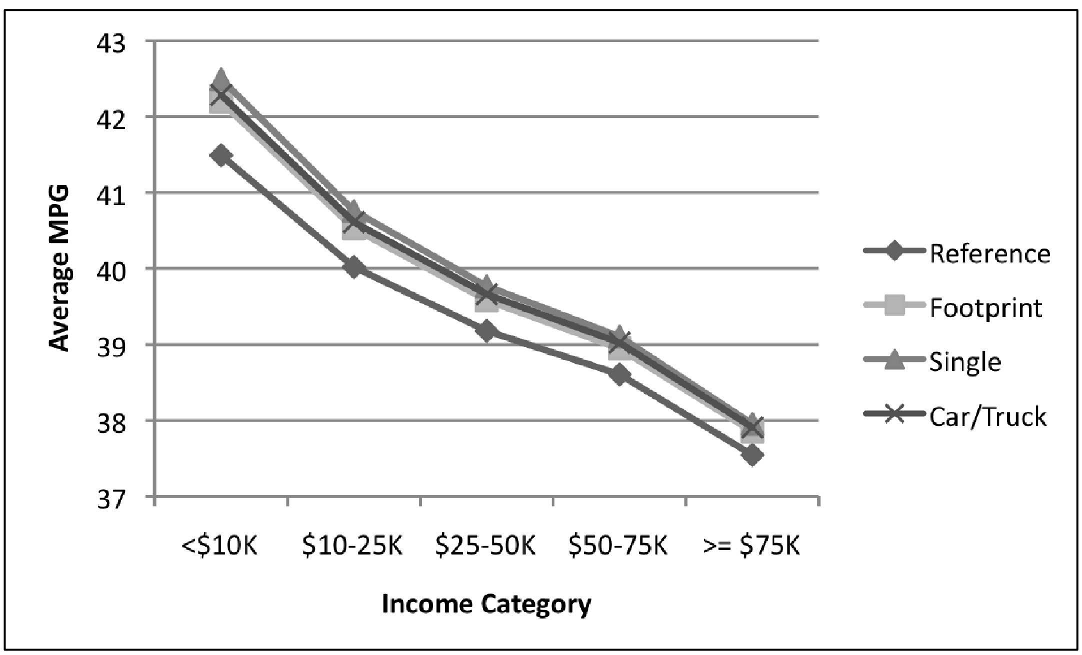


Figure 9.34 Average MPG for New Vehicle Purchases by Income Category (2011-2025)

A related question is: If households purchase new vehicles, what do the average mpg's look like? See Figure 9.34. The differences between income groups are much larger than for held vehicles, as perhaps might be expected. In contrast to held vehicles, new vehicles' average mpg increases with decreasing income over the entire range. So, although the lowest-income households might have slightly lower mpg in their held vehicles versus the second-lowest income group, if they decide to purchase a new vehicle it will have higher mpg. Another feature of Figure 9.34 is it illustrates that, for CARBITS, the differences in new vehicle average MPG are extremely small for the three benchmark systems.

9.3. Related findings from focus groups, interviews, and the survey

The following sections discuss the results of the research efforts to gauge the opinions and attitudes of the public and other stakeholders, including automakers and auto dealers. Key findings are discussed with regard to opinions and attitudes about feebate programs in general, along with responses to specific potential features of feebate programs. These opinions and attitudes were assessed with a statewide telephone survey (n=3,072), a series of a dozen focus groups around the state, and interviews with several automakers and auto dealers.

Following discussion of the main findings from the various aspects of the stakeholder research, specific findings related to feebate program design are discussed below. Finally, key caveats and limitations of the study methods are summarized.

9.3.1. Detailed Statewide Survey Analysis

As discussed in Section 5.2, the statewide survey was conducted in Fall 2009 using a "computer assisted telephone survey" (CATI) method. The survey found that a majority of the public would support a feebate policy in California with roughly 76% (~3 in 4) of respondents in support.

Ewald & Wasserman Research Consultants LLC of San Francisco, California performed the survey data collection. The goal of the telephone survey was to collect data from a representative sample of California residents who fulfilled the criteria of living in California for nine months or more out of the year, planning on leasing or purchasing a vehicle within the next 10 or 15 years, and speaking either English or Spanish. The following sections describe the survey procedures in detail followed by the discussion of the analysis and results.

Telephone Interviewer Training

A total of 32 interviewers were trained on the feebate study, together with five supervisors and two project managers. During the interviewer training, the purpose of the study was explained, and every survey question was discussed to ensure a complete understanding of the items and major terms. The telephone interviewers were also provided with an extensive overview of the research study as well as a sheet of Frequently Asked Questions (FAQs). For the survey items Q10 and Q12, alternate descriptions and explanations were created to provide respondents, who did not understand the initial concept, with an alternate explanation. All interviewers reviewed the programmed survey instrument and started with a group reading of the survey items, which was followed by an explanation of survey items and a question and answer period. After the read-around, interviewing staff partnered with another interviewer to practice the verbiage of the survey instrument and how to respond to all other possible respondent questions in a "mock interview". Additionally, all bilingual (English and Spanish) interviewing and supervision staff familiarized themselves with the Spanish translation of the survey, which also included a briefing of all questions that might arise for Spanish speaking respondents.

Interviewers were encouraged to ask questions and clarify any ambiguities prior to conducting the actual interviews on the telephone as well as during the data collection process, to continuously improve the survey research process and the data quality. In addition to the project-specific training, all telephone interviewers received a certificate of participation from a multi-mode online course on Human Subject Assurance Training provided by the Office of Human Research Protection (OHRP) of the Department of Health and Human Services.

The Sample

The records dialed consisted of a random digit dialing (RDD) sample, which is artificially generated based on all relevant telephone exchanges in the State of California. The RDD dialing approach was chosen to maximize the representativeness of the respondent data, by assuming all Californians having the same chance of being included in the study for all existing and possible telephone numbers in the State of California. RDD sample points were generated and then purged by a professional sample vendor of all listed business numbers, as well as of non-working phone numbers to the extent possible. In addition, random digit dialing cell phone numbers were created, also randomly generated on existing and known cell phone exchanges, to reach the subgroups of the population that no longer own a landline, or never use a landline, ensuring the representativeness of otherwise overlooked ethnic minorities and young adults typically assumed to be wireless. E&W presumed one person per household as a contact person for each sample point and the assumed incidence of vehicle drivers in the RDD sample was estimated at about 85% because the sample was screened for participants younger than age 18. A total of n=55,525 RDD records were dialed for this project, out of which n=857 records were generated cell phone numbers and n=54,668 were generated land-line telephone numbers.

The Survey Instrument

The survey instrument was designed by the UC team in collaboration with the project client and E&W and included a screener for household eligibility followed by questions on the household vehicle fleet, the respondents understanding of environmental concepts, their stated political affiliation and then basic household demographics.

Overall, three separate studies were set up with the final survey instrument. The three separate studies included:

1) General RDD dialing study
2) Cell phone RDD dialing study
3) Ethnicity quota study

The first study labeled general RDD study was programmed according to the final and IRB approved survey version. A total of n = 47,668 records were loaded into the general RDD study. The second study was set up as a cell phone study consisting of RDD generated cell phone numbers with a total of n = 857 cell phone RDD records. For the cell phone RDD study, the dialing procedure was slightly different from the main study, hence the requirement of a separate study. Every number of the cell phone sample was dialed manually by the interviewer using an external dialing pad, to ensure compliance with current law. Additionally, the telephone interviewers were trained to ask a respondent if they were in a place where they could answer the survey questions to avoid putting the respondent in an unsafe condition. Upon request, cell phone respondents were called at a later time or at a different number.

The third study set up was a CATI study modified to target only non-white and non-Caucasians. This was done to make the best effort possible to obtain a demographic base that would match the California state composition. For the purpose of the third study, the ethnicity questions in the survey instrument (Q36) were moved directly to the beginning on the survey, directly behind the other qualifying screening questions. For the ethnicity quota study, a total of n=7,000 records were loaded and only respondents that stated to be non-white or non-Caucasian were included. All white/Caucasian only respondents were thanked for their time and terminated.

For the final data delivery, all completed surveys were merged into a single SPSS data file and Excel File, which included an indicator for cell phone sample completes and also delineated those records that were delivered as pilot records.

Response Overview

The combined response for all three study setups were as follows: n = 3,072 surveys were completed and n = 114 surveys ended in a partial complete with a total of 55,525 unique sample points. This includes the cell phone RDD dialing study, which is outlined separately below. In total n = 3,186 surveys, or 10.02% of the usable sample ended in a complete or partial complete. Despite multiple attempts to re-contact a respondent to complete a started survey, many could not be reached within the dialing time frame of the study. About 42.7% (or 23,735 records) were excluded from the survey population because of disconnected or wrong numbers, businesses, language barriers, fax and modems or because the respondent either was unavailable or did not meet the screener. Out of the non-eligible population, 12.6% of all respondents were excluded after the White/Caucasian quota cell for the study was filled. All respondents who stated at that point to be White/Caucasian, were thanked for their participation and terminated the interview. About 2.3% of the entire sample dialed was excluded from the survey because the respondents either did not live in California most of the year or they did not plan on buying or leasing a vehicle within the next 10 to 15 years.

For the cell phone RDD dialing study, a total of n=57 surveys were completed plus one partially completed survey, out of which 55 were conducted in English and three surveys in Spanish for a corrected 13% response rate. A total of 46% or 394 records were excluded from the cell phone survey population because they were either non-working or disconnected cell phone numbers, beeper/fax/modems, business numbers, language barriers or because respondents did not meet the screener.

For all studies combined, a total of n=3,072 completed surveys and n=62 of the partially completed surveys were delivered. The remaining n=52 partially completed surveys did not contain sufficient data for analysis and were missing the demographic information and were therefore excluded from the final data set delivered. Table 9.7 shows the distribution of language of the interview for the completed and partially completed and delivered records. While about 9.8% of all completed telephone surveys were conducted in Spanish, 62.9% of the partially completed surveys were conducted in Spanish. Overall, the number of Spanish speakers who did not complete a survey due to time constraints or other matters is almost twice as high as the English partially completed surveys.

Table 9.7 Survey completes by language

Number of surveys	Language of interview: English	Language of interview: Spanish
Completed: n= 3,072	n=2,772 (90.2%)	n=300 (9.8%)
Partially completed: n = 62	n=23 (37.1%)	n=39 (62.9%)

The dialing time frame of the study was from October 16, 2009 through December 13, 2009, weekdays and weekend days, with the exception of Thanksgiving Day, November 26 and November 27, 2009, when the E&W office was closed. The final analysis applied only the fully completed results due to the fact that the sample was reweighted to match the California population distribution of demographic and socioeconomic variables.

Dialing Statistics

Table 9.8 shows the Feebate study dialing statistics. A total of 281,060 dialing attempts were made to reach the n=3,186 completes, with an average of 68 dialing attempts per complete. The average length of the telephone survey varied between 13 and 16 minutes with the Spanish version taking on average two minutes longer than the English version. A total of 19,416 records received a final disposition after the maximum number of ten attempts was reached, and 36,109 records were recorded after being completed or excluded from the survey population.

Table 9.8 Feebate study dialing statistics

Total number of dialings	281,060
Number dialing attempts per complete	68.00
Average length of interview	13-16min
Number of cases with disposition after maximum of 10 attempts were reached	19,416
Number of cases with final disposition (complete or non survey population)	36,109
Number of HH identified Spanish speakers (by Spanish AM or respondent)	1,868
Number of HH identified English speakers (by English AM or respondent, incl. Hispanics)	26,493

To the extent possible, all households with Spanish speaking individuals were identified, to ensure that a proportionally significant number of Hispanic/Latino households were reached. All answering machines that had a recording in Spanish were coded as Spanish answering machines, as were households were a respondent answered the call in Spanish. Of the overall sample, n = 1,868 records were identified as Spanish speakers, which included surveys completed in Spanish. This number however, does not represent the number of Hispanic/Latino respondents, since the majority of this population also speaks English and cannot be identified by language spoken. Please see the results section later in the report for a synopsis of the key survey findings.

The survey ultimately collected a total of 3,072 completed surveys from the population of California. While a concerted effort was made during the data collection process to produce a demographic distribution that closely matched that of the state, there was some departure within the sample from the general population along certain demographic attributes. That is, the distribution of age, income, education and race are somewhat different from that of the general population within the state. Such departures can often occur in CATI surveys, due to the fact that populations with certain demographics have a higher propensity to respond to telephone surveys than others. Typically, people with higher age, education, and income have a greater propensity to respond to telephone surveys and this propensity will skew the sample towards a wealthier, more educated cohort.

However, the impact of this departure on the overall results can be corrected through a re-weighting of the sample. For this analysis, the sample is re-weighted using post-stratification weights, which adjust the demographics of the sample to closely match that of the state population. This adjustment scales the opinions of respondents of under-represented demographics to have a greater weight (>1) on the distribution of opinion. Similarly, respondents of over-represented demographics are adjusted to have a reduced weight (<1) on the distribution of opinion.

The post-stratification weights applied to this analysis were developed to rebalance the sample along the demographics of income, education, age, and race. Before weighting can proceed, missing values within these attributes needed to be imputed. Missing values would occur when the respondent did not know or refused to respond to a given question. The imputation method applied in this analysis was the commonly used "hot deck" method, which relies on the distribution and random ordering of existing respondents to generate an imputed estimate of the missing value. The hot deck method utilized the existing distributions of income, education, age, and race within the sample to impute the missing values.

To generate the post-stratification weights, it is necessary to know how the demographics of interest are distributed within the state population. However uni-dimensional demographic distributions alone are not sufficient if the re-weighting is to occur along the dimension of more than one demographic attribute.[53] Rather, knowledge of the joint population distribution for all demographics of interest is preferred for more accurate weighting. The US Census publishes data called the Public Use Microdata Sample (PUMS) for the annual American Community Survey (ACS) (US Census, 2009). For each state in the nation, the PUMS dataset offers the complete de-identified data of a 1% sub-sample of the ACS for each year. The sample itself is provided with weights such that the representation of each observation within the PUMS subsample scales appropriately such that the sum of all weights matches the California population. With the PUMS subsample, the joint-distribution of income, education and age is computable for the state population. For the analysis within this study, the sample was re-weighted using post-stratification weights built off of a 3-dimensional joint-distribution of income, education and age using the 2006-2008 PUMS dataset for California. This also resulted in some re-weighting of the sample by race, in ways that were mostly more representative of the state population except for the Asian group (see Table 9.9 below). Given the three dimensions available, this was the most representative re-weighting result possible. The joint distributions of the sample and population were then used to develop the weights on each observation within the sample.

Ultimately, the weighting of the sample along the selected demographics produces small changes to the distributions of opinions to key questions pertaining to feebate policies. That is, the weighting does not alter any general conclusions that would be drawn from the raw sample. To maintain

[53] There is a procedure known as the "raking procedure", which can reweight data using uni-dimensional distributions. However, when the population joint distribution is known and the sample provides good coverage of the joint distribution along all relevant dimensions, it is generally preferred to scale and weight using the joint distributions of the sample and population.

analytical transparency, both the weighted and unweighted distributions are presented for key results to show the impact of the sample weighting on the overall results. To begin, Table 9.9 shows the distribution of key demographics of the original sample, the population, and the re-weighted sample for comparative purposes.

Table 9.9 Distribution of Key Demographic Attributes

(a) Household Income	Raw Sample	California Population	Reweighted Sample
Less than $10,000	4%	5%	6%
$10,000 to $25,000	9%	14%	12%
$25,000 to $35,000	8%	9%	8%
$35,000 to $50,000	11%	13%	13%
$50,000 to $75,000	17%	18%	18%
$75,000 to $100,000	16%	13%	14%
$100,000 to $150,000	18%	15%	16%
More than $150,000	16%	13%	12%

(b) Age	Raw Sample	California Population	Reweighted Sample
18 - 24	4%	14%	12%
25 - 34	11%	19%	20%
35 - 44	17%	20%	21%
45 - 54	25%	19%	20%
55 - 64	24%	13%	14%
65 - 74	14%	8%	8%
75 or over	6%	7%	6%

(c) Education	Raw Sample	California Population	Reweighted Sample
Did not complete high school	6%	20%	17%
High school graduate	10%	24%	23%
Some college	18%	23%	25%
2-year college degree	12%	7%	7%
4-year college degree	28%	17%	18%
Graduate degree	25%	9%	10%

(d) Race	Raw Sample	California Population	Reweighted Sample
Caucasian or White	55.8%	42.6%	44.5%
Hispanic	24.5%	36.1%	36.9%
African American	5.2%	6.0%	5.5%
Asian	8.2%	12.1%	6.1%
Native American or Alaskan Native	2.4%	0.5%	2.7%
Hawaiian or Pacific Islander	1.0%	0.3%	1.3%
Other	2.7%	2.4%	3.0%

Table 9.9 illustrates the general demographic attributes of the sample, population and the re-weighted sample for income, age, education and race. The population distributions are based on the 2006 - 2008 ACS estimates. Table 9.9(a) presents the distributions for household income, which show that the raw sample is skewed slightly towards higher income in comparison to the population. The weighted sample is adjusted to match income sample more accurately. The raw sample distributions in Table 9.9(b), (c) and (d) are skewed a bit more significantly away from the population distribution. The raw sample was older, more educated and more Caucasian than the California population. The weighting of the sample adjusted the demographic distribution to more closely match the demographic distribution of the population within California. The same weight that adjusts the relative influence of sample respondents to produce the new demographic distribution is applied to the respondent opinions to produce weighted response distributions. The gender split of the raw sample was 47% male, 53% female; the weighted sample shifted the share to 48/52, while the population is estimated to be 50/50.

Overall, the results of the survey suggest that a majority of the public would support a feebate policy in California. In both the raw and weighted sample, roughly 76% (~3 in 4) of respondents said that they would be supportive of a feebate policy. These results suggest that the population would be supportive of a feebate policy design on automotive purchases. However, this result should be understood within the context that a remaining 22% (~1 in 5) of the population is opposed to a feebate policy. As a share of the state population over the age of 18, this population opposing the policy constitutes roughly 6 million people versus the estimated 20 million people that would support the policy.

The survey began by asking respondents basic questions about household vehicle holdings, driving distances and vehicle choice. Then, respondents were introduced to the concept of greenhouse gases and the feebate policy. The respondents were first read a statement that briefly introduced to them the concept of greenhouse gases and how they relate to fuel economy. The statement read as follows:

> Now, I would like to get your opinion on a number of transportation topics starting with vehicle **emissions**. Some emissions may cause smog, while other emissions include “greenhouse gases.” Greenhouse gases may contribute to climate change or what some people call “global warming.” Greenhouse gases are closely related to the miles per gallon a vehicle gets. If a vehicle gets higher miles per gallon (for ex. 25, instead of 20), then there are fewer greenhouse gas emissions per mile.

This statement was followed by an initial question that assessed whether they understood the term “greenhouse gases”. This was followed by a question that asked them whether they understood the term “climate change”. The results suggest that both terms were understood by a majority of people, but more people understood the term “climate change” in comparison to “greenhouse gases”. The distribution of responses for both raw and weighted sample is presented below in Figure 9.35.

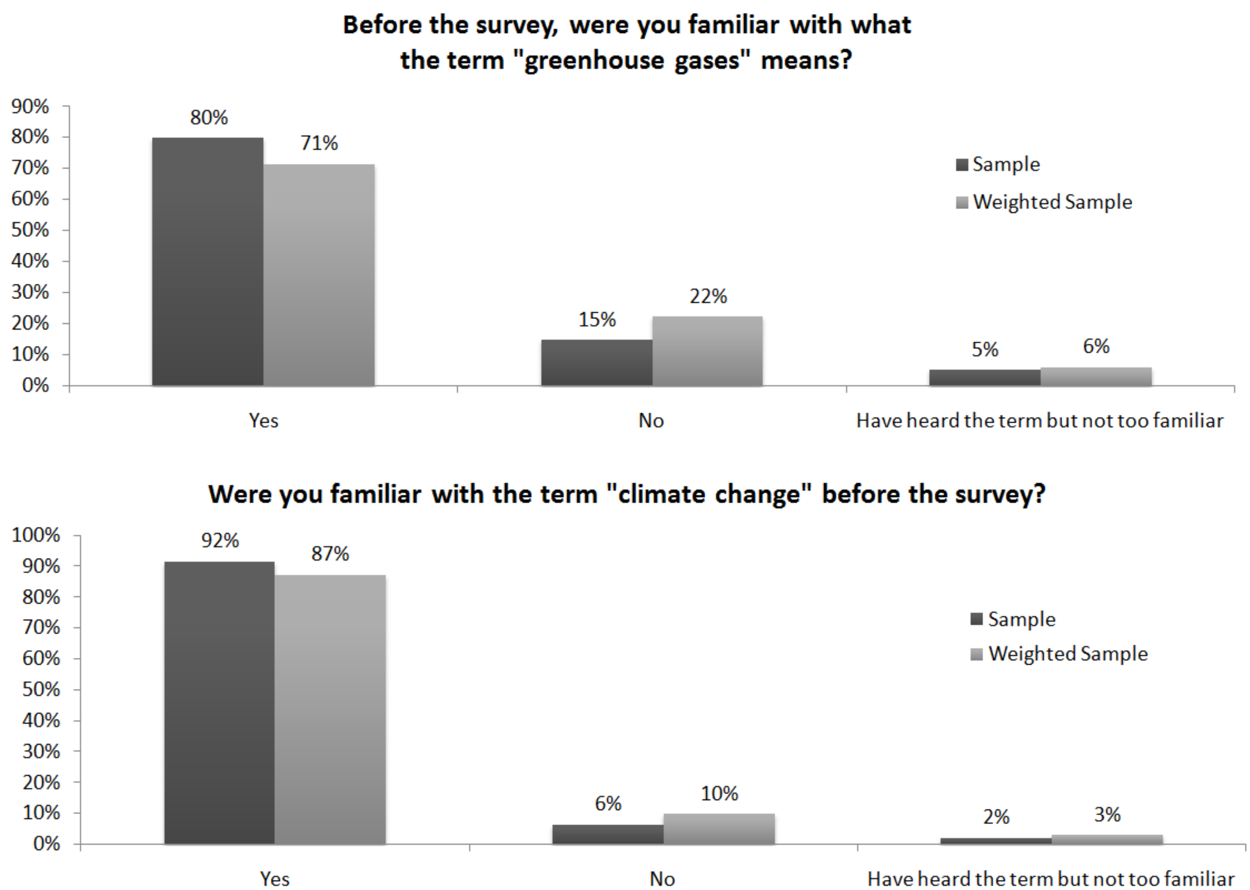


Figure 9.35 Familiarity with terms “greenhouse gases” and “climate change”

Figure 9.35 shows that the majority of people understood both terms, but the weighted sample does present a 9 percentage point drop in the proportion of people familiar with the term "greenhouse gases." Regardless of whether the respondent gave a "yes" or "no" answer to these questions, all respondents were read a definition of greenhouse gases. Following this definition, each respondent was read a definition of a feebate policy as it could be applied in California. The definition was designed to be a clear and concise statement of how feebates could work. The statement that was read to the respondents was the following:

> For the purposes of this survey, we are using the following definition for greenhouse gases: "Greenhouse gases trap heat in the atmosphere, and are released by burning fuels such as gasoline. Some believe the build-up of greenhouse gases is contributing to a gradual warming, which is changing the Earth's climate."
>
> Now I would like to describe a transportation program for NEW vehicle buyers. Under this program, when a new vehicle is FIRST purchased, it could be subject to either a one-time fee or a one-time rebate. The program sets a target for vehicle emissions. If you buy a vehicle with emissions higher than the target you have to pay a fee. If you buy a vehicle with emissions lower than the target you get a rebate. The amount of the fee or rebate depends on the vehicle's greenhouse gas emissions. Vehicles with the lowest emissions—and highest MPG—get the biggest rebates. Vehicles with the highest emissions—and lowest MPG—get the biggest fees. The program is designed to help reduce California's greenhouse gas emissions.

The respondents were then asked a series of questions designed to capture their overall sentiments towards the policy and how they might react to it. These questions were given in the form of statements, and respondents were asked to state whether they agreed or disagreed with the statement along a Likert scale with the options of "Strongly Agree", "Agree", "Disagree", and "Strongly Disagree"

A key statement given to the respondents asks directly whether they would be supportive of the policy as described. The results of this question are presented in Figure 9.36, which shows the distribution of Likert responses to the statement "I would be supportive of this kind of policy to slow the rate of climate change."

The distribution of responses shows that for both the raw sample and weighted sample, a majority of respondents stated that they would generally be supportive of the feebate policy. The re-weighting of the sample to reflect population demographics shifts the distribution of opinion slightly. This moves opinion towards the center of the scale. Thus, in spite of the fact that the weighting of the sample produced considerable shifts in demographics such as education, race, and age, the resulting shift in opinion from the same weights is less pronounced. Overall, the raw sample distribution suggested that 76% (~3 of 4) were supportive of the feebate policy and 22% (~1 in 5) were opposed to feebates. The remaining 2% volunteered that they could not express an opinion on the policy. With respect to the weighted sample, the results follow a similar distribution, with a shift away from "Strong Agree" and "Strongly Disagree" with 76% of the sample stating support and 22% stating opposition to feebates.

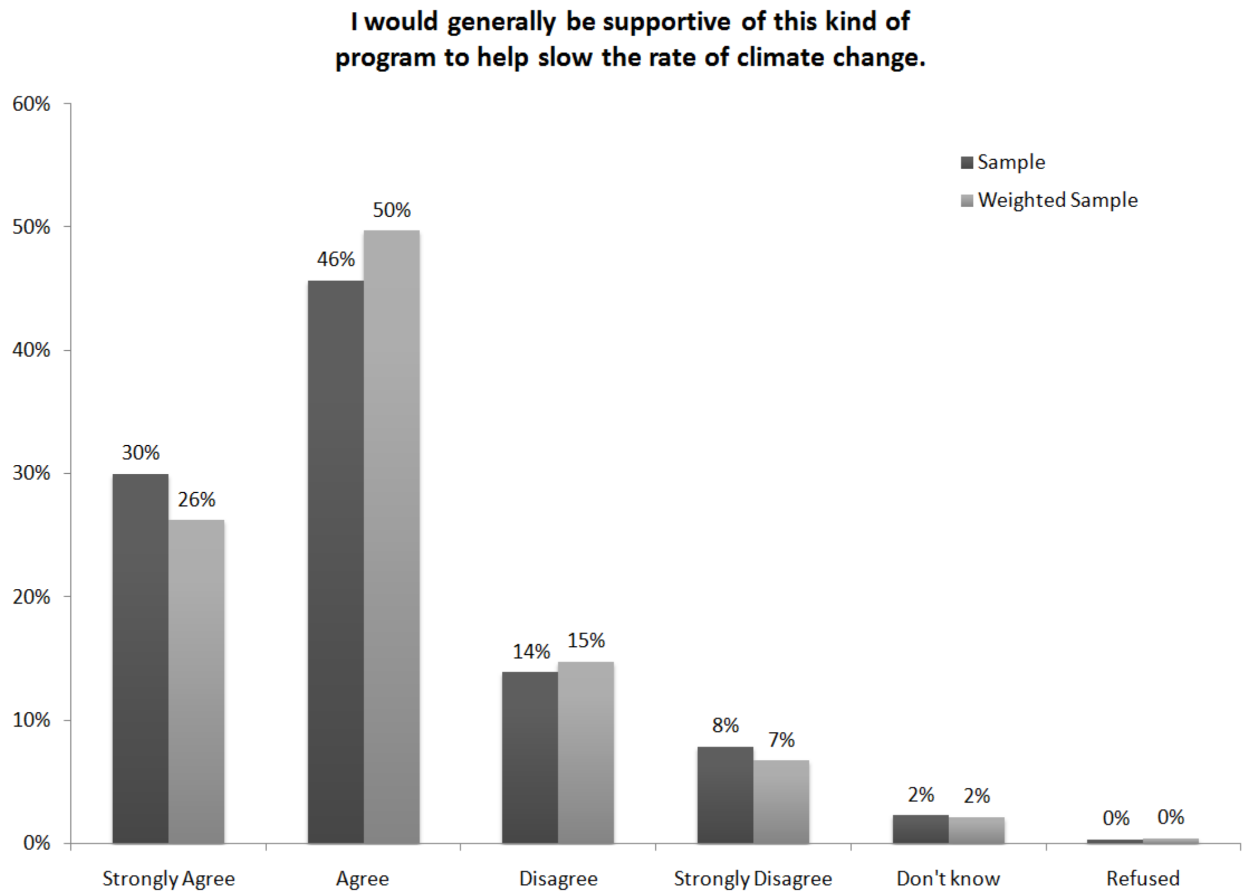


Figure 9.36 Distribution of Stated Feebate Policy Support

The breakdown of this distribution by demographic and socioeconomic attributes can illustrate some of the underlying cohorts that drive the overall position on the feebate policy. The cross-tabulation of opinions by income, age, race, education, and politics offer a more in-depth perspective of the cross-section of opinions. Table 9.10 illustrates a cross tabulation of support for feebates by racial ethnicity for both the raw sample and weighted sample. The percentages presented in the table are the within-group percentages of each ethnic group subscribing to the given position. For example, the top left cell in Table 9.10 indicates that 32 percent of Caucasian respondents in the raw sample strongly agree with being supportive of the policy.

Table 9.10 shows that positions of support and opposition to the feebate policy crosscut racial groups with relative uniformity. Within both the raw and weighted sample, the cohort with largest opposition to feebates consists of those who refused to provide their racial background. This was followed by those providing “Other” responses and then by Caucasians, 30% of whom were found to oppose feebates in the reweighted sample. For the remaining racial ethnic groups, the proportion of the cohort opposing feebates fell within the range of 10 to 20 percent. Overall, Table 9.10 shows that distinctions in opinion as distinguished by racial cohorts are not considerably different across the major racial ethnic groups in California, with the exception of somewhat lower support among Caucasians.

Further analysis of respondent cross-tabulations shows divisions on position by other socioeconomic attributes, including education, income and age. Table 9.11 through Table 9.14 show the cross tabulation of response based on these three characteristics. Because the results of the raw sample and weighted sample do not differ significantly, only the results from the weighted sample results are presented. Table 9.11 illustrates the cross-tabulation of response by education in the same format as Table 9.10.

Table 9.11 shows that across all education levels, between 70% and 80% of respondents were in support of a feebate policy. The lowest proportional opposition (10%) to feebates was found among those that did not complete high school. The trends in education show that opposition to feebates rises with increases in education and then falls. Opposition is at the greatest proportions among cohorts that have achieved some level of college education without graduate work. That is, opposition is proportionally highest among those with some college education (25%), a 2-year degree (including vocational schools) (25%), and a 4-year degree (23%). Opposition declines to 18% among those with a graduate degree.

Table 9.10 Cross-tabulation of policy support by race

I would generally be supportive of this kind of program to help slow the rate of climate change.									
Raw Sample (Race)	Caucasian or White	Hispanic	African American	Asian	Native American or Alaskan Native	Hawaiian or Pacific Islander	Other	Refused	Total (N = 3072)
Strongly Agree	32%	30%	25%	28%	24%	33%	32%	22%	30%
Agree	40%	55%	59%	53%	50%	53%	34%	37%	46%
Disagree	16%	10%	12%	13%	14%	7%	15%	21%	14%
Strongly Disagree	10%	3%	4%	3%	7%	3%	13%	17%	8%
Don't know	2%	2%	1%	3%	6%	3%	6%	4%	2%
Refused	0%	1%	0%	0%	0%	0%	0%	0%	0%
Total	1671	735	157	247	72	30	82	78	3072
Weighted Sample (Race)	Caucasian or White	Hispanic	African American	Asian	Native American or Alaskan Native	Hawaiian or Pacific Islander	Other	Refused	Total (N = 3072)
Strongly Agree	27%	27%	22%	24%	20%	23%	21%	16%	26%
Agree	41%	58%	64%	54%	64%	55%	38%	43%	50%
Disagree	19%	10%	11%	13%	10%	11%	26%	22%	15%
Strongly Disagree	11%	2%	4%	4%	2%	2%	11%	13%	7%
Don't know	2%	2%	0%	4%	4%	9%	4%	5%	2%
Refused	0%	1%	0%	0%	0%	0%	0%	0%	0%
Total	1342	1114	165	184	81	39	90	56	3072

Table 9.11 Cross tabulation of policy support by education

I would generally be supportive of this kind of program to help slow the rate of climate change.							
Weighted Sample (Education)	Did not complete high school	High school graduate	Some college	2-year college degree	4-year college Degree	Graduate Degree (Masters, PhD, MBA, JD, etc.)	Total (N = 3072)
Strongly Agree	23%	26%	21%	30%	28%	40%	26%
Agree	62%	49%	51%	43%	45%	40%	50%
Disagree	7%	18%	18%	16%	14%	12%	15%
Strongly Disagree	4%	6%	7%	9%	9%	6%	7%
Don't know	4%	1%	2%	2%	3%	2%	2%
Refused	1%	0%	1%	0%	0%	0%	0%
Total	520	722	754	228	554	294	3072

Income and education are positively correlated within the sampled population, but relatively weakly (an approximate correlation coefficient is 0.46 between the two attributes). Unlike education, the within-cohort share of opposition increases monotonically with rising income. The proportion of respondents within each income cohort supporting feebates ranges from 90% at the lower income levels to 65% at the higher income levels. With income, support for feebates tends to decline among the population as incomes increase. Support for the policy is still projected by a majority among all income levels at a minimum of 65% within each income level. While 31% of respondents with annual household incomes higher than $100,000 per year stated that they would not be supportive of the policy. Table 9.12 presents these distributions by income, which suggests that as income rises, so does the proportion of opposition. Opposition tops out at about 30% at the highest income category, while 66% of respondents in the highest income category support the policy.

Support for the policy as distributed by age represents similar patterns to income, which is due in part to the fact that age and income are correlated. Table 9.13 illustrates the cross-tabulation of policy support by age group. The distribution shows that support for the policy is relatively uniform in proportion across age groups. Younger populations exhibit a higher level of proportional support, with 79% of the 18 – 24 year old cohort supporting the policy. The proportional support for feebate policy declines gradually with age. The policy is supported by between 70% and 80% of the young-adult and middle age cohorts, but declines to 63% for those 75 and older. Commensurately, opposition to feebates ranges from 20% to 33% across age groups, rising slightly with increased age.

Table 9.12 Cross tabulation of policy support by income

I would generally be supportive of this kind of program to help slow the rate of climate change.									
Weighted Sample (Income)	Less than $10,000	$10,000 to $25,000	$25,000 to $35,000	$35,000 to $50,000	$50,000 to $75,000	$75,000 to $100,000	$100,000 to $150,000	More than $150,000	Total (N = 3072)
Strongly Agree	29%	30%	24%	20%	32%	22%	25%	26%	26%
Agree	60%	56%	59%	54%	49%	50%	42%	40%	50%
Disagree	9%	11%	13%	14%	12%	18%	18%	19%	15%
Strongly Disagree	2%	1%	3%	8%	5%	7%	12%	12%	7%
Don't know	0%	2%	1%	3%	1%	3%	2%	3%	2%
Refused	0%	0%	1%	0%	0%	0%	1%	1%	0%
Total	185	365	260	406	560	426	487	383	3072

Table 9.13 Cross tabulation of policy support by age

I would generally be supportive of this kind of program to help slow the rate of climate change.								
Weighted Sample (Age)	18 - 24	25 - 34	35 - 44	45 - 54	55 - 64	65 - 74	75 or over	Total (N = 3072)
Strongly Agree	17%	24%	27%	33%	30%	23%	20%	26%
Agree	62%	52%	52%	44%	46%	44%	43%	50%
Disagree	18%	15%	9%	13%	13%	20%	29%	15%
Strongly Disagree	2%	6%	8%	9%	7%	6%	4%	7%
Don't know	0%	2%	3%	1%	3%	7%	3%	2%
Refused	0%	0%	1%	1%	0%	0%	1%	0%
Total	362	604	653	601	429	248	176	3072

Tables 9.10 through 9.13 illustrate how the distribution of support for the feebate policy breaks down by key demographic and socioeconomic attributes. The results show that there is no racial ethnicity, education, income or age cohort that has a majority of respondents in opposition to the feebate policy. The proportion of support and opposition to feebates tend to cut across most demographic attributes rather uniformly. There are some within-group distinctions, such as education, where respondents with mid-level higher education have greater opposition than those with lower education or graduate work. The trends in income suggest that increased income tends to lower the overall support for feebates. However, in all demographic cohorts, the majority of respondents supported the idea of a feebate policy.

One of the more important discerning factors that dictate respondents' position on the feebate policy may be political philosophy. Respondents were asked towards the end of the survey to self-assess their political alignment. Specifically, respondents were asked "Which of the following best describes your usual position on political issues?" with options of "Very liberal", "Liberal", "Moderate", "Conservative", and "Very conservative". Respondents could also state an "Other" response as well. The cross-tabulation of support for feebates by political alignment, as presented in Table 9.14, shows a starker contrast in the distribution of within-cohort support for the policy.

Table 9.14 Cross tabulation of policy support by political alignment

I would generally be supportive of this kind of program to help slow the rate of climate change.									
Weighted Sample (Politics)	Very liberal	Liberal	Moderate	Conservative	Very conservative	Other	Not sure	Refused	Total (N = 3072)
Strongly Agree	53%	39%	27%	17%	11%	11%	15%	13%	26%
Agree	35%	51%	52%	49%	31%	74%	57%	49%	50%
Disagree	8%	7%	16%	20%	28%	8%	13%	23%	15%
Strongly Disagree	3%	2%	4%	11%	27%	5%	7%	9%	7%
Don't know	1%	1%	2%	3%	1%	2%	8%	3%	2%
Refused	1%	0%	0%	1%	2%	0%	0%	2%	0%
Total	172	706	926	738	205	112	151	62	3072

Table 9.14 shows that the distribution of position on the feebate policy is relatively strongly influenced by the political alignment of respondents. Roughly 88% of respondents who felt that they were liberal or very liberal were supportive of the policy. For moderates, the largest of all political cohorts, supporters of feebates represented 79%, with 20% of moderates opposed to feebates. Support for feebates declines as people identify themselves as more conservative, where 64% of those within the conservative cohort stated support for feebates. Roughly 32% of conservatives were opposed to feebates. Those describing themselves as "very conservative" were more opposed to feebates than any other demographic cohort. A majority of respondents (58%) of those describing themselves as "very conservative" stated that they would be opposed to feebates, while 40% stated that would be in support of a feebates program.

To gain a further sense of respondent views on issues relevant to vehicle emissions policies, respondents were asked questions to gain perspective on their views of specific environmental issues related to the feebate policy. Given a Likert scale, respondents were asked whether they agreed or disagreed with the following statements:

1) The earth is currently experiencing climate change.
2) Human activity contributes to climate change.
3) Dependence on foreign oil is a serious problem facing the United States.

In addition, respondents were asked to compare the importance of climate change and energy security with the question: "Which issue do you think is more important: climate change or improved energy security for the United States?" Figure 9.37 shows the distribution of responses from the raw and weighted sample to questions (1) and (2), which assess the degree to which the population agrees with the fact that climate change is occurring and with the relationship between climate change and human activity. The graphs show the distribution of both the weighted and unweighted sample.

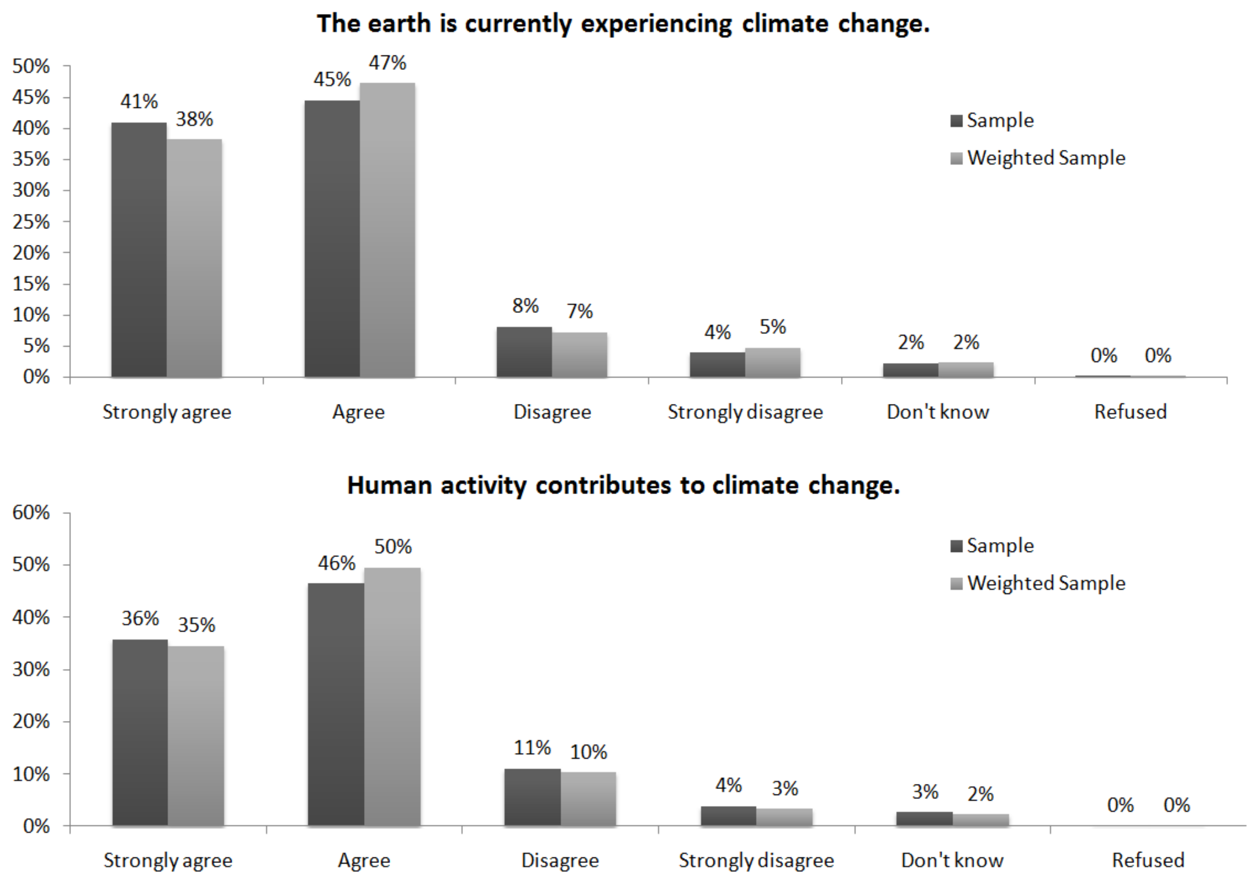
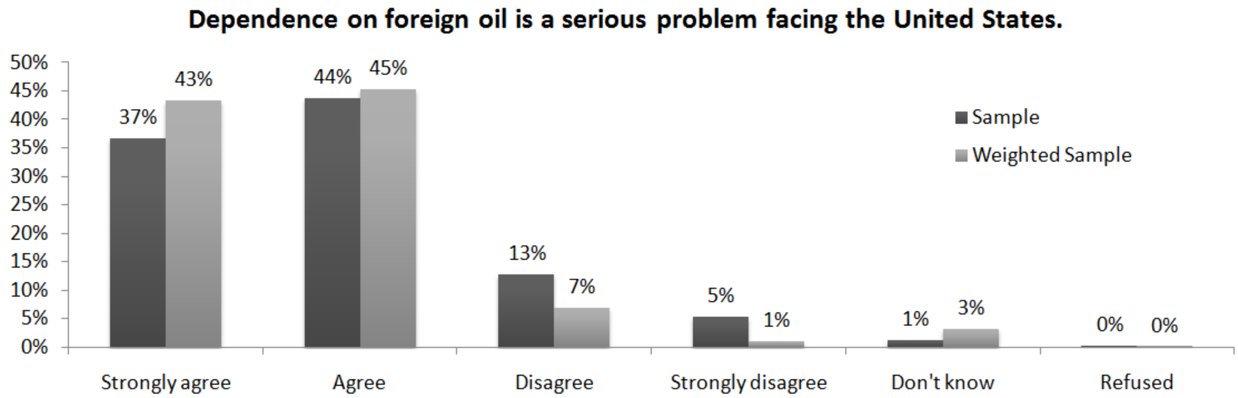


Figure 9.37 Distribution of Response to Climate Change

The distribution shows that the majority of the California population agrees with the statement that the earth is experiencing climate change and that humans are contributing to it. Based on the weighted sample, the top graph of Figure 9.37 suggests that roughly 85% of the population agrees or strongly agrees that the earth is experiencing climate change. A similar share (85%) also agrees or strongly agrees that human activity is contributing to climate change. The raw sample shows very similar results. The results suggest that a strong majority of the population considers climate change to be a real concern and consider humans to be a contributing factor. Figure 9.38 shows the results of questions relating to energy security. The questions focus on the importance of foreign oil dependence and comparatively assess whether climate change or energy security is more important to the population.



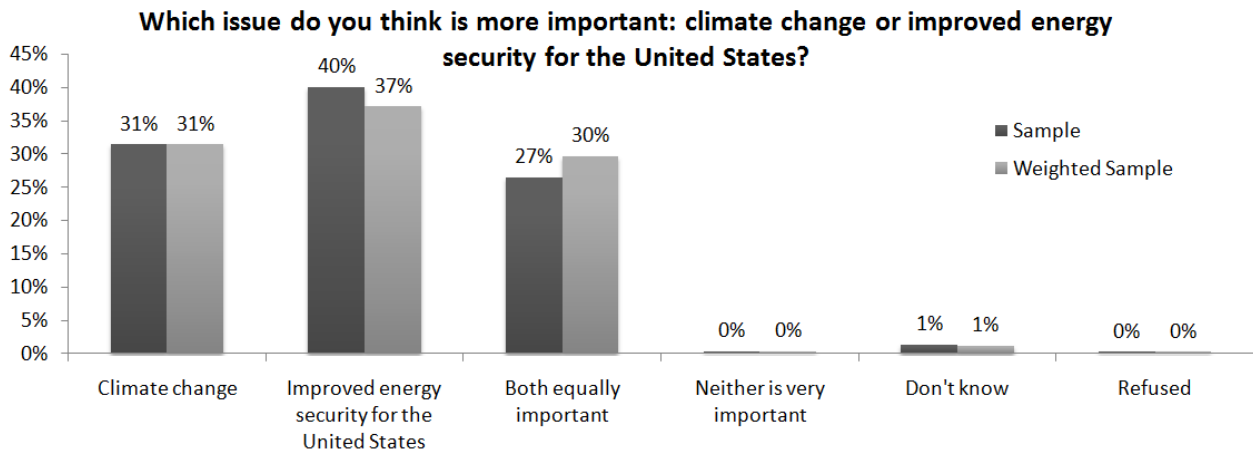


Figure 9.38 Distribution of Response to Energy Security

Based on the weighted sample, the distribution of the top graph in Figure 9.38 suggests that a vast majority (88%) of the population believe that foreign oil dependence is a serious concern. The raw sample provides similar results with a slightly lower proportion (81%) considering foreign oil dependence to be a serious problem. The bottom graph suggests that more people (~40%) in the California population consider improved energy security for the U.S. to be more important than the issue of climate change. In contrast, 31% of respondents consider climate change to be more important. However, neither perspective constitutes a majority, and the perspectives are separated by less than 10% of the population. Nearly 30% of the population considers both climate change and energy security to be equally important.

Naturally, the opinions that respondents have with respect to climate change and energy security have some impact on their perception of the feebate policy. The distribution of responses can be viewed in another way to illustrate how people with specific perceptions on climate change view the feebate policy. Figure 9.39 addresses this issue with two graphs that show what people who are supportive of feebates think of climate change as compared to how people who are against feebates perceive climate change. The dark bars in the graph represent the population that is supportive of feebates, whereas the lighter bars represent the population that opposes feebates. The distribution of the bars shows how those supporting and opposing feebates responded to the questions regarding climate change. The sample size of each group within the weighted sample is given in the legend. Only the results of the weighted sample are given in the graphs below.

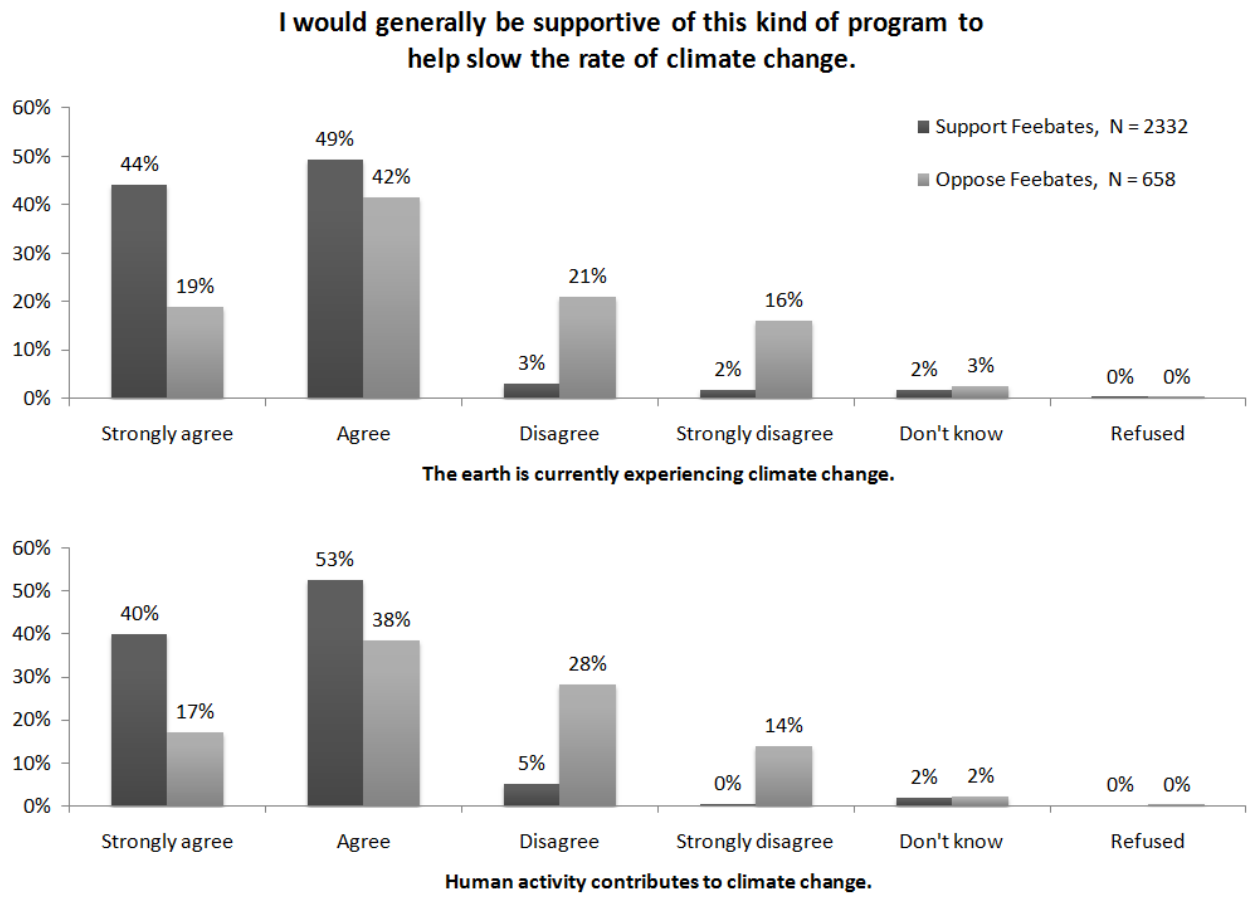


Figure 9.39 Support for Feebates Crossed with Opinions on Climate Change

The top graph shows that roughly 93% (2166) of respondents that were supportive of feebates considered the earth to be experiencing climate change. About 61% (397) of those opposing feebates also believed that the earth is experiencing climate change. The remaining 37% (260) of those opposing feebates did not believe that the earth is experiencing climate change. A similar interpretation, along with a similar response distribution follows for the results of the bottom graph, which reflects the same sample. The results suggest that for 50% to 60% of the subpopulation that opposes feebates, the reason is not due to a lack of acknowledgement of the existence of or human contribution to climate change.

The survey collected information on vehicle holdings within each respondent household. Respondents were asked to provide the make, model, and year of each vehicle held within the household. This information was used to link each vehicle to the combined fuel economy of the vehicle as listed in the EPA Fuel Economy database. The linkage allows for an analysis of feebate policy support in the context of vehicle holdings. Specifically, this analysis explores whether the vehicles owned by a household influence their support for feebates, which is a policy that impacts consumers proportionally based on the fuel economy of the vehicle purchased. Table 9.15 shows a cross tabulation of policy support by the average combined fuel economy of vehicles in the household. The within-household differential in household fuel economy was not very wide across the sample population. For example, only 14% of households had two or more vehicles that were separated in fuel economy by 5 miles per gallon or more (max fuel economy – min fuel economy). The population considered in Table 9.15 is the weighted sample.

Table 9.15 Cross Tabulation of Policy by Average Combined Fuel Economy

I would generally be supportive of this kind of program to help slow the rate of climate change.								
Average Fuel Economy (combined mpg)	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50
Strongly Agree	18%	30%	27%	30%	42%	22%	45%	43%
Agree	34%	43%	49%	54%	48%	61%	4%	43%
Disagree	38%	15%	15%	14%	6%	12%	51%	5%
Strongly Disagree	8%	10%	7%	2%	3%	6%	0%	8%
Don't know	1%	1%	2%	0%	0%	0%	0%	1%
Refused	0%	1%	0%	0%	0%	0%	0%	0%
Total (N)	82	787	948	242	47	22	5	24

Table 9.15 illustrates an inverse correlation of average household vehicle fuel economy and support for a feebate policy. The table shows that 46% of households with an average vehicle fuel economy ranging between 10 and 15 miles per gallon stated that they would not be supportive of feebates. Within this category, a slim majority (52%) of respondents stated that they still would be supportive. As the household average fuel economy increases, the proportion of respondents stating support for feebates rises. The proportion of opposition to feebates declines from 25% among households with an average fuel economy between 15 to 20 miles per gallon, to 9% for households with an average fuel economy of 30 to 35 miles per gallon. Interestingly, the proportion of respondents opposing feebates rises for the categories spanning 35 to 45 miles per gallon. The reason for this rise is not apparent, but it is notable that these two categories have the smallest weighted sample sizes. Hence, a few anomalous observations within such small samples will disproportionately shift the balance of opinions rather easily and are more likely to be influenced by sample error. The opposition to feebates drops to 13% for respondents in the highest fuel economy category of 45 to 50.

As less support for feebates is found among people who have a conservative political alignment, it is relevant to consider whether the degree to which the fuel economy of the vehicles held by a household with more conservative views also have dramatically different fuel efficiencies than households with a more moderate to liberal ideology. To illustrate this distribution, Figure 9.40 shows the distribution of average household vehicle fuel economy split by political alignment. For example, Figure 9.40 shows that 5% of respondents that stated a moderate to liberal political alignment lived in households that had an average vehicle fuel economy between 10 to 15 mpg. As above, the figure illustrates data from the weighted sample. The distribution shows that households with moderate to liberal political alignment tend to have slightly higher average fuel economy within the household. However, this difference is not extraordinary. In addition, at the lowest fuel economy category, the proportion of moderates to liberals is greater than that of conservatives.

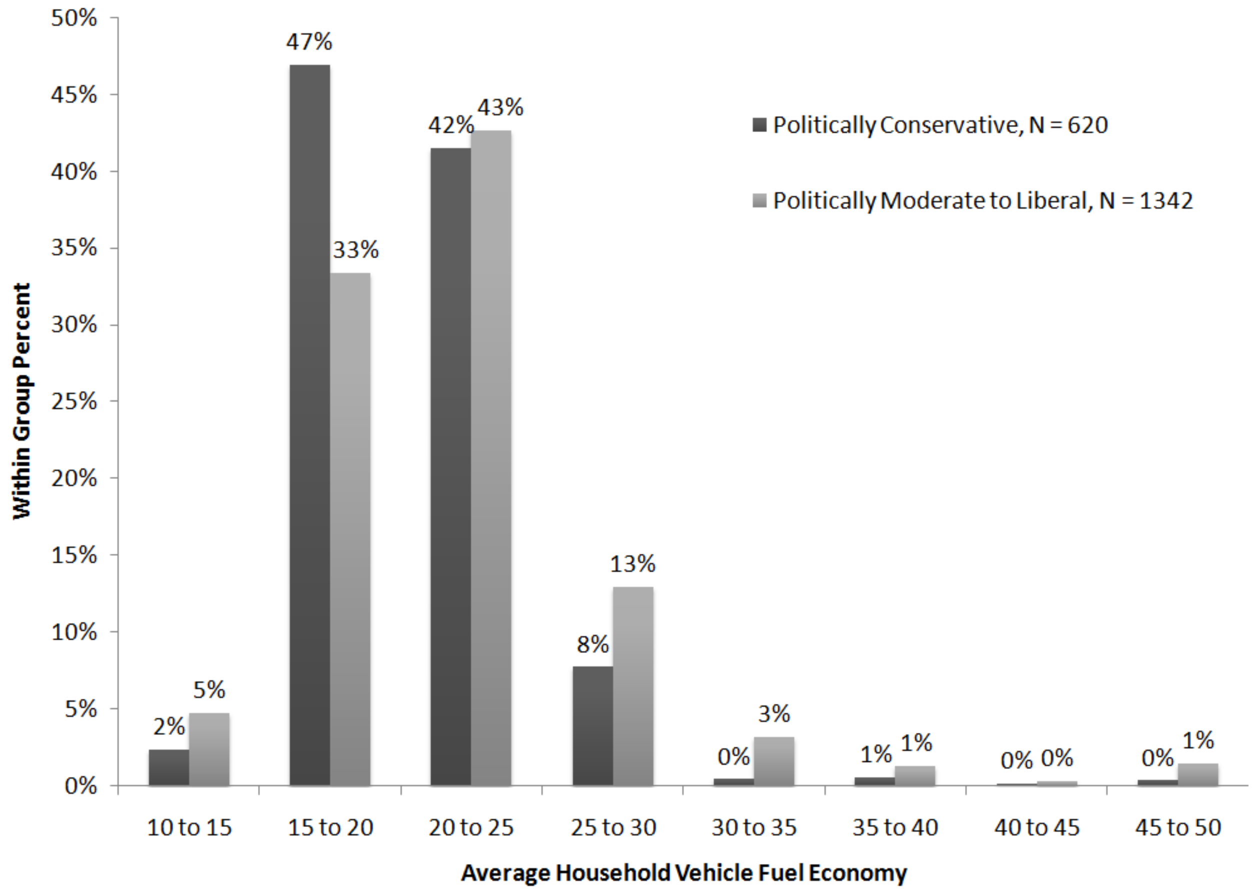


Figure 9.40 Distribution of Average Vehicle Fuel Economy by Political Philosophy

To examine this issue more closely, Table 9.16 reproduces the cross-tabulation of Table 9.15, but splits the data into two tables illustrating the within-category distributions of support for feebates by fuel economy as partitioned by political alignment. For example, the top half of Table 9.16 shows that a weighted sum of 15 conservatives (or about 0.5% of the total sample) owned vehicles with a fuel economy of 10 to 15 miles per gallon. Among this cohort, which has a small sample size, 58% stated that they would not be supportive of a feebate policy. In contrast, the bottom half of Table 9.16 shows that 43% of the 63 respondents who considered themselves moderates or liberals within the same category of fuel economy stated that they would not be supportive of a feebate policy.

The trends in Table 9.16 show that opposition to feebates generally declines within increasing fuel economy within both partitions of political alignment. Exceptions to this trend notably occur within the categories of 35 to 45 miles per gallon. Again, this anomaly is exaggerated by the small sample size (< 30) of these cohorts and as a result the uncertainty about these sample proportions is very large. Because opposition to feebates is higher at lower levels of fuel economy regardless of political alignment, the cross tabulations of Table 9.16 suggest that the average fuel economy of the household does influence support for feebates at lower fuel efficiencies. Table 9.16 shows that households with a relative low average fuel economy oppose feebates in proportions that are greater than the overall weighted sample. However, the proportion of this opposition is greater among those with a conservative political alignment and declines less rapidly with increases in fuel economy when compared with respondents of a moderate to liberal political alignment.

Table 9.16 Cross Tabulation of Policy Support by Fuel Economy by Political Alignment

I would generally be supportive of this kind of program to help slow the rate of climate change. (Politically Conservative)								
Average Fuel Economy (combined mpg)	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50
Strongly Agree	5%	18%	18%	26%	22%	0%	100%	0%
Agree	31%	38%	41%	50%	7%	64%	0%	43%
Disagree	28%	24%	20%	20%	71%	0%	0%	57%
Strongly Disagree	30%	17%	18%	4%	0%	36%	0%	0%
Don't know	3%	1%	3%	0%	0%	0%	0%	0%
Refused	2%	2%	0%	0%	0%	0%	0%	0%
Total (N)	15	291	257	48	3	3	1	2

I would generally be supportive of this kind of program to help slow the rate of climate change. (Politically Moderate to Liberal)								
Average Fuel Economy (combined mpg)	10 to 15	15 to 20	20 to 25	25 to 30	30 to 35	35 to 40	40 to 45	45 to 50
Strongly Agree	21%	40%	34%	34%	42%	26%	35%	50%
Agree	35%	46%	50%	53%	53%	61%	4%	41%
Disagree	40%	8%	13%	12%	2%	13%	61%	0%
Strongly Disagree	3%	5%	2%	1%	3%	0%	0%	9%
Don't know	1%	1%	1%	0%	0%	0%	0%	0%
Refused	0%	0%	0%	0%	0%	0%	0%	0%
Total (N)	63	448	572	174	43	18	4	19

These trends indicate that households with lower average household fuel economy are more likely to oppose feebates. But it is important to recognize that in all but one category across the political spectrum, the proportion of respondents supporting feebates is in the majority. Hence while those of a conservative political alignment are more likely to not express support for feebates, a large proportion of conservatives did state support for the policy. As indicated in Table 9.16, a majority of those describing themselves as conservative (64%) stated that they would be supportive of the policy, while (40%) of those describing themselves as very conservative also supported the policy.

Overall, within the weighted sample, the concept of a feebate policy was supported by about 76% of the respondents, and opposed by 22%. Table 9.17 shows the distribution of respondents by support for feebates and brings the overall opinion towards feebates into perspective. While the analysis above illustrates the shares of opinions within specific cohorts, Table 9.17 illustrates the breakdown across all demographics. Table 9.17 shows that across income, education, age, and race, feebates found a majority of support within each demographic category.

Table 9.17 Demographics by Support for Feebates

(a) Household Income	Support Feebates	Do not support Feebates
Less than $10,000	6%	1%
$10,000 to $25,000	11%	1%
$25,000 to $35,000	7%	1%
$35,000 to $50,000	10%	3%
$50,000 to $75,000	15%	3%
$75,000 to $100,000	10%	4%
$100,000 to $150,000	11%	5%
More than $150,000	8%	4%
Total	78%	22%

(b) Race	Support Feebates	Do not support Feebates
Caucasian or White	31%	13%
Hispanic	32%	5%
African American	5%	1%
Asian	5%	1%
Native American or Alaskan Native	2%	0%
Hawaiian or Pacific Islander	1%	0%
Other	2%	1%
Refused	0%	0%
Total	78%	22%

(c) Education	Support Feebates	Do not support Feebates
Did not complete high school	15%	2%
High school graduate	18%	6%
Some college	18%	6%
2-year college degree	6%	2%
4-year college degree	14%	4%
Graduate degree	8%	2%
Total	78%	22%

(d) Age	Support Feebates	Do not support Feebates
18 - 24	10%	3%
25 - 34	15%	4%
35 - 44	17%	4%
45 - 54	15%	4%
55 - 64	11%	3%
65 - 74	6%	2%
75 or over	4%	2%
Total	78%	22%

Table 9.17 illustrates results of the reweighted sample such that the distribution of demographics closely matches those found within the population. The percent value shown in each cell is a percent of all weighted respondents. For example, 10% of all respondents in the weighted sample both supported feebates and were between the ages 18 and 24. Similarly, 4% of all respondents in the weighted sample both did not support feebates and had a 4-year college degree. The results of the unweighted sample are similar, but favor feebates by a slightly larger margin. The total number of respondents across all demographics are the same, but the total equals less than the 3072 respondents that completed the survey because a weighted sum of 79 respondents (80 unweighted respondents) did not answer the question regarding their support of the policy.

Overall, the table suggests that the concept of feebates would receive support from about 3 of 4 Californians. Taken across the state population over 18 years old, this amounts to about 20 million people. The share of the population expected to oppose the policy is (~1 in 5), which amounts to about 6 million people.

To explore whether households varied in their opinion based on family size, the survey asked respondents general questions that would give a general perspective on household size and age distribution. A cross tabulation of respondents by family size, and by the number of children in the household can show the relative support and opposition that larger families had to the feebate policy in comparison to smaller families.

Table 9.18 shows the cross tabulation of policy support and opposition by the number of people within the household of the respondent.

Table 9.18 Cross Tabulation of Policy Support by Household Size

I would generally be supportive of this kind of program to help slow the rate of climate change. [Total Household Size]								
Weighted Sample (Total HH Size)	1	2	3	4	5	6 or more	Refused	Total (N = 3072)
Strongly Agree	24%	24%	29%	28%	23%	28%	19%	26%
Agree	46%	46%	47%	51%	59%	51%	54%	50%
Disagree	19%	20%	13%	14%	10%	11%	8%	15%
Strongly Disagree	6%	7%	7%	6%	5%	8%	9%	7%
Don't know	4%	3%	2%	2%	1%	1%	6%	2%
Refused	1%	0%	0%	0%	1%	1%	5%	0%
Total (N)	361	665	504	616	386	512	27	3072

Table 9.18 shows how the distribution of support and opposition varied within the weighted sample across different household sizes. The most common household size was 2, but a near equivalent share of 3 and 4 person households were also part of the sample. The distribution of policy opposition across different household sizes remains within a range of 15% to 27%. The highest share of opposition is actually found among the smallest households. A total 25% of single person households and 27% of two-person households were opposed to the policy. The shares of opposition hover between 15% and 23% at household sizes above two people. These shares are at or below the overall share of opposition at 22%, which suggests that in fact it is smaller households that are pulling the share of policy opposition up.

A similar analysis on the number of children in the household presents a similar result. Table 9.19 illustrates a cross tabulation of policy support and opposition as defined by the number of children in the household ages 18 and under. This demographic is important to consider because households with larger non-driving family members can gravitate towards acquiring larger vehicles.

Table 9.19 Cross Tabulation of Policy Support by Number of Children in Household

I would generally be supportive of this kind of program to help slow the rate of climate change. [Children 18 and under in the household]									
Weighted Sample (Children)	0	1	2	3	4	5	6 or more	Refused	Total (N = 3072)
Strongly Agree	26%	24%	31%	22%	23%	36%	54%	18%	26%
Agree	47%	51%	51%	55%	66%	44%	34%	55%	50%
Disagree	17%	17%	11%	12%	6%	16%	2%	8%	15%
Strongly Disagree	7%	7%	6%	9%	4%	4%	5%	8%	7%
Don't know	3%	1%	2%	2%	1%	0%	4%	6%	2%
Refused	1%	0%	0%	1%	0%	0%	0%	5%	0%
Total (N)	1448	550	539	289	145	39	35	27	3072

Nearly half of all households in the weighted sample have no children currently living in the household. Roughly an equivalent share of households with children had either one or two. The distribution of opposition to the policy shows that the within-cohort share of opposition generally declines as the number of children increases. For example, the share of zero- and one-child households opposing the policy is 24%, constituting two-thirds of the total weighted sample, slightly above the overall average opposition of 22%. The share of opposition for most of the remaining households varies between 10% and 21%.

Hence, the survey found that an increased number of children in the household does not increase overall opposition. The results of Tables 9.18 and 9.19 suggest that increased household sizes are not a predominant factor that would increase opposition to the feebate policy. This is not to suggest that there do not exist large households opposed to feebates because they are large, but it does suggest that the large households are not overwhelmingly opposed to the policy in shares larger than that of the overall weighted sample. In contrast, the results suggest that in fact the opposition to feebates is relatively higher within smaller households.

The survey asked other questions of the respondents to gauge their general attitude towards automotive policy and motivations for policy intervention to influence emissions. The results of these questions suggest that the sample was generally amenable to policy intervention in the automotive industry, and felt that the policy was fair overall. The distribution of responses roughly matches the distribution of support for feebates discussed in the analysis above. The distribution of the reweighted sample responses to these questions is presented in a series of graphs within Figure 9.41.

The distributions suggest that the population generally has a favorable opinion of automotive policy to the same degree that it was supportive of feebates. Roughly 80% of the weighted sample felt that the feebate policy design would be a good way to send a signal to the auto industry to produce vehicles that emit fewer greenhouse gases. A similar share of respondents felt that people should be rewarded for buying vehicles that emit relatively few greenhouse gases. On the issue of fairness, a smaller majority (69%) felt that the policy was fair, while a large minority (29%) felt that the policy was unfair. Respondents were also asked whether they felt the policy was unfair. A majority (51%) disagreed, while 45% agreed. Hence, while respondents generally supported the policy, some did believe that the policy could have complications of fairness to consumers. This might especially be the case for households that need to buy large vehicles due to large family sizes or business needs. Due to time limitations, the survey was not able to convey different potential feebate policy designs or explain nuances that might mitigate issues of fairness within the policy. For example, a class-based feebate system could scale fees and rebates within vehicle classes (such as pick-up trucks), meaning that certain trucks would receive rebates and certain trucks would receive fees. The explanation presented in survey conveyed the policy as if all vehicles were on the same scale (a single benchmark) for simplicity. Hence, these and other issues may arise in the further discussion of feebates. Finally, between 70% and 80% of respondents felt that government should encourage automakers to produce more efficient vehicles and to encourage consumers to purchase more efficient vehicles.

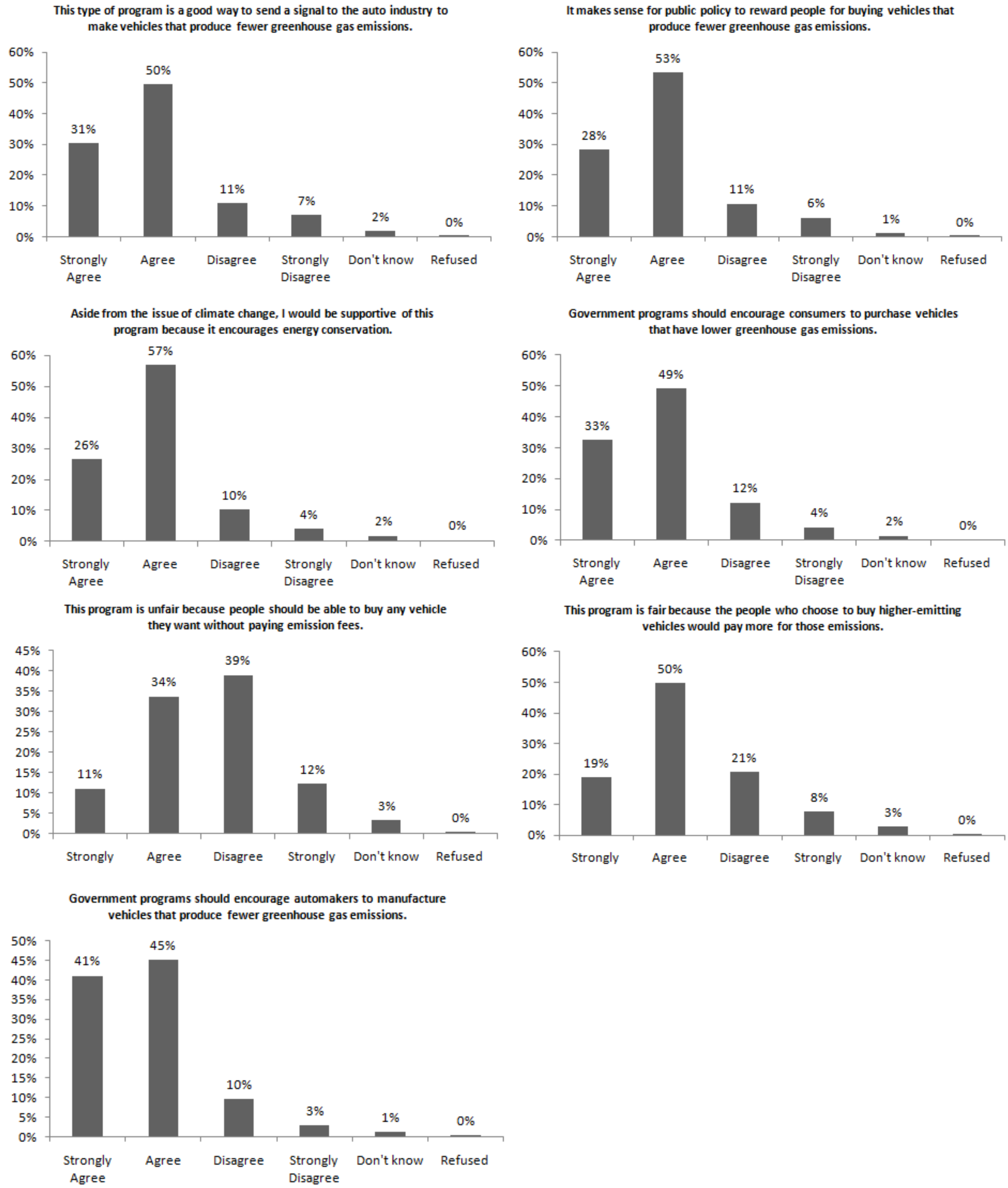


Figure 9.41 Weighted Distribution of Response to Policy Questions

Analysis by Regional Weighting

The results of the survey thus far make a few points clear. About 75% of the weighted sample, that which is adjusted to match key demographic attributes of the state, was supportive of feebates. But another key point that emerges from the analysis is that political alignment plays a prominent role in formulating opinions. As is evident from national elections, the politics of the population can in part be correlated to a person's location of residence. California has a political heterogeneity similar to the nation has a whole, as certain parts of the state are inclined to be more liberal and others more conservative. Therefore, beyond ensuring a congruency of key demographic and socioeconomic variables, the following analysis considers how the sample aligned geographically within the state.

The weighted sample was re-weighted to match the geographic distribution of the population. The survey asked each respondent to provide his or her zip code, which informs the county in which the respondent most likely resides. The proportional representation of each county within the sample was then scaled to match the proportional representation of each county within the population. This creates a new weight for each respondent, which taken across all respondents, adjusts the county share within sample to match the corresponding county share within the population.

California has 58 counties, and the raw sample provided good geographic coverage of the state. Of the 58 counties, 57 were represented in the sample. Only Sierra County, which has the 2nd smallest state county population of about 3,000, was not represented within the sample. In terms of the geographic balance of respondents, the sample shares of the counties were distributed in close alignment with the state population. The counties containing urban regions, such as Los Angeles, Orange and Alameda County, were relatively under-represented, and less populated regions were relatively over-represented on a regional basis.

Table 9.20, below, first shows how the regional weighting impacted the key demographics of the sample as compared to the population.

Table 9.20 Geographically Re-Weighted Demographic Attributes

(a) Household Income	Raw Sample	California Population	Regionally Reweighted Sample
Less than $10,000	4%	5%	7%
$10,000 to $25,000	9%	14%	12%
$25,000 to $35,000	8%	9%	9%
$35,000 to $50,000	11%	13%	13%
$50,000 to $75,000	17%	18%	16%
$75,000 to $100,000	16%	13%	14%
$100,000 to $150,000	18%	15%	16%
More than $150,000	16%	13%	13%

(b) Age	Raw Sample	California Population	Regionally Reweighted Sample
18 - 24	4%	14%	12%
25 - 34	11%	19%	19%
35 - 44	17%	20%	21%
45 - 54	25%	19%	19%
55 - 64	24%	13%	14%
65 - 74	14%	8%	8%
75 or over	6%	7%	6%

(c) Education	Raw Sample	California Population	Regionally Reweighted Sample
Did not complete high school	6%	20%	16%
High school graduate	10%	24%	23%
Some college	18%	23%	25%
2-year college degree	12%	7%	8%
4-year college degree	28%	17%	18%
Graduate degree	25%	9%	10%

(d) Race	Raw Sample	California Population	Regionally Reweighted Sample
Caucasian or White	55.8%	42.6%	42.8%
Hispanic	24.5%	36.1%	37.9%
African American	5.2%	6.0%	6.1%
Asian	8.2%	12.1%	6.4%
Native American or Alaskan Native	2.4%	0.5%	2.2%
Hawaiian or Pacific Islander	1.0%	0.3%	1.4%
Other	2.7%	2.4%	3.1%

The re-weighting of the sample to match the regional distribution has only a small impact on the demographic distribution. This distribution would be expected to shift slightly away from the population distribution, as a re-weighted of respondents towards under-represented counties will not necessarily match up perfectly with the distribution of demographic and socioeconomic attributes of the state. But, Table 9.20 above shows that the re-weighted distribution by region is still close to the overall population distribution of key attributes. Figure 9.42 presents the impact of the regionally weighted results on the overall support for the policy. The figure shows the raw sample, the weighted sample, and the regionally weighted sample together.

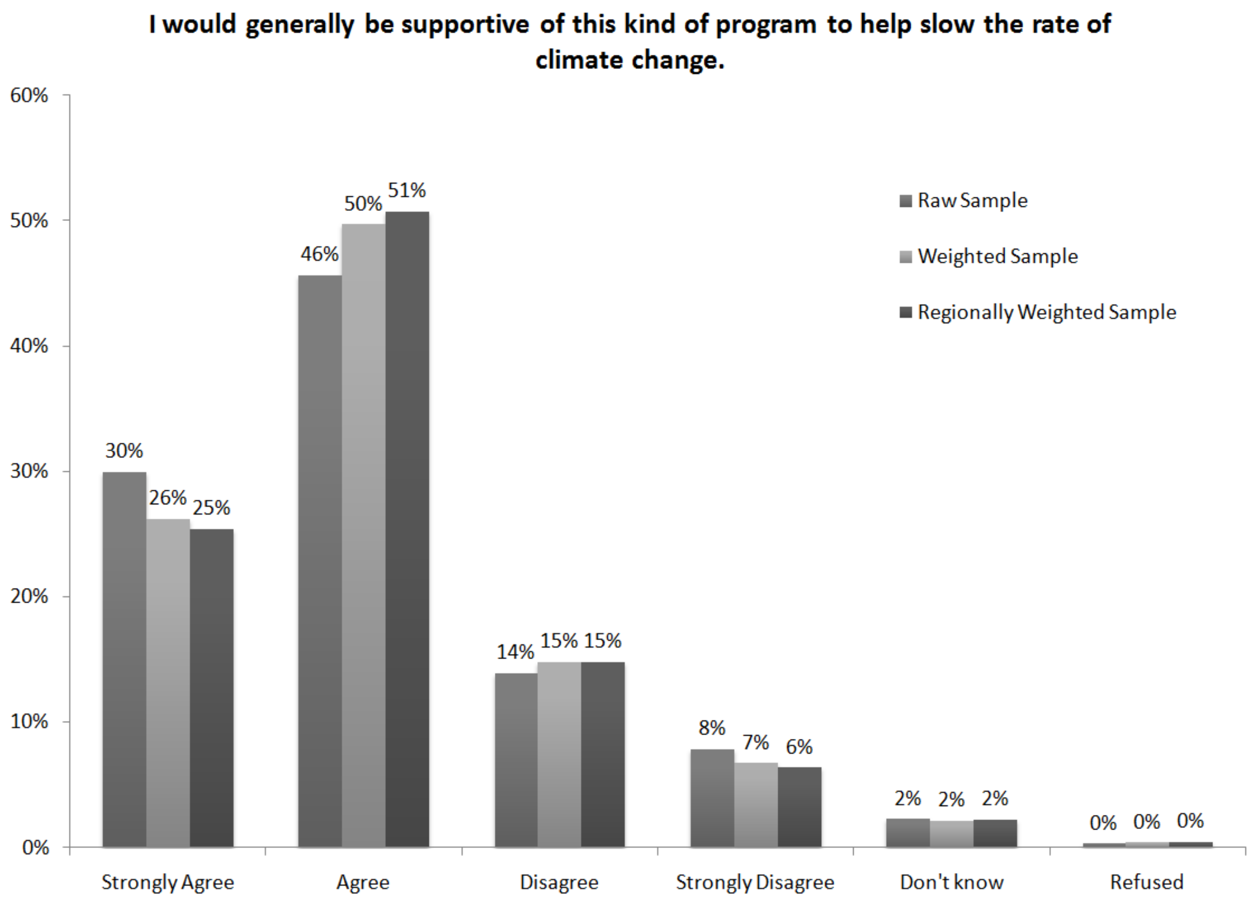


Figure 9.42 Distribution of Response to Overall Policy Support Question – Raw, Weighted, and Regionally Weighted

The results of the regionally weighted sample show that little changes in comparison to the weighted sample. That is, there is slight decrease in those who strongly agree with the policy compensated by an increase of those who agree with the policy. The balance of those respondents disagreeing with the policy remains relatively unchanged. Hence, the weighted sample, when rebalanced to match the regional distribution of the population, holds the same conclusions with respect to the total share of policy support and opposition.

9.3.2. Summary of Findings: Focus Groups

As discussed in more detail in Section 5.2, above, a total of twelve focus groups were conducted by the research team during the late Summer and early Fall of 2009. The focus groups were held in two rounds of six focus groups each, with a total of 110-120 participants, and occurred in different regions of the state. In each round, one focus group was conducted in Spanish and the remaining five were conducted in English. The consulting firm of Ewald & Wasserman Research Consultants, LLC in San Francisco, California, was engaged to recruit participants for the focus groups. The focus groups took place over two hours in the early evening, at a public library or other convenient location for participants. The focus groups were moderated by research staff with UC Berkeley's TSRC.

The series of focus groups allowed the project researchers to probe the concept of feebates more deeply than in the statewide survey, but with a much smaller total population of about 100 participants. As revealed in the detailed focus group summaries in Appendix B, several of the focus groups were very different from one another in terms of the overall reaction to feebate type programs and with regard to some of the particular issues associated with them. The most pronounced differences in the focus group findings related to the geographic locations of the groups, where the groups in major urban areas were typically more receptive to feebate type programs than those held in more rural areas.

To the extent that generalizations of the focus group findings are possible, key findings are discussed below. Detailed summaries of each individual focus group can be found in the Appendix B, where more details are available.

First, when designing the focus group protocol, a major concern was how hard it might be for respondents to understand feebates. However, in all the focus groups participants seemed to quickly understand the concept of a feebate program. A second overall finding is that in most cases, after discussion over the course of the focus groups, the overall response to feebate programs was *negative*. Many participants generally had a negative view of both manufacturers/dealers and government programs, and viewed feebate programs with suspicion. There was concern expressed in a number of the groups that manufacturers/dealers would find a way to manipulate feebate-related transactions to their benefit.

Additional overall findings include participants in several cases suggested alternative policy approaches to address vehicle fuel efficiency, including gas taxes and direct regulation of manufacturers, as alternatives to feebates that would put more of the burden on manufacturers and less on consumers. It was generally a popular sentiment to target fees directly at manufacturers rather than consumers (i.e., have manufacturers transact fees and rebates directly with the state in ways that would be less apparent to consumers). Furthermore, participants generally felt that a feebate program would be ineffective in influencing vehicle purchase decisions. This may have been due to the relatively small (compared to the "Cash for Clunkers" levels) amounts of fees and rebates that were discussed. When pressed to estimate the level at which feebates might be effective, they indicated that the fee or rebate would need to be 10-25% of the sticker price, or alternatively, in a range from $1,000-$5,000.

At the same time, there was an understanding that higher emitting vehicles could receive rebates while lower emitting vehicles could be charged fees under a class-based system. This also seemed "unfair" and, moreover called into question the purpose and effectiveness of the program. The possibility of special exemptions or other breaks for large families or businesses was recognized as a way to address the fairness issue, but with concerns that it be administered fairly.

Finally, an additional concern raised in several of the focus groups was skepticism that a feebate program could be managed so as to meet the goal of revenue neutrality. Participants seemed perceptive on this issue, and raised the concern that under some conditions (for example with high gasoline prices) vehicles with rebates might prove to be more popular than expected, making the maintenance of revenue neutrality a potential issue. Additional findings from the focus groups related to specific *feebate program design issues* are discussed in section 9.3.5 below.

9.3.3. Summary of Findings: Automaker Interviews

From July to December 2009, the UC Berkeley research team conducted six interviews with experts from five automobile manufacturers in the US and abroad (one company was interviewed twice). For the most part, UCB interviewers followed a protocol containing six basic questions (see below). In addition to these interviews, the team also received a written response from a sixth automaker. Identified below are some of the common comments and themes that arose from these interviews. The transcripts from these interviews are included in the report appendices.

With regard to various themes that emerged through the interviews, we find both some consistent and some divergent results. First, three of the five automakers interviewed are generally supportive of a feebates program, though several of them indicated that their continued and future support depends on the structure and design of the program. For two automakers, this support stems from the belief that a feebates program sends a signal to the market and car buyers that the government supports a fleet wide shift toward more fuel-efficient vehicles. One automaker supports feebates as part of the company's overall shift toward greater environmental stewardship. One interviewee indicated that they have not taken a position on feebates, since, to them, it's not a "black and white," pro-feebate or anti-feebate issue.

Two interviewees expressed general opposition to a feebates program. For one automaker, this sentiment stems from the belief that the program would be biased against consumers with large families or needs that require larger vehicles and trucks. This automaker believes that CAFE standards will likely result in the fleet wide improvements that CARB hopes to achieve with feebates. Another automaker described feebates as "unnecessary and duplicative" and an "inefficient, expensive and complicated way to get small environmental benefits." Like the other opposing automaker, this company believes that Federal and state vehicle fleet average fuel economy and greenhouse gas regulations are a preferred alternative to feebates along with cap and trade programs already authorized in California and proposed nationally. This automaker added that feebates has the potential to reverse reforms that may be brought about by CAFE standard improvements.

Four of the five automakers indicated a preference for a continuous feebate structure as opposed to a step-based structure or a structure with a zero-band, and three of these indicated a preference for a single class system that places all vehicles on the same scale. Two automakers prefer a multiple-class system that would "compare vehicles that are really comparable;" for example, a class-based system that would compare SUVs to SUVs, and compact cars to compact cars. One automaker that is generally opposed to feebates prefers class-based as the "lesser of two evils." None of the automakers indicated a preference for a step-based function (one strongly opposed it), and two pointed out that the step-based structure could lead to market distortions, gaming, and border issues, where manufacturers make slight changes to vehicles to make them eligible for incentives.

When presented with the concept of a footprint-based function, one automaker indicated that this kind of system would be too complicated for consumers to understand and another expressed dislike for footprint-based systems in general. Two of the six automakers preferred footprint-based: one likened the footprint-based system to the shadow area-based program in the Netherlands (which this automaker favored), and another prefers a feebate system that aligns with CAFE (so thus prefers footprint-based).

Four of the six automakers indicated that a feebates program in California would likely impact product design and product planning. Three of these indicated that the program would primarily result in product adjustments at the manufacturer level, while one indicated that feebates would result in a mixture of product design changes and shifts in production allocation. One of the four argues that this impact on product planning will be largely negative and that the program will cause "planning mistakes" and "wasted resources."

Two of the six automakers indicated that the program would not impact product planning and design, either because they did not believe that the program will be effective overall or because they believe that the program is more likely to cause shifts in production allocation. Feelings about how the program would affect product planning also influenced automakers' preferred lead-times and advance notice for program adjustments to maintain revenue neutrality.

In general, most automakers pointed out that the more lead-time, the better (for product planning and sales mix shifts). Three automakers think that one- to two-years notice would be adequate to make internal adjustments to meet consumer demand shifts. Automakers that believe that the program will and should impact product planning indicate that more lead-time (3-4 years) is needed to influence product design. Two of the five automakers used Cash for Clunkers as an example of how late notice and fast implementation leads to dealer frustration and other problems with implementation.

When asked about previous experience with similar incentive/disincentive programs, three of the five automakers indicated that they had had relatively positive experiences in the past. One automaker felt that the Canadian feebate program—though relatively short-lived—was generally good and motivated the company to improve one model in order to make it eligible for the incentive. Another automaker felt that Cash for Clunkers was successful at influencing consumer decision-making and also attracted new car buyers to the new car market. A third automaker described the Dutch feebate program—which they explained as a multiple-class, vehicle "shadow area"-based program—as a model for future feebate programs.

Four of the six automakers also described negative experiences with past programs. Cash for Clunkers, according to two automakers, disrupted dealership cash flows and provided little lead-time for dealers and manufacturers to prepare for program implementation. Two automakers used the Canadian program as an example of what not to do with a California feebates program, since they argue that the program was too short-lived and resulted in a lot of gaming and little technological change and environmental benefit.

Three of the six automakers responded that the feebate program should be administered by the dealership, where they believe it would more effectively influence consumer decision-making (one company indicated that an automaker-administered feebate would seem like a "hidden tax," and as such, would not influence consumer purchases). One automaker pointed out that administration by any entity other than the government (i.e. via vehicle registration) would dilute the signal from the government and incorrectly associate the feebate to the dealer or manufacturer. Another automaker argued that, if the point of the feebates program is to drive new technology, the only option is to administer the program at the manufacturer level, since this is where new technology development occurs. This automaker also believes that it would be easiest and most amenable to dealers to centralize program administration at the manufacturer level.

All automakers that were asked about national versus state-by-state feebates programs much prefer a national program. If a national program could not be developed and if state programs were adopted, manufacturers would prefer similarly designed and aligned state programs.

9.3.4. Summary of Findings: Auto Dealership Interviews

From July to November 2009, the UC Berkeley research team interviewed general managers at eight different car dealerships around the state. For the most part, UCB interviewers followed a protocol that contained seven key questions. Identified below are some of the common comments and themes that arose from these interviews. The transcripts from these interviews are also appended below.

With regard to overall findings from these interviews, several themes became apparent. First, six of the eight dealers interviewed voiced opposition to the feebates program. One dealer expressed support for the rebate aspect of the program but opposes the fee (due to fears of depressed sales, described further below), and one dealer was generally supportive of feebates, describing the program as a "win" for his dealership.

Dealers who were opposed to feebates voiced a variety of concerns about the program. Two dealers raised the issue of equity, and argued the program would create "classes" of consumers and disproportionately and negatively impact larger families and those that need larger vehicles for their business or lifestyle. One dealer added that the program would reward those that do not necessarily need the rebate (i.e. those that can afford cars with more expensive, fuel-efficient technology) and penalize people who do not drive as much. One dealer also noted that many consumers rank functionality and purpose as more important than fuel economy and cost when making vehicle purchase decisions, and thus the feebate would penalize these consumers. Two of the six dealerships believe that a feebate program would deter consumers with older trucks, SUVs, and more polluting vehicles from replacing them with newer, less polluting vehicles, thus resulting in a net negative for greenhouse gas emissions. Two of the six dealerships oppose the program because they believe CAFE will result in the fleet-wide improvements that CARB hopes to accomplish with feebates.

Two dealers expressed concerns about the impact of a feebate program on vehicle sales and revenues. One dealer attributed the bulk of this impact to domestic dealers and expressed concern about placing additional pressure on the already struggling domestic auto industry. The dealer that opposes fees but supports rebates also believes that the fees will depress sales at a time when dealers are already struggling under the current economy. As an alternative means of funding this program, this dealer promotes an increase in the gas tax.

In fact, when asked about preferred alternatives to the feebates program, three of the eight dealers expressed a preference for an increase in fuel taxes. Higher fuel taxes, they argued, are more likely to influence driving habits and reduce vehicle miles traveled and can also influence consumers' purchase decisions. These dealers used observed shifts in vehicle purchasing behavior when gas prices increased in the past to support this argument.

When asked about past experiences with similar incentive and disincentive programs, two of the eight dealers described “Cash for Clunkers” as an overall positive experience—one of these dealers described Cash for Clunkers as the "single most successful program in [his] thirteen years in the car business" and another indicated that he saw a lot of business that he would not have otherwise seen. The same dealer spoke highly of the Cash for Clunkers website as a model that should be used for future rebate programs. Two of the eight dealers, however, disliked Cash for Clunkers, since they found the administration and paperwork to be complicated and cumbersome. One dealer described past hybrid tax credit incentive programs as "OK," but not as much of a "call to action" as a program that provides an instant rebate.

Regarding program administration, three of the eight dealers strongly opposed dealership-level administration, mostly because of the administrative burden. One interviewee described his dealership as already "inundated as a business in handling the State's business." Two dealers also described past problems with other programs administered at the dealership—like the tire tax—which has resulted in steep fines when dealers make mistakes when reporting and making payments to the State. Two of the eight dealerships, however, indicated that they would likely handle the program similar to how sales tax revenues are currently handled, and as such, may be able to undertake the administrative aspects without much trouble.

When asked about compensation from the State for administration, four of the eight dealers provided estimates for acceptable reimbursement. Two dealers indicated that $50-$100 per transaction would be adequate, one dealer preferred a monthly compensation of ~$1000 per month, and one dealer argued for a percentage reimbursement rather than a fixed per transaction or per month repayment. When asked about the timing for the administration of fees and rebates, two dealers expressed a preference for delivering rebates at the point-of-sale, rather than asking the consumers to apply for rebates.

Six of the eight dealers interviewed expressed willingness to set aside time to train salespeople about the program, if implemented. Five dealers stated that this training would not be a problem, since salespeople already undergo training on a regular basis, and one dealer indicated that they would comply if compelled by the State. One dealer argued that the training should be as simple as possible—to mirror the desired simplicity of the program—and as such, indicated that the training should last a few minutes, rather than 1-2 hours.

When asked about preferred features of a feebates program, one dealer specifically requested clear and concise rules for the program and advance notice to allow dealers to prepare (this dealer used Cash for Clunkers as an example of a program that did not provide enough lead time or clear rules in advance of program administration). Another requested that the State give dealers the benefit of the doubt when it comes to program administration, and forgo steep and harsh fees for small mistakes (to address problems like those raised with the tire tax). When asked, two of the eight dealers opposed a class-based system and argued that this structure would be confusing to consumers and risks sending the wrong signal about the goals of the program.

9.3.5. Specific Findings Related to Feebate Program Design

In order to explore how the general public and other stakeholder groups have existing opinions about feebate program design, some aspects of feebate program design were explored during the focus groups and interviews and to a lesser extent in the statewide survey (owing to time limitations in the phone survey). The focus groups offered the best opportunity to explore program design details, as poster-board graphics showing different program designs were helpful in quickly conveying the key concepts in ways that could be readily grasped. The key findings from these efforts are summarized below.

Focus group findings related to feebate program design

The focus group findings were generally mixed with regard to consumer reactions to program design details. There was some general agreement among certain issues – such as that a "continuous" type system seemed better than a "step" type system by most participants – but there were mixed views on other details of program design, as well as concerns about program "fairness" and concerns about how the state would maintain the program's revenue neutrality.

One key larger finding is that many focus group participants proposed that the fees and rebates be targeted towards manufacturers instead of consumers, with an emphasis that manufacturers should pay the fees. It was also expressed that having manufacturers pay the fees would benefit the environment because manufacturers would produce more fuel-efficient vehicles to attract consumers.

As mentioned above, the majority of participants supported the continuous design because they felt basing a fee/rebate on the "exact" miles per gallon of each vehicle was fairer than a "step based" system. They did not seem to have difficulty with the notion that fees/rebates would be for varying amounts, noting that sales taxes and other fees are often handled that way, and actually felt that the greater simplicity of the continuous system would be attractive to consumers.

However, proponents of the step function design preferred the design simplicity and the direct link of vehicles to climate change with the use of the global warming score (GWS) now in use in California. These scores are now found on window stickers on new vehicles for sale in California, along with a smog score. The 1-10 scales are designed to inform consumers about the relative smog and greenhouse gas emissions from the vehicles they are considering so that they can make more informed purchase decisions (note: the GWS was only introduced in the first six of the statewide focus groups).

While there was some disagreement about this, the majority of participants preferred a class-based system that would have separate categories for (at least) cars and light trucks. Participants stated that the class-based system is fairer than the uniform system because it is more flexible for families and businesses, allowing people who want to purchase larger vehicles a chance to choose the cleanest car of its class and obtain a rebate. A significant point is that many of the participants felt the program would be unfair to large families and businesses that require bigger vehicles and thought that an exemption for businesses might be appropriate, if administered fairly.

As for the mechanics of fee collection and rebate payment, the majority of participants stated that they preferred fees to be added to their vehicle cost at the time of purchase to reduce administrative costs and so the fee could be included in their monthly payments. Most participants would like to receive their rebate by having the cost of their vehicle reduced at the time of purchase, rather than receiving the rebate on a delayed basis.

Finally, although the majority of participants felt that the idea of revenue neutrality made sense and was fair, few thought revenue neutrality was actually possible because consumers would purchase more vehicles with rebates than fees, and there would not be enough funds to pay the rebates.

Interview findings related to feebate program design

The interviews that the research team conducted with the automakers touched on the program design issue and a few insights were found with regard to automaker views on the subject. The automakers generally were mixed in their overall views of feebate programs (as discussed in detail in Appendix C), with some in opposition and others in weak support (thinking that they may benefit somewhat) but with concerns about impacts on their dealer networks.

To briefly summarize key findings, four of the five automakers indicated a preference for a continuous feebate structure as opposed to a step-based structure or a structure with a zero-band, and three of these indicated a preference for a single class system that places all vehicles on the same scale. Two automakers preferred a multiple-class system that would "compare vehicles that are really comparable;" for example, a class-based system that would compare SUVs to SUVs, and compact cars to compact cars. One automaker that is generally opposed to feebates preferred class-based as the "lesser of two evils." None of the automakers indicated a preference for a step-based function (one strongly opposed it), and two pointed out that the step-based structure could lead to market distortions, gaming, and border issues, where manufacturers make slight changes to vehicles to make them eligible for incentives.

When presented with the concept of a footprint-based function, one automaker indicated that this kind of system would be too complicated for consumers to understand and another expressed dislike for footprint-based systems in general. Two of the six automakers preferred footprint-based programs. One likened the footprint-based system to the shadow area-based program in the Netherlands (which this automaker favored), and another preferred a feebate system that aligns with CAFE (so thus footprint-based).

Statewide survey findings related to feebate program design

The statewide survey did not ask any questions that directly addressed program design because its relatively short length (15 minutes) did not allow for enough background to be given for such detailed questions to be asked. The survey did ask if the imposition of a fee would cause respondents to delay or defer the purchase of a new vehicle, and if the imposition of a rebate would cause respondents to be more likely to purchase the vehicle. Based on a $2,000 fee imposed on a hypothetical vehicle, 16% of respondents said they would “buy the vehicle anyway,” 39% said that they would “buy a different new vehicle,” 20% said that they would “buy a used vehicle,” 14% said that they would “save money to buy the same vehicle later,” and 11% were unsure or did not respond. This general finding does not imply anything specific with regard to feebate program design, but does suggest that fees of this level could be effective in shifting consumer purchase behavior.

9.3.6. Survey and Focus Group Limitations and Caveats

The survey data provide insights into the opinions of a large sample of Californians on the subject of feebates. However, the survey has several inherent limitations that should be understood in the context of interpreting the results. The first limitation is inherent with all surveys, in that the survey respondents are subject to self-selection bias. Respondents have to consent to being surveyed and must take the time to do so. Certain subpopulations can be more prone to taking the time to answering questions over the phone for which they will not be compensated. For CATI surveys, a common self-selection bias skews samples towards older and generally more Caucasian cohorts. In this survey, the sample is older and more educated than the general population, with more than 50 percent holding a Bachelor's degree or higher. Within California, this share is 30 percent. The reason for this bias may be a result both inherent to CATI survey respondents and to the subject of feebates, which required the respondent to evaluate a complex policy idea over the phone for the first time. Because survey demographics are traditionally asked at the end, we do not have empirical data on those that responded to the survey but stopped part way through.

For much of the population, feebates are a new and unfamiliar concept. This survey had to both introduce the policy concept and then solicit reactions to the policy. The reactions to the policy were generally positive within the sample. But this should be understood in the context of the limited level of initial exposure that respondents had. While the results indicate support for feebates, this should not be interpreted as a guarantee of permanence in that support. The survey has accessed these opinions prior to a time in which feebates are widely known, understood, or politicized. Public opinion could change with greater exposure to feebates, especially if this exposure is presented in a negative context through the media. It is clear from the results that roughly 20 percent (1 in 5) of the population is not receptive to feebates from this short exposure. It is quite possible that the share of people switching from in-favor to against will outweigh the share of people switching from against to in-favor as the policy is debated in public. Unlike tax credits for hybrid vehicles, which only reward people, feebates create a cost through the fees. For this reason, it is possible that these cohorts expecting to incur the cost will gain a fair share of media coverage.

While focus groups provide a rich qualitative resource for group interactions on a topic and can identify key trends, they have several limitations. They are limited in size and are not quantitative in nature. Thus, one cannot generalize from the results. Further, the results are highly dependent upon the interactions among the group and the moderator, and dominant personalities can influence other respondents.

Potential exogenous reasons for divergence of the survey results from the focus groups

With regard to the somewhat disparate findings from the survey and focus groups, we note that the survey and the focus groups were conducted at different times of a tumultuous economic year, with a variety of changing circumstances. Along with basic differences between the two types of approaches, these "exogenous factors" may have had some effect on the results that were found and may help to explain some of the differences seen. First, the state of the U.S. economy was a major focus of media attention during the period when the focus groups occurred, in the months of August and September 2009. Meanwhile, the survey was conducted a few months later, from mid-October to mid-December 2009.

During the period of the focus groups, "Cash-for-Clunkers" was a prominent and widely discussed government policy within the media. This discussion was often negative, with media critics questioning the policy effectiveness. This policy followed a summer of unprecedented automotive bankruptcies and contentious town hall meetings that took place throughout the country centered on healthcare reform. A series of conservative "tea party" rallies were also occurring throughout this period (April 15, July 4, and September 12, 2009). In addition, California was issuing "IOUs" between July 2, and September 4, 2009, which directly overlapped with the focus group period. These IOUs did not help the state's reputation, and thus may not have reflected favorably during discussions of a new state policy. In addition, the bailouts of large banks in the midst of rising unemployment and foreclosures within the State and nation created a dismal picture of economic health and fairness.

The economic picture improved slightly towards the end of 2009. The economy was technically out of recession, and home prices began to rise. In addition, the healthcare debate in Washington, D.C. and temporal distance from the acute state budget crisis may have made the aforementioned issues less prominent in the mind of the survey respondents. Hence, the policy discussions at the forefront of the American media shifted rapidly in 2009 because of the extraordinary economic and policy events occurring within the state and nation. These changing conditions during the second half of 2009 may have had some effect seen in the opinions in the focus group and survey, where the survey (conducted later in the year) revealed a more positive overall response to the concept of a feebate type policy. Other factors related to the group dynamics of focus groups also seem to have been important to understanding these differences, as were discussed above.

10. POLICY IMPLICATIONS

The results from the research tasks in this project (see Figure 4.1) have produced a variety of useful insights for policy makers to consider as they decide about a potential feebate policy for California. Case studies of feebate policy outcomes in Europe as well as results of the Feebate Analysis Model suggest that feebate policies can be used to reduce greenhouse gas emissions from new passenger vehicles, and can do so while co-existing with other policies that also affect greenhouse gas emissions. In evaluating the Feebate Analysis Model results, potentially important considerations include: the degree of emissions reductions from alternative feebate systems, tradeoffs with regard to changes in consumer welfare, the effect on total social costs and benefits, spillover and leakage effects, and the sensitivity of the model results to base case assumptions. A broader policy perspective includes an examination of the effect of feebates if they were to be adopted by additional states, or nationwide. Also of concern to policy makers are issues related to equity, other economic and fiscal impacts (including revenue neutrality), and the opinions and views of various stakeholders, including consumers, automobile dealers, and manufacturers. Finally, interaction between feebate policies and other AB 32-related policies are of potential concern. This chapter summarizes the policy implications of our research findings for these issues.

10.1. Efficacy in Reduction of Emissions

The base case feebate system for this study is based on footprint functions (one for cars, and one for light-duty trucks) and uses a feebate rate of $20/g/mi. Under the assumptions adopted in this study, this and other feebate systems can be used in California to achieve *additional reduction of greenhouse gases* from new passenger vehicles beyond those projected under national emission standards alone.

However, the size of the reduction is not large when compared to the impact of emissions standards. For example, the total reduction in 2020 from a feebate program is projected to be in the 3-4 $MMTCO_2E$ range, versus the 31.7 $MMTCO_2E$ target for the combined Pavley I and LEV-III standards. A major finding is that, because California represents only 10% of the new vehicle market, a California-only feebate policy is likely to have minimal influence on vehicle design decisions. Conversely, our results highlight the critical role that national emissions standards would play in influencing manufacturers' decisions to reduce vehicle emission rates: the increased availability of improved vehicles creates more rebate options, contributing to the potential effectiveness of feebate programs. At the same time, if emissions standards are stringent enough to force the adoption of emission-reduction technologies that also require manufacturers to shift sales using a pricing strategy, feebate systems can lose their effectiveness in those instances when they would act as a replacement for such a strategy. Finally, we emphasize again that these and other findings always depend on the modeling assumptions.

10.1.1. Evaluation and Comparison of Feebate Policies

Our study compares a large number of feebate policy options by combining various design elements that together comprise a feebate system. Two main design elements are: 1) type of benchmark, and 2) feebate rate. Choosing a benchmark system requires consideration of a variety of tradeoffs, whereas the feebate rate primarily effects the strength of the response. In the next sections we evaluate feebate programs for three different benchmark systems using a baseline feebate rate of $20/g/mi, and discuss tradeoffs. Discussion of the sensitivity to higher or lower rates is addressed in section 9.1.3. Outcome measures for evaluating the overall impact of policies include:

- New vehicle emissions averages
- Sales mix and sales levels
- Effect on consumer welfare
- Total reduction of CO_2
- Social costs and benefits associated with CO_2 reduction

Emissions Reductions

A key design issue is the type of benchmark system to use. The literature suggests that different benchmarking systems can differ in overall effectiveness, and on their impact on individual stakeholders. Although the level of the feebate rate is also important, it primarily magnifies (or reduces) the effect of a system if the rate were to be increased (or decreased). Results in this section address both the overall effectiveness of feebates as well as the relative effectiveness of different benchmark systems. Equity-related issues are addressed in other sections.

Figure 10.1 shows the estimated effect on California average new vehicle emission rates of three feebate systems introduced under the national emissions Reference Standard (reductions of 2% per year starting in 2017), as determined by the Manufacturer Decision Model (MDM)—see sections 8.1 and 9.1 for details on MDM development and scenarios. Results are reported as *changes* from the rate under the Reference Standard with no feebate system (negative values imply a reduction in the rate). Each system uses the same feebate rate of $20/g/mi, roughly equivalent to a carbon price of $200 per tonne of CO_2.[54] This rate is comparable to those used in similar programs in Europe. The solid lines denote the total change (dashed lines are discussed below). The first is the footprint-based system patterned after the proposed 2011-2016 national emissions standard [diamonds]. Specifically, the system uses two benchmark curves: one for passenger cars, and one for light-duty trucks. The second system uses a single benchmark value for all vehicles [squares], and the third uses two benchmark values (one for passenger cars, and one for light-duty trucks)[triangles]. Note

[54] This is a rough estimate that assumes 100,000 lifetime miles for a vehicle (with no discounting). NHTSA estimates a larger value for lifetime miles, but also discounts. One issue is whether or not GHG emissions should be subject to discounting. Whether or not this is a reasonable price for carbon is another discussion in itself. There are arguments regarding economic externalities (e.g., energy security, failure of the market to properly value fuel economy) that arise when discussing what an appropriate price for carbon might be.

that when simulating these systems the MDM seeks a *revenue neutral* version of each system by allowing benchmark values to vary from year to year.[55]

These results are consistent with what has been found in other studies. The effect is largest for the single benchmark system (an average 14 g/mi reduction for the period 2011 to 2020, the year for which AB 32 targets are specified), and smallest for the footprint system (an average 9 g/mi reduction for 2011-2020). In later years the level of GHG emissions reduction relative to the standard diminishes as the standard becomes more stringent. These emissions *rate* reductions can be used to estimate *total* emission reductions in California (versus the Reference Standard case) for the year 2020 for comparison with AB 32 targets:

- Single benchmark => 4.4 MMTCO_2E reduction
- Car/truck benchmark => 3.9 MMTCO_2E reduction
- Footprint => 3.3 MMTCO_2E reduction

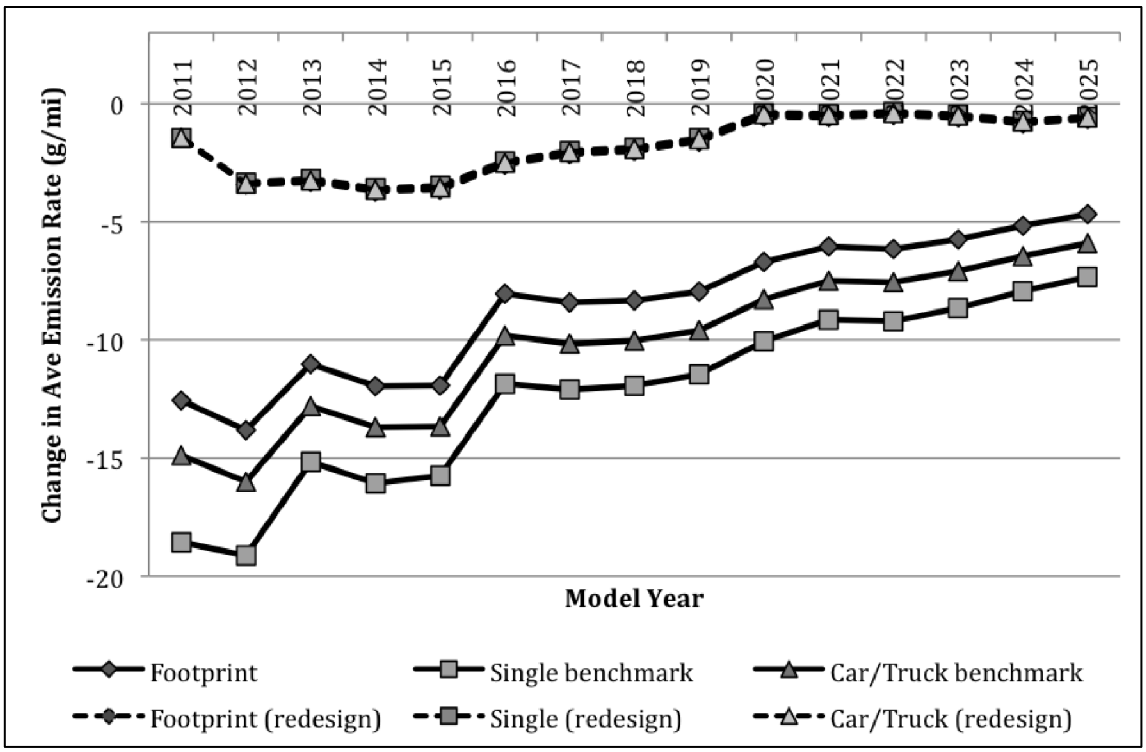


Figure 10.1 Change in California average new vehicle emission rates from feebates for three benchmark systems (total change, and portion of change due to vehicle redesign).

[55] The MDM includes an estimate of program administrative costs (discussed in a later section), as well as rebates for ZEV vehicles mandated in California. Benchmarks are found so that these expenditures plus the net fees and rebates for new vehicle sales are revenue neutral over the entire life of the program.

These totals are based on MDM projections of new vehicle sales for 2011 to 2020, the average emissions rates for new vehicles sold in those years, and assumptions on average miles driven in 2020 for new vehicles sold for 2011-2020. These figures are simple approximations that do not take into account other effects such as fleet turnover, etc., and should be viewed accordingly. These estimates suggest that feebate programs could be used to reduce emissions on a scale comparable to the discussions in the AB 32 Scoping Plan.

Another finding is that these feebate systems reduce average emissions *primarily by inducing sales-mix shifts.* The dashed lines in Figure 10.1 are estimates of the amount of change attributed to redesign. Although the feebate systems induce some redesign, the effect is rather small relative to the total. Moreover, the change due to redesign is about the same for all three systems, so that the differences are due to sales mix shifting. The average reduction for 2011 to 2020 model year vehicles due to design change is about 2.4 g/mi for all three benchmark systems, versus a 14 g/mi *total* reduction for the single benchmark (less than 20%). Moreover, *the effect becomes very small starting in 2020* (less than 5%). This is noteworthy because a widely-stated potential benefit of feebates is their potential to incentivize the introduction of new vehicle technology. Our view is that, because California is roughly 10% of the domestic new vehicle market, a California-only feebate would lack the leverage to induce manufacturers to adopt additional emission reduction technologies. Implications for feebate policies that extend beyond California-only are discussed in section 10.1.7.

To summarize, these results provide an evaluation of the three benchmark systems with respect to *emissions reductions*. The single benchmark system yields the greatest reductions, and the footprint-based one yields the least. However, a more complete comparison requires consideration of other factors. These include the overall impact on consumer welfare, other social costs and/or benefits associated with the programs, and questions of implementability and acceptance by the public.

Consumer Surplus

One feature of the MDM is that it uses a consumer surplus (CS) measure in its calculations. CS can be viewed as a monetary measure of total consumer welfare (or utility) associated with the existence of the new vehicle market. It accounts for welfare from purchasing new vehicles (for those who do), as well as the opportunity to purchase (for those who do not). Changes in CS can be used to compare policies that alter market behavior.

Figure 10.2 shows the total change in CS for Californians under each benchmark system (versus the Reference Standard case). In all cases CS decreases, but there are systematic differences: the footprint yields the smallest CS reduction, and the single benchmark the largest. This is consistent with expectations: the footprint system has the most flexibility for producing patterns of fees and rebates that might satistfy the most consumers. The single benchmark is clearly the least flexible, and the car/truck benchmark is in between.

In addition to emissions reductions and consumer surplus, another impact of feebate policies is the *social benefit associated with increased fuel savings*. Specifically, the MDM assumes that consumers value only the first three years of fuel savings when making vehicle purchase decisions. This value therefore acrues to the consumer and is included in Consumer Surplus as a *personal* benefit. However, the expected lifetime of a vehicle is 14-16 years, and any additional fuel savings that accrue after the first three years will not be accounted for in the CS measure. The monetary value of this additional fuel savings can be considered a *social benefit* for the purpose of making policy decisions, and it can be substantial.

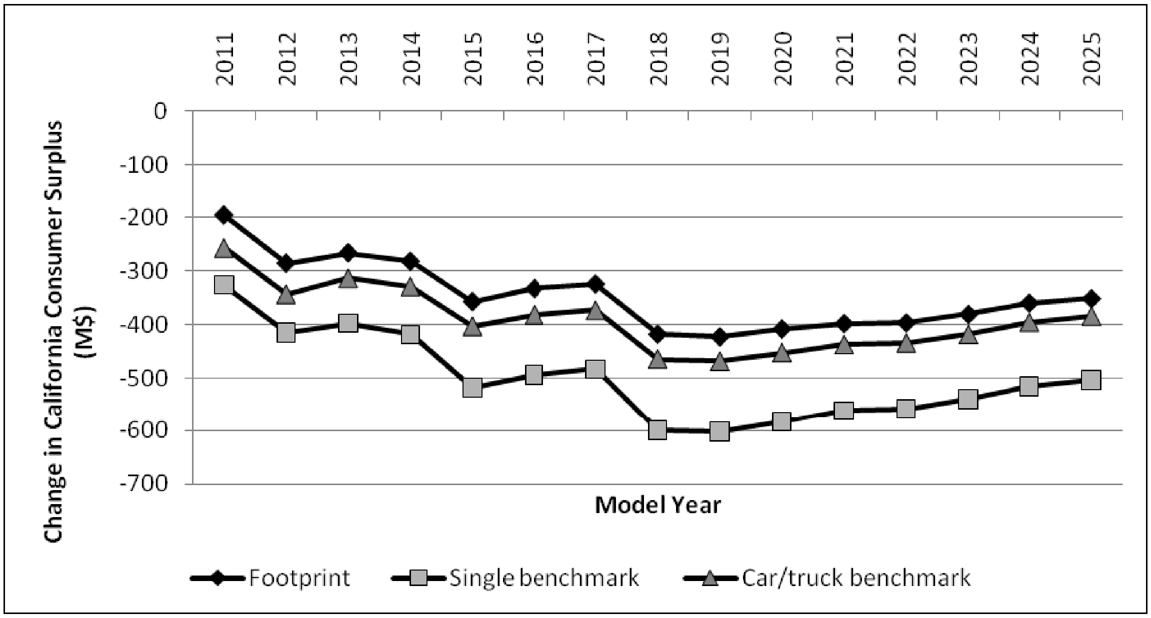


Figure 10.2 Change in California consumer surplus ($M) for three benchmark systems (versus 2% National Standard scenario with no feebate policy)

Our analysis indicates that when all costs and benefits are taken into account, the monetary value of fuel savings outweighs other costs (including loss of consumer surplus, adminstrative costs, etc.) so that *all three feebate systems generate a net negative social cost*. In other words, in addition to reducing greenhouse gas emissions, feebates also generate net *postive* social benefits.[56] Because emissions improvements are linked to fuel savings, the single benchmark system yields both the largest emissions reductions and the largest social benefit. Similarly, the footprint system yields the least. It is up to policy makers to evaluate whether this criterion should determine the choice of a benchmark system (if any), or whether other issues (e.g., equity considerations) should also play a role.

10.1.2. Feebates to Replace LEV III-GHG?

To explore the concept of feebates as a replacement for LEV III-GHG we use the 0% National Standard scenario. Specifically, we consider the case where the national standard is assumed to stay at 2016 levels through 2025, and a more stringent LEV III-GHG standard is introduced in California starting in 2017. The key question is: "What could be achieved if feebates were used as an alternative to LEV III-GHG?"

Our earlier findings suggest that manufacturers would be unlikely to respond with major emissions reductions by adopting additional fuel economy technologies in their vehicle designs. Figure 10.3 illustrates the effect on average new vehicle emissions of one of our previous feebate programs (a

[56] Given that the usual objective is to find cost-effective policy options, it is noteworthy that these feebate programs yield negative overall costs, i.e. net savings.

$20/g/mi-footprint feebate in California starting in 2011) under a 0% National Standard. The 2% National Standard averages are included for comparison purposes. The feebate program averages prior to 2017 are the same for the 0% and 2% National Standard scenarios because the standards are the same during the period 2011-2016. For the period 2017-2020 the feebate yields larger emissions reductions than the 2% National Standard, providing an indication of the effectiveness of the feebate. For example, if the LEV III-GHG standard were roughly the same as the 2% National Standard, the feebate would be more than adequate as replacement during this period (particularly when cumulative effects are taken into consideration). However, obtaining emissions reductions that match (or exceed) the 2% standard post-2020 would require higher feebate rates.

This example was provided to clarify the replacement issue. Using separate MDM runs, we also identified the schedule of feebate rates over time that would be required to *exactly match* a 2% emissions standard in California—see Table 10.1.

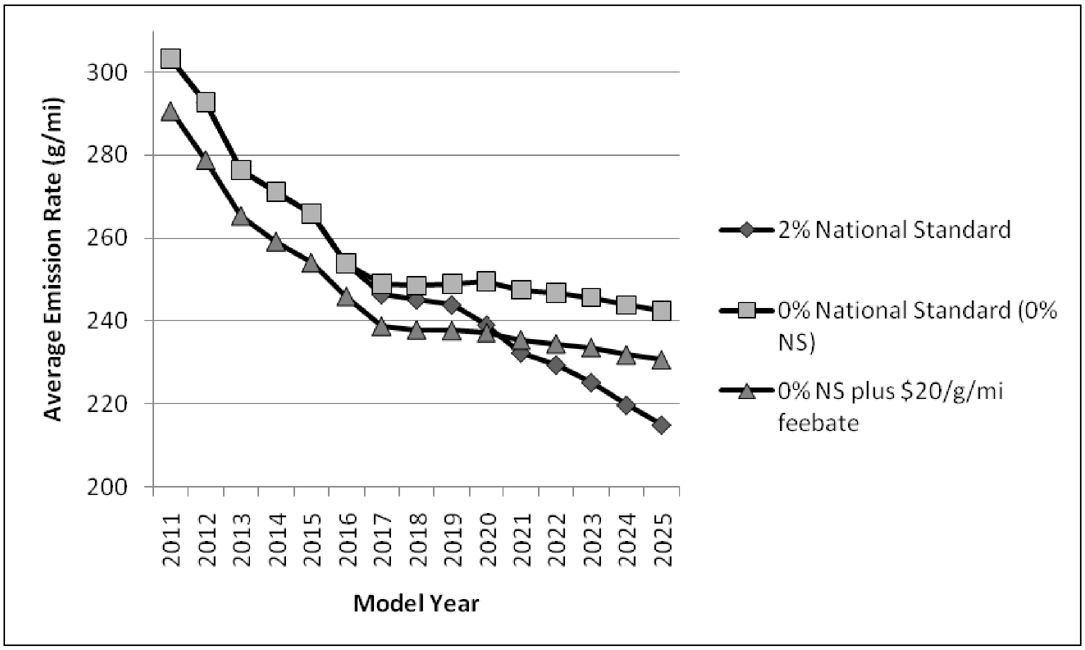


Figure 10.3 Effect of a $20/g/mi footprint feebate program under a 0% National Standard scenario (2% National Standard included for comparison purposes)

Table 10.1 Feebate rates to replace a LEV III-GHG standard (2% annual reduction starting in 2017)

Model Year	2017	2018	2019	2020	2021	2022	2023	2024	2025
Feebate rate ($/g/mi)	5	5	5	10	15	20	30	35	40

Note: In MY 2025, a $40/g/mi rate translates to average fees of $1400 and average rebates of $1050.

10.1.3. Spillover and Leakage

A frequently discussed issue for feebate systems is how they interact with markets outside the feebate region. There is the possibility of *spillover*, i.e., a feebate program within a region affects broader market conditions in ways that yield emissions reductions *outside* the feebate area. There is also the possibility of *leakage*, where emissions reductions inside the feebate region are offset by increased emissions outside the feebate region. One potential source of spillover would be a feebate's effect on manufacturer redesign decisions, which would alter vehicle offerings for the entire market. One possible source of leakage arises from the fact that consumers in different regions have different vehicle preferences. In this case, feebate policies could create a situation where the industry meets its overall *national* emissions requirement through sales mix shifts that balance emission reductions within the region with emissions increases outside the region.

Figure 10.4 shows the change in new vehicle average emissions for the "Rest of the U.S." when feebate programs are offered *in California*. The line for Rest-of-US is obtained for the footprint program; however, the lines for the other two programs are almost identical and are eliminated for readability. Figure 10.4 is a modification of Figure 10.1, so that averages for California are included for comparison purposes. There is evidence of spillover (for all years before 2018 except 2016) but

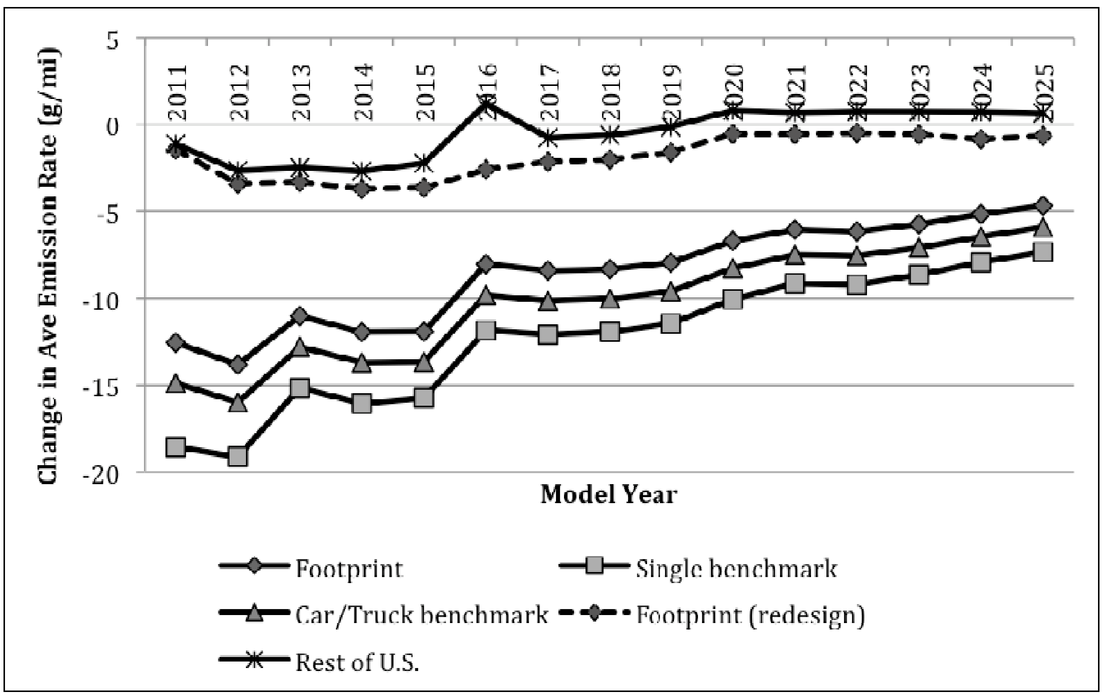


Figure 10.4 Change in new vehicle average emissions due to California feebate programs (includes change in Rest of United States).

also some leakage (for 2020 to 2025). The pattern suggests that spillover occurs when feebates induce the largest design changes. Note that, although Rest-of-US changes might be considered small compared to California's, these are *per-vehicle changes* for 90% of the domestic market. If the cumulative effects are calculated over the entire period, the spillover and leakage effects approximately cancel out.[57] Having observed this effect, it is important to remember that these results (and others) depend on our baseline assumptions, including those about future technological progress. Slower technological progress could lead to more leakage, and faster progress could lead to more spillover.

10.1.4. Sensitivity to Assumptions

All findings summarized thus far use the same base case modeling assumptions previously described. Our study also includes scenarios to test sensitivity to changes in base case assumptions. Figure 10.5 shows what happens if consumers are assumed to fully value fuel savings over the lifetime of a vehicle when making their vehicle purchases. All three cases use the 2% National Standard, so the profile labeled "Three Years of Fuel Savings" (the base case modeling assumption) corresponds to the previous result for a 2% National Standard (with no feebate). When consumers are assumed to value fuel savings for the full lifetime of the vehicle, the results are dramatically different. Manufacturers *voluntarily* choose to sell vehicles with average emissions that are *much better* than the emissions standard because of consumer preferences. In this case an emissions standard would not be required. Adding a $20 footprint feebate yields additional emissions reductions, but these are relatively small compared to the effect of changing the assumption about the value of fuel savings.

Another sensitivity case (not shown here) assumes that consumers are less sensitive to vehicle price—see section 9.1.7. For this case consumers are much less responsive to feebate policies, so the emission reductions are lower than those in the base case. Sensitivity to other base case assumptions are explored in section 9. For example, the model requires projections on fuel prices, technology costs, etc. However, the two assumptions reviewed here appear to be the most important ones in terms of sensitivity.

Finally, we note that our base case assumptions on value of fuel savings and price sensitivity are, in a sense, "feebate friendly." If consumers were to place a higher value on fuel savings then feebates would perhaps not even be necessary. If consumers were much less price sensitive, then feebates would not have the desired effects. However, it is important to note that the base case assumptions were developed using our best judgement based on experience with both the literature and industry practices, and were adopted prior to generating the results summarized here.

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[57] Some readers might notice a small spike that occurs in the year 2016. Although it exists for all results, it is particularly noticeable for the Rest-of-US profile in Figure 3.5. The spike occurs due to the abrupt discontinuation of certain emissions credits. Manufacturers address the loss in credits (at least in part) by re-pricing their vehicles to produce sales-mix shifts that satisfy the emissions standard.

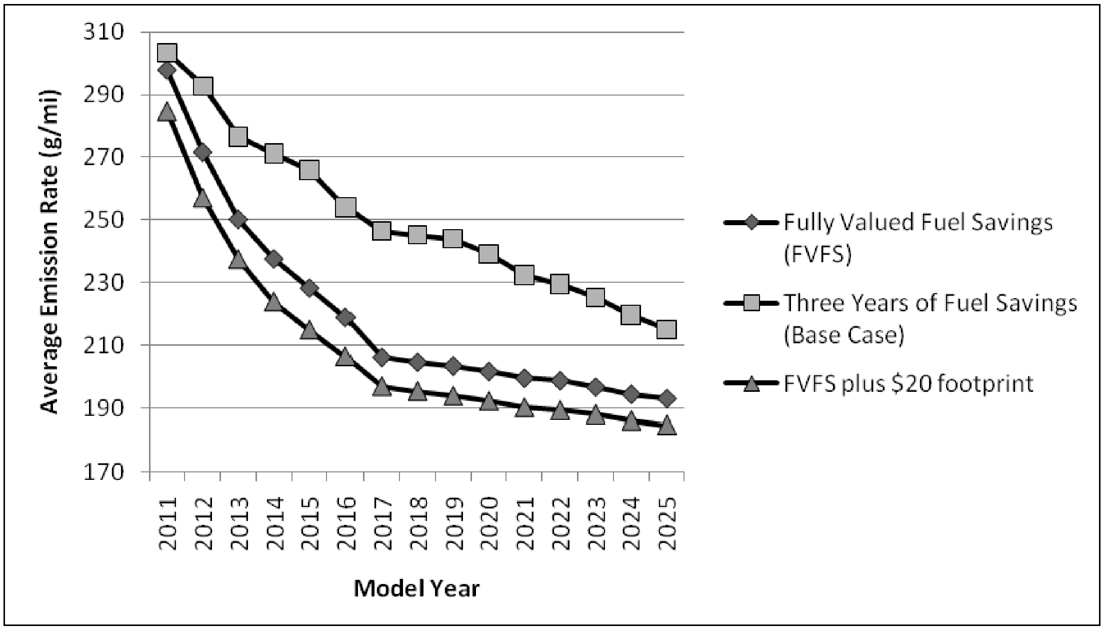

Figure 10.5 Effect of assumptions on consumer value of fuel savings.

10.1.5. Effect of Feebate Programs Outside of California

The AB 32 Scoping Plan specifically calls for an evaluation of feebate programs in California. However, California has historically played a leadership role in the area of environmental policy whereby other states might choose to adopt the same or similar policies based on California's example. In the case of the Clean Air Act, states are specifically given the option to adopt either national emission standards or California emission standards. If multiple states were to follow California by adopting its feebate policy, it would have significant implications for policy effectiveness. To explore this possibility, our study includes scenarios that assume other states adopt California's feebate program, effectively increasing its geographic coverage. We consider two scenarios, where market coverge consists of: (1) California plus the thirteen "Opt-In States" (Arizona, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New Mexico, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington), and (2) the entire nation (complete market coverage).

Figure 10.6 shows the *change* in new vehicle average emissions in California for a $20/g/mi footprint program under three market coverage scenarios (California only, California plus Opt-in States, and National). The nature of the results is what would be expected, i.e., impact increases with larger geographic coverage. Furthermore, the size of the improvements is substantial. One key finding is that, as geographic coverage increases, a larger portion of the feebate's impact is due to its effect on the redesign decisions of manufacturers. Figure 10.7 includes separate lines for the portion of change attributed to redesign (California-only results were shown in Figure 10.1, and are omitted here for clarity). In the year 2018, the percentage of change due to redesign is 60% and 87% for the California/Opt-in and National coverage scenarios, respectively. The averages for the period 2011-2018 are 54% and 77%, respectively. After 2018 the relative amount of change due to redesign steadily falls (as does the total change).

Effects of increasing the market coverage of a feebate program are summarized in Table 10.2. In addition to the effects within California, there would obviously be important implications for what would occur outside California. In particular, for the California plus Opt-in States scenario, our results indicate that there could be spillover effects in the non-feebate states. These would most likely be due to the increased impact on vehicle redesign decisions induced by the larger market coverage.

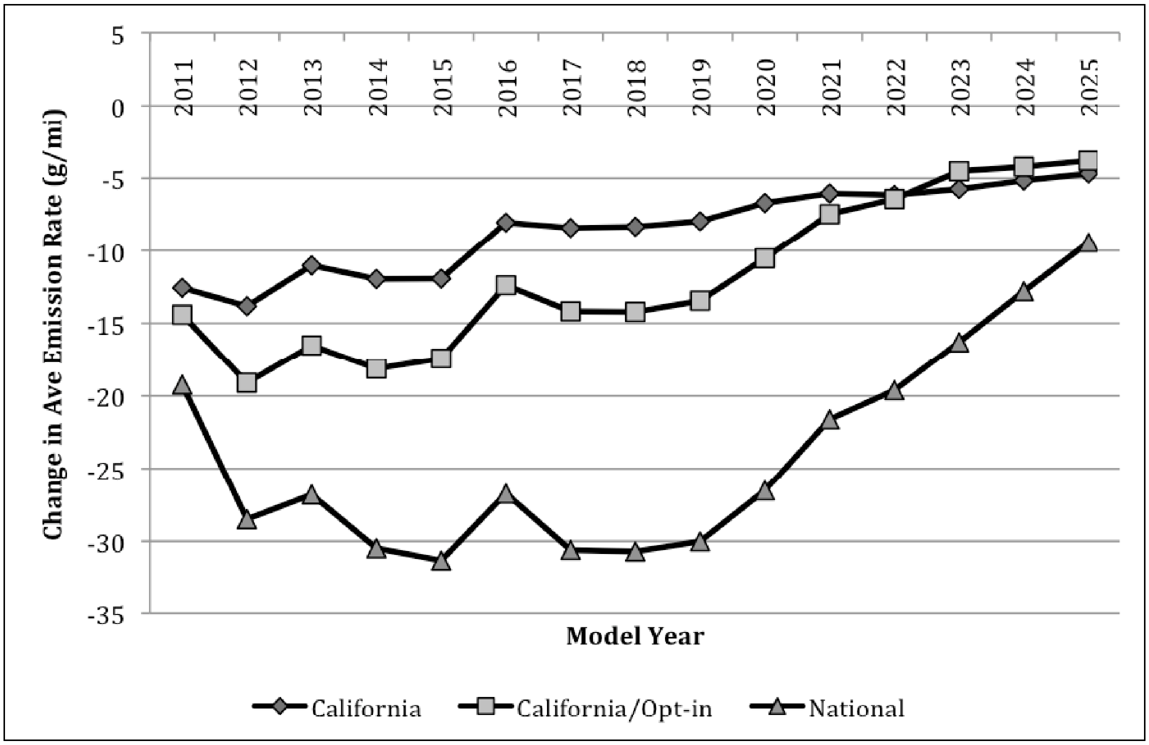

Figure 10.6 Effect of increasing geographic coverage on new vehicle average emissions for a $20/g/mi footprint feebate program.

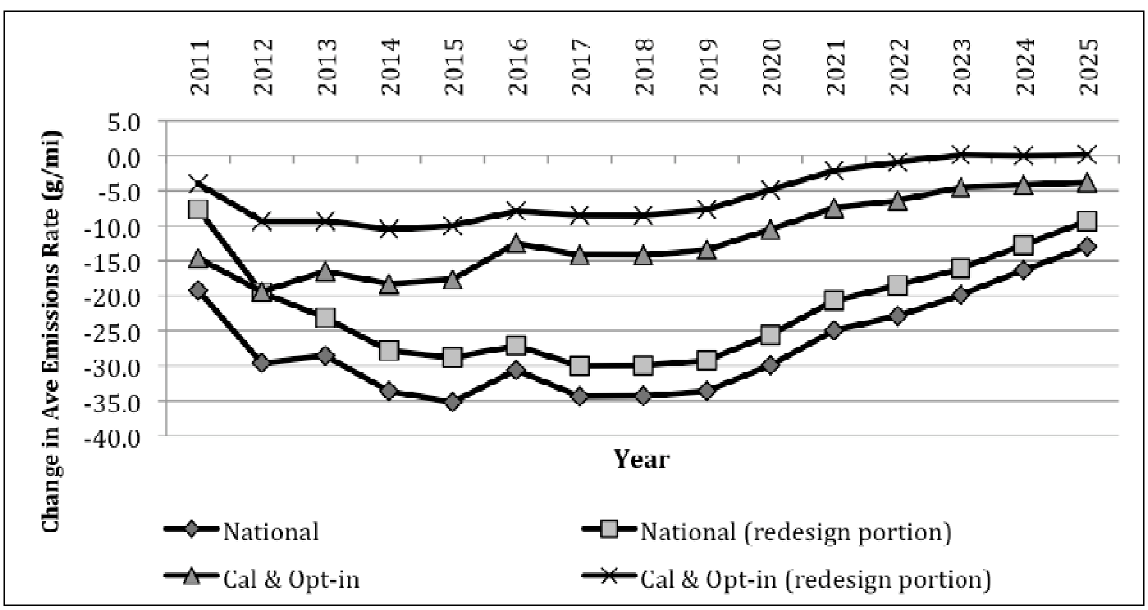

Figure 10.7 Change in new vehicle average emissions for a $20/g/mi footprint program for two geographic coverage scenarios (including portion due to redesign).

Table 10.2 Changes Induced by a Footprint-based Feebate Program ($20/g/mi) for Three Levels of Program Coverage (See text for the list of Opt-in States).

Program Coverage	Reduction of Average New Vehicle Emission Rates in CA (g/mi)	Percent Change in Average New Vehicle Emission Rates in CA	Average Fee per New Vehicle	Average Rebate per New Vehicle	Total Emission Reductions from Feebates in 2020 in CA ($MMTCO_2E$)
California-only	9 g/mi	3% reduction	$700	$600	3 MMT
California + 13 "Opt-In" States	12 g/mi	5% reduction	$675	$550	5 MMT
Entire U.S.	24 g/mi	10% reduction	$600	$500	9 MMT

10.2. Distributional impacts on consumers

It is often the case with significant policy measures that there will be subtle and/or explicit "social equity" impacts of various types. These can be in various forms, from direct economic effects through taxation or other direct welfare loss to more subtle effects such as health impacts from exposure to increased levels of pollution. In many cases it is desirable to have policies that are not "regressive" from a social equity perspective. Other policies may be explicitly "progressive," but many others seek to be neither progressive nor regressive and to accomplish some other policy goal (e.g., GHG emission reduction) without major impacts on social equity.

The CARBITS model includes a variety of assessment measures that can be broken down by household demographic groups to explore issues related to social equity. For example, in the case of income there are five income categories. CARBITS modeling results capture effects due to shifts in vehicle-purchasing decisions by income group, allowing an examination of the social "incidence" of feebate programs from the least well off to the most well off of the income quintiles. Section 9.2.4 provides CARBITS results for the impact on various metrics by income category. We summarize the main findings here. With regard to payment of fees and rebates:

- The average rebate per vehicle is similar across income categories.
- The average fee per vehicle varies by income category. The average fee is smallest for the lowest income group, and average fees increase with increasing income.
- Overall net feebates are actually *positive* for the lowest income group. For the single benchmark, they are also positive for the second-lowest income group. Net feebates are negative for all other groups, and become increasingly negative with increasing income.

Based on these findings, feebate programs could be characterized as "non-regressive" with regard to the payment of fees and rebates. It is also important to recall that feebate programs apply only to the purchase of *new* vehicles, and that the incidence of new vehicle purchases increases dramatically with increasing income.

Of potentially greater interest is an evaluation of the "ripple effects" that can be expected to occur over time through the used vehicle market. This can be examined using an overall measure of consumer surplus (CS) that captures household utility for the entire vehicle market. The basic measure is the change in CS for a feebate system versus the Reference Standard case. CARBITS CS results differ from the MDM in certain ways, for reasons discussed in section 9.2. However, for purposes of comparing feebate systems they behave similarly, and CARBITS measures are specifically useful for assessing the differential impacts across income categories. One main caveat regarding the CARBITS results: The changes in consumer surplus are rather small in virtually all cases.

Before discussing dynamic effects, we consider the *average* change in CS by income group taken over the entire period 2011-2025. The change in CS is *positive* for the two lowest income groups, and *negative* for the three highest income groups—see Figure 9.28. This is true under all three feebate systems (footprint, single benchmark, and car/truck benchmark), although the patterns vary. This is another piece of evidence to suggest that the types of feebate programs assessed here are not likely to be regressive.

Looking at the *yearly* change in CS, the average change in CS per household (across all households) is generally positive for the early years. The change in CS initially increases, but then falls so as to become negative, and then becomes increasingly negative in the later years. The crossover from positive to negative occurs in 2018 for the single benchmark case, and in 2020 for the footprint and car/truck cases—see Figure 9.27. The interesting thing to observe is what happens when these yearly changes are broken down by household income category. In all years, for all feebate systems, *the lowest income group has a positive change in consumer surplus*—see Figures 9.30 to 9.32. For many years the second lowest income group also has a positive change in consumer surplus. The higher income groups are the ones that experience *negative* changes in CS, and it is these households that drive the average CS results over all households. Our interpretation of this finding is that there are two effects. First, if lower income households purchase new vehicles, the vehicles they choose lead to positive net feebates and therefore increased consumer surplus. Second, as higher fuel economy vehicles continue to diffuse into the used vehicle market over time, lower income households benefit from the availability of used vehicles with higher fuel economy.

Another approach to exploring equity-related issues is to consider data on the income demographics of new car buyers. Data on new car purchases by vehicle class from the Power Information Network (J.D. Power and Associates) for 2003-2008 show somewhat subtle variations in average fuel economy of new vehicles purchased by income group, once the data are aggregated in terms of the fuel economy of the vehicle classes. As shown in Figure 10.8 below, while the pattern varies some by year, it appears that the lowest income group (<$25,000 per year) does tend to purchase new vehicles that are on average slightly lower fuel economy and higher emissions than average. The next income groups, that range from $25,000 - $150,000 per year, tend to buy vehicles that have the highest fuel economy, and the two highest income groups (over $150,000 per year) tend to purchase cars with the lowest fuel economy. This is largely because the lowest income group category buys a relatively high number of full-sized pickup trucks, with the lowest fuel economy of any vehicle class.[58] But as seen in the figure, the differences are fairly slight and

[58] This particular example illustrates the potential for how different benchmark systems could possibly affect different income groups. In this case, a footprint-based feebate system would clearly result in a smaller impact on the lowest income group versus, e.g., the single benchmark system.

again vary some by year. Note also the higher average fuel economy of vehicles purchased in 2008, partly as a result of high gasoline prices that year.

Taken at face value, this initial analysis appears to suggest that a feebate program could be *slightly* regressive for the lowest income group, based on vehicle purchase patterns. However, these are national numbers, and the patterns in California may be different than the U.S. as a whole. Analogous numbers for California are available from CARBITS. The pattern of the 2003-2008 national results is slightly different from the new vehicle fuel economy averages projected by CARBITS for the period 2011-2025. In addition to being California-specific, the CARBITS analysis captures the effect of increased emissions standards as well as changes in the structure of the automobile industry. In the CARBITS results, the lowest income group has the highest average fuel economy for new vehicle purchases, and average fuel economy decreases with increasing income—see Figure 9.34. At the same time, the CARBITS results for *held* vehicles more closely resemble those from Figure 10.8, i.e., the lowest income group has a slightly lower average mpg than the second lowest income group—see Figure 9.33. This could be due to the presence of larger, used vehicles in the vehicle portfolio. In any case, these results taken together exhibit a pattern indicating that the effect of feebate systems is generally non-regressive with respect to the effect on lower versus higher income groups.

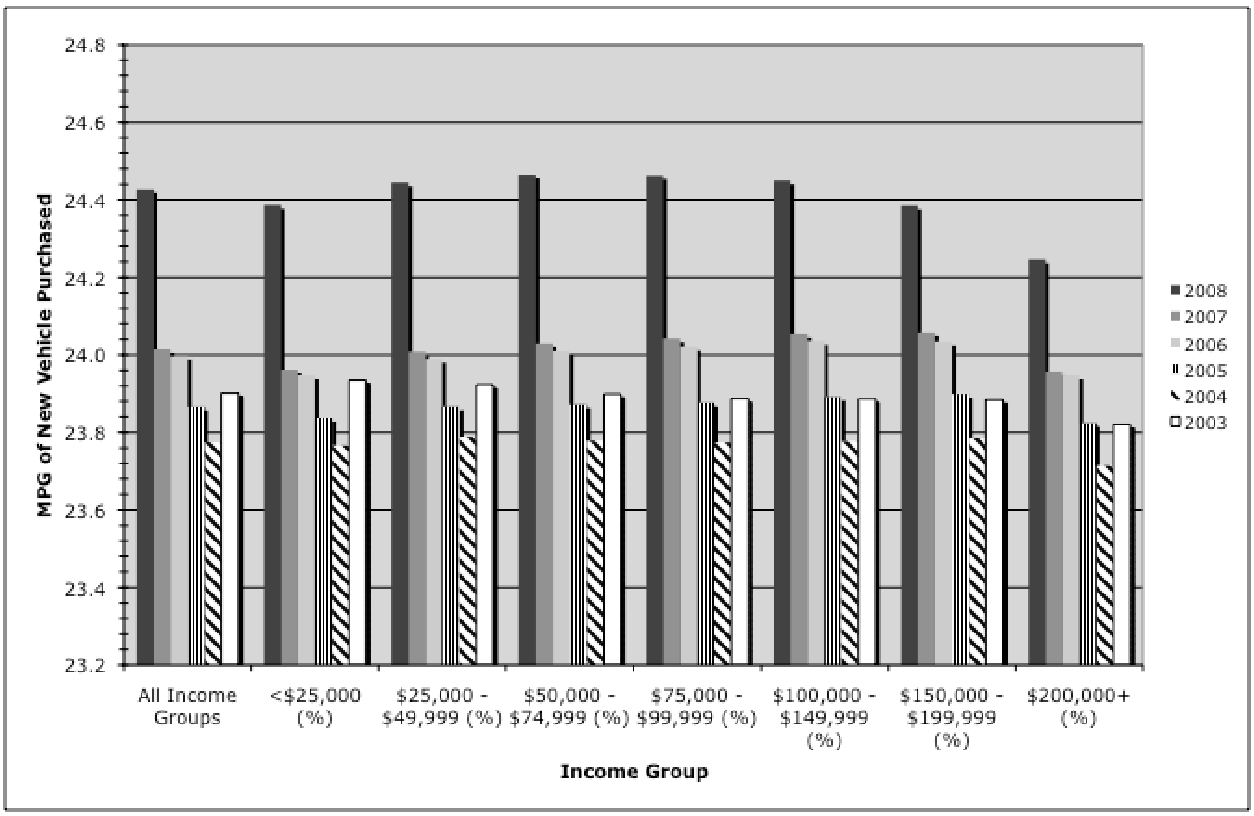

Figure 10.8 New Vehicle Fuel Economy by Income Group in the U.S. (Sources: JD Power data, author analysis)

10.3. Impacts on Manufacturers

10.3.1. Overall impact on vehicle sales and revenues

Economic analyses derived from MDM results show that feebate programs can generally be expected to depress both industry sales and revenues in California to some extent.[59] The overall effect is expected to be small, but the relative effects across manufacturers could vary, depending on the specific program design. This is further addressed in the section on equity issues. Findings related to the overall impact are:

- Feebate programs in California could reduce annual California sales by about 10,000 to 15,000 units per year. There are modest increases in sales in the rest of the country, but they offset no more than 1,000 units per year (on average). These sales declines imply a decrease in total industry revenues in the range of several hundred million to over one billion dollars per year (or about 1%). This translates into a negative impact on California dealers in the form of a *0.5% to 0.75% reduced sales volume*. These sales declines suggest that used vehicles would stay in the market longer, yielding secondary impacts related to the used vehicle market (repair shops, aftermarket sales, etc.). Many of these impacts would yield increased revenues for those businesses. For example, if consumers retain older vehicles for longer periods, they may spend more money at auto garages to maintain them.
- Increases in the feebate rate ($10 to $20 to $30 /g/mi) would yield larger total sales declines, and magnify any disparities among manufacturers (and also dealers).
- Impact of a California feebate program on national employment in automotive manufacturing and related businesses would be very small. Typical industry practice is to measure impact per 100,000 vehicle sales lost, and the reductions projected by the MDM are only on the order of 10-20% of that level.

To provide additional perspective, we also consider scenarios where feebate programs cover larger portions of the market. Under a *nationwide* feebate program:

- Annual new vehicle sales in California would decline by up to 20,000 units. The sales-related effects discussed above for a California-only program would be similarly magnified.
- National new vehicle sales would decline by an average of 135,000 units per year. This could have a measurable impact on national employment in automotive manufacturing and related businesses. Depending on how the sales losses are distributed over manufacturers, the number of displaced workers could vary from 2,000 to 20,000. However, these job losses could be partially offset by changes in the market for used vehicle-related services.

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[59] Note that these results are obtained for feebate programs under conditions of increasingly stringent national standards. Previous studies of feebates with no tightening of emissions standards have shown *increases* in revenue even though unit sales *decrease*. This can occur because increased use of fuel economy technologies can raise the price of vehicles at a faster rate than the decrease in sales. See, e.g., Greene, et al. (2005).

- Total industry revenues would generally decline, up to several billion dollars per year (or about 1%).

10.3.2. Manufacturer equity

As noted above, total industry revenues would decline by a small percentage under feebate programs. However, because industry revenues in this sector are so large, this still amounts to a large amount of money and one potential concern could be whether feebate programs affect different manufacturers and dealers in disparate ways.

Table 10.3 summarizes the sales mix for seven vehicle segments (Standard Small Car, Standard Midsize/Large Car, Prestige Small Car, Prestige Midsize/Large Car, Pickups, Vans, and SUVs) for the scenarios discussed in section 10.1 (2% National Standard, three benchmark systems using a $20/g/mi feebate rate). The no-feebate results provide a reference case for comparison. Sales mixes are averages over the period 2011-2025; however, the year-to-year variation is extremely small. Raising or lowering the rate would be expected to magnify or shrink the changes that are observed. The Standard versus Prestige distinction is included due to its importance in determining consumer preferences and sales shares. Briefly, each vehicle brand is designated Standard or Prestige based its perceptual position in the market. For example, Standard brands include Chevrolet, Ford, Honda, and Volkswagen, and Prestige brands include Cadillac, Lincoln, Acura, and Audi. Assignment of a vehicle configuration to a category is therefore based on its brand and not, e.g., vehicle price or amenity packages. A detailed listing of Standard versus Prestige brands is included in Table 8.3.

Table 10.3 Estimated Sales Mixes under Different California Feebate Programs

	Small Car	Mid/ Large Car	Prestige Small Car	Prestige Mid/ Large Car	Pickup	Van	SUV
Reference Case	27.6%	19.5%	6.7%	5.8%	10.0%	3.1%	27.2%
Footprint	28.9%	20.0%	6.2%	5.4%	9.9%	3.1%	26.5%
Single Benchmark	30.6%	20.1%	6.4%	5.4%	8.9%	3.0%	25.6%
Two Benchmark	29.6%	19.3%	6.5%	5.5%	9.6%	2.9%	26.6%

Note: Rows may not sum to 100% due to rounding.

As indicated in the table, the main impact of feebate systems is to increase the demand for non-prestige cars and decrease the demand for all other vehicle types, primarily SUVs. The differences among the systems are what would be expected based on theory. The footprint yields the smallest increase in small car demand, single benchmark yields the largest, and the two benchmark (car/truck) system lies in between. The single benchmark yields the largest increase in non-prestige midsize/large cars, and the largest decreases for Pickups and SUVs. At the same time, none of these changes is particularly large. The single largest increase is for small cars with the single benchmark, a change from 27.6 to 30.6% (a 3 percentage point increase).

Manufacturers' product portfolios will determine how they are affected by these sales shifts. Portfolio mixes tend to be correlated not only with the prestige versus standard distinction, but also with country of origin. To provide a high-level comparison, we have added a regional dimension and assigned each manufacturer to one of six groups. The effect of feebate programs on sales revenue share is summarized in Table 10.4.

Table 10.4 Estimated Revenue Shares for Six Manufacturer Groups Under Different California Feebate Programs

	Domestic-Standard	Europe-Standard	Asia-Standard	Domestic-Prestige	Europe-Prestige	Asia-Prestige
Reference Case	27.9%	1.4%	39.2%	2.6%	17.6%	11.3%
Footprint	27.5%	1.2%	41.6%	2.5%	16.2%	11.0%
Single Benchmark	26.9%	1.3%	42.2%	2.4%	16.3%	11.0%
Two Benchmark	27.1%	1.3%	42.1%	2.4%	16.2%	11.0%

Note: Rows may not sum to 100% due to rounding.

The changes in share are relatively small, as might have been expected from the results shown in Table 10.3. Under all benchmark systems, revenue shares increase for Asia-Standard, and decrease for all other groups. The increase for Asia-Standard is smallest for footprint, and largest for single benchmark. Conversely, Domestic-Standard loses the least share for footprint, and the most for single benchmark. This is consistent with Table 10.3, in that Asia-Standard dominates both the Small and Midsize/Large car markets. Again, although these effects are consistent with what would be expected, they are still quite small.

10.4. Opinions of Stakeholders

The survey and particularly the focus group results provide some information on how the general public perceives potential feebate programs. The survey results from the raw sample suggest that 76% (~3 of 4) of those surveyed were supportive of the feebates policy. About 22% (~1 in 5) were opposed to feebates, and the remaining 2% were unwilling to express an opinion on the policy. When the sample was weighted to make is somewhat more representative of the state's demographics, the results follow a similar distribution. There were small shifts away from "Strongly Agree" and "Strongly Disagree" but 76% of the sample still was in general support and 22% in general opposition to a feebates type policy (See Figure 10.2 below). Support for the policy was found to be strongest among younger respondents, lower income respondents, and lower and higher education level respondents (i.e., respondents with a medium level of education had the highest opposition). Support was also highest among Caucasian and Hispanic respondents. See Section 9.3 for the full presentation of the raw and weighted survey results.

The focus group results, however, were far less conclusively in support of feebates type policies, and in fact tended to reveal a considerable level of apprehension and in many cases outright opposition to the feebate program concept. Some opposition was softened when concepts such as ways to compensate lower income groups and the idea of a vehicle class-based system were raised (as discussed above in the "program design" Section 9.3). In addition, the focus group results were highly variable by geographic location, with general support in some areas (the more urban ones) and almost complete opposition in the more rural areas.

We attribute much of the disparity in results between the survey and the focus group to two factors: 1) focus group participants were given a better understanding of the feebate program and its “pros and cons”; and 2) the group effect of the focus group allowed some individuals to become aware of concerns that others raised that they themselves might not have thought of because they did not directly apply to them. These include mostly issues of fairness for larger family sizes, lower income groups, and certain occupation types.

Additional focus group findings related to the overall feebate policy include concerns about maintaining “revenue neutrality” if the rebate vehicles end up being more attractive than expected, and concerns about how the dealers would handle the fees/rebates (if they were handled by the dealers). As noted above, the concerns about fairness were for larger family sizes, lower income families that purchase new vehicles, and for those who need certain types of vehicles that they must own themselves for their jobs (e.g., workman and pickup trucks, nannies and minivans, etc.). Furthermore, the focus groups revealed that participants also seemed to require fairly significant incentives to move their vehicle purchase decisions, on the order of 10-20% of vehicle sticker price. We note that the “cash for clunkers” program operational at the time of the focus groups offering a $4,500 rebate toward a new vehicle may have influenced this finding somewhat.

With regard to the auto dealer and manufacturer interviews, the auto dealers were typically opposed to feebate policies for both “ideological” and “practical” reasons. These included their general feeling that government should not be intruding this far into vehicle sales transactions (in some of their words affecting “consumer choice”) as well as concerns about impacts on sales and revenues. Automakers were less consistently opposed to feebates, with some expressing some support for the program, but also suggesting that they were unwilling to be vocal supporters due to concerns about impacts on their dealer networks. Thus, it seems that some auto OEMs may actively oppose any feebate legislation, and that this would almost certainly be the case for the auto dealers associations, but that some automakers that feel feebates could be in their benefit would be silent or perhaps “quietly” in support of potential feebates policies. See Appendix C for additional details and findings from these stakeholder interviews.

10.5. Additional Policy Implications

The following sections discuss additional policy implications of feebate programs. These include: 1) interaction with other major state policies; 2) the estimated administrative costs of the feebate program that would need to be covered by program revenues in order to avoid drawing on other sources; 3) other issues associated with maintaining program revenue neutrality; and 4) the potential for some unintended consequences of the program such as the potential “rebound effect.” This latter effect could occur where lower emitting/higher fuel economy vehicles become more economical to drive and thus are driven somewhat more after being purchased than the vehicle that would otherwise have been bought.

10.5.1 Interaction with Other Major Policies

Any feebate program, whether at the state, regional, or national level, takes place in the context of an existing network of regulatory policies that affect greenhouse gas emissions. In this case, there are several policies, both existing and being discussed for the near future, that could interact in important ways with potential feebates programs. The most important of these are reviewed below, along with issues related to potential program overlap and “leakage” through double-counting or other loopholes that might be created from the intersection of these programs.

California's Light-Duty Vehicle Greenhouse Gas Standards

Pursuant to California Assembly Bill 1493, authored by Senator Fran Pavley and signed into law by Gov. Gray Davis in 2002, the ARB developed and adopted greenhouse gas emissions standards for new passenger vehicles (frequently referred to as "the Pavley standards") in 2004. The regulations were threatened by lawsuits and denied a December 2005 request for the necessary Clean Air Act waiver by the Bush Administration. With the lawsuits resolved and the waiver granted by the end of June 2009, on 24 September 2009 CARB approved amendments to the regulations for adoption by the Executive Officer and submission to the Office of Administrative Law (Air Resources Board, 2009a).

The Pavley standards set the maximum allowable fleet average greenhouse gas exhaust emissions for passenger car, light-duty truck, and medium-duty passenger vehicle weight classes. These limits, typically expressed in grams of CO2-equivalent emissions per mile (gCO2e/mi), begin in 2009 and decrease until 2016. The standards are estimated to reduce GHG emissions by 27.7 MMT in 2020, or about 16% of the total AB32 target—the single largest measure identified in CARB's Scoping Plan for AB32 compliance (Air Resources Board, 2009b).

There are important interactions between the Pavley standards as they stand now, a future "LEV III-GHG" extension of the program, and potential California or broader feebate programs. Essentially, the Pavley standards requires automakers to produce vehicles with lower GHG emissions, and feebates could help to provide a "market pull" for those vehicles. Instead of the automakers internally "subsidizing" the lower emitting vehicles to push them into the market, a feebates program could effectively fulfill that same roll. Some manufacturers might thus be somewhat "agnostic" about feebates programs (assuming they did not expect them to confer a market advantage to their rivals), and in fact this is borne out by some of the automaker interviews that were done as part of this research project.

More specifically, assuming that a feebate program benchmark is appropriately set to account for any differences in the methods of establishing vehicle emissions ratings and in the way vehicles are grouped, a feebate program should provide a consumer-financial incentive that makes automaker compliance with GHG emissions standards easier. Effectively, instead of automakers cross-subsidizing sales of more efficient vehicles with those of others, in order to have a market clearing outcome, feebates could provide similar market signals for consumers to purchase the lower-emitting vehicles. This could reduce the need for automakers to internally manipulate prices for the clean-fuel vehicles to be sold, with the additional feature of reinforcing consumer purchases with the concept of the clean-vehicle rebates being sanctioned by the state.

California Low Carbon Fuel Standard

Pursuant to Executive Order S-01-07, the ARB considered and approved a "Low Carbon Fuel Standard" (LCFS) as one of the discrete, early-action GHG emission reduction measures required to be identified and implemented by AB32, the Global Warming Solutions Act of 2006 (Jenne, 2009). On 25 November 2009, the Executive Officer of ARB adopted and submitted the regulation to the Office of Administrative Law for implementation in 2010 (Air Resources Board, 2009c).

The LCFS requires the average carbon intensity of transportation fuels supplied by regulated parties for use in California to decrease. Carbon intensity is a measure of the direct and indirect greenhouse gas (GHG) emissions over the full lifecycle of a fuel (i.e., well-to-wheels) and is typically expressed in grams of CO2-equivalent per megajoule (gCO2e/MJ) (Air Resources Board, 2009d). The LCFS requires a 10% average reduction by 2020 relative to 2010 levels. This represents a 15

MMT reduction in GHGs or about 10% of the total AB32 target (Air Resources Board, 2009e). The regulated parties of the LCFS are largely upstream suppliers (e.g., producers, blenders, or importers) of transportation fuels and can meet their annual average carbon-intensity obligations using credits earned, banked, or purchased from other suppliers.

The primary ways in which a feebate program might interact with the LCFS regulations are:

1) somewhat restricting the total volume of fuel sold, thus allowing fuel suppliers to provide a lower volume of low-carbon fuels and still meet the LCFS targets; and

2) over time, as more clean and efficient vehicles are sold and technological progress is achieved, affecting the determination of carbon intensities for electricity and hydrogen-based fuel cycles, which include "energy efficiency ratio" values to account for the much higher driveline efficiency of electric vehicle (i.e., the "wheels" portion of "well-to-wheels").

It is unclear the extent to which a feebate program would actually improve consumer demand and spur technological progress for electric and hydrogen fuel cell-electric vehicles, but to the extent this does occur there could be interaction with the LCFS program in this regard.

Thus some level of coordination between, or at least incorporation of, changes over time that affect the two programs may be warranted. Further analysis should be conducted to better determine and characterize the likely impact of changes in vehicle GHG emission levels brought about by other policies and how those changes may need to be incorporated into feebate implementation. Further, in doing so, continued care should be taken to harmonize California and federal fuel-cycle and vehicle-emission ratings so as to avoid unintended effects caused by the disparity between them as they evolve over time.

Finally, it should be noted that a feebate program based on vehicle emissions obviously addresses transportation GHG emissions differently than the LCFS's full fuel-cycle approach. These differences are most pronounced for vehicles with zero-tailpipe-emission operation such as plug-in-hybrid, battery-electric, and fuel-cell vehicles (which would presumably receive large rebates). These policies are likely to be complimentary in this regard: the LCFS provides the additional incentive to not only buy vehicles with low carbon emissions, but to fuel them with low carbon fuels, and the feebate program provides further incentive to the commercialization of advanced vehicles with low-carbon fuel cycles than the LCFS's approach would provide alone. The opposite effects are less likely to be true (e.g., that the feebate program will steer California towards low-vehicle but high lifecycle emissions pathways or that the use of LCFS-favored fuels will unintentionally slow the commercialization of ultimately more beneficial vehicles).

Low Emission/Zero Emission Vehicle Program

A state feebate program could assist with the success of the California Low-Emission/Zero Emission Vehicle (LEV/ZEV) program, which requires increasing numbers of zero and very low-emission "partial zero emission vehicles" (PZEVs) to be sold in California in the coming years. The rules of the program have become quite complex, as the program has evolved extensively since first introduced in 1990. The regulations now lay out paths by which automakers of various sizes *must* and *may* meet the regulation (thus with some flexibility).

The gist of the current LEV/ZEV regulation is that major manufacturers must meet an 11% ZEV requirement for 2009-2011, rising to 16% in 2018 and beyond, with some combination of ZEVs, "enhanced advanced technology-PZEVs," "advanced technology-PZEVs," and "PZEVs," again with complex rules that are described in the latest regulation. While most of the credits can be made up with the other vehicle types, an increasing number of "true ZEVs" is required through the phases of the regulation. Key interactions with feebates are as follows.

- By providing incentives for consumers to purchase these efficient and low-fuel cycle GHG vehicles, feebates could help to assure that manufacturers are able to sell the cleaner but higher-priced vehicles that they are required to deliver for sale in the coming years under the LEV/ZEV program.
- Feebates programs could either replace or complement other statewide incentive programs to encourage the sale of ZEVs and other very clean vehicles for their environmental and human health benefits, such as the recent Alternative Fuel Vehicle Incentive Program and the planned Clean Vehicle Rebate Program.
- As with the LCFS, some harmonization could help to reduce consumer and confusion and ease automaker efforts for program compliance. Whereas incentive levels for various electric-drive vehicle types in the past have been somewhat arbitrary, a feebates program offers the potential for a more rationalized level of incentives for a more finely-grained (model by model) set of vehicle types, and that importantly would be based on the actual expected GHG emission levels of the individual vehicle models rather than being the same across broad classes of vehicles.

With regard to this last point, based on the stakeholder research conducted for this project, this greater degree of rationalization in incentive levels would appear to be welcomed by both consumers and automakers.

Land Use Planning/SB 375 and Other State GHG Reduction Programs

Other important state programs that could interact with future feebate programs include those directed at "smart growth," "sustainable communities," and better land use planning (e.g., SB 375), as well as additional programs directed at reducing vehicle GHG emissions such as a potential statewide cap-and-trade program. These broader types of GHG reduction policies could interact with potential feebates programs in various ways, depending on how they are designed and implemented. Since SB 375 is now being developed and implemented, and the cap-and-trade program details are still being finalized, it is not possible to assess these interactions in much detail, but a few points are worth noting.

With regard to SB 375 and land use planning policies, intended to address the issue of urban sprawl, the potential interactions with a feebates program are subtle but potentially significant. Greater "densification" of urban areas would in theory reduce VMT from personal vehicles (and toward other modes such as transit and bicycling), possibly reducing both demand for vehicles and shifting consumer preferences for vehicles in subtle ways. Previous research has suggested that denser cities are associated with consumer preferences for smaller and more efficient vehicles. Thus, the implementation of SB 375 may provide an additional stimulus for consumer purchases of vehicles that would receive rebates under a feebates program, potentially requiring earlier than otherwise needed reductions in the program "pivot point" to maintain revenue neutrality.

With regard to a potential GHG "cap and trade" program that has been widely discussed, a key issue with such a program is the difficulty of appropriately including the transportation sector in ways that addresses actual emissions from vehicles rather than simply the types of vehicles (LEVIII/ZEV and Pavley standards) or fuels (e.g. as prescribed by the LCFS) that consumers can find in the marketplace. Depending on how it is implemented, a cap and trade program could provide the opportunity for manufacturers to generate credits for emission reductions in excess of those required by other programs, that they then could sell to other interests that needed them. Alternately, and we think more likely given the relative costs of emission reductions in various sectors, it could allow automakers to purchase emission credits from other industries that can reduce emissions at lower costs, meaning that they would be able to do less in terms of introducing lower-emitting vehicles.

These potential emission credit trading dynamics could affect the types of vehicles that manufacturers choose to sell in the future, the overall fees or rebates that their vehicles would generate in the market, and the overall fee/rebate balance over time of the feebates program. However this all remains somewhat speculative given that the key details of a potential California cap-and-trade program under AB32 are just being established, including how it would apply to various sectors of the economy and the extent to which vehicle manufacturers would be included.

10.5.2 Administrative Costs of Feebates Programs

The administrative costs of feebate programs would vary considerably depending on the design of the program, what exactly is included in administrative costs, and how various state agencies would respond to the imposition of any specific program. Key cost categories include costs of administering, managing, and enforcing the program (which can include both initial "startup" and annual costs), costs of preventing new out-of-state vehicles from immediately entering the state without paying fees, costs of maintaining and auditing state "budget authority" that falls outside of spending from the state general fund, and so on. Additional program costs include those borne by automakers and/or dealers, and these would depend in part on the design of the program and how it is administered.

The research team has estimated approximate program costs by administering agency, and by key program design considerations. These considerations include the "locus of transaction" issue, where the fees and rebates could be assessed directly at the dealership (and where project focus group research suggested that they might be most effective) and whether fees and rebates are determined using a linear or stepwise function, among other factors. Additional variations would include those related to the exact number of transactions (especially for cases in which the dealer would be reporting and managing them) and the exact manner in which rebates are processed (e.g., "on the spot" or based on the submission of an application for later reimbursement).

Estimates of program administrative costs were developed based partly on assessments of feebate program costs conducted for the AB 493 program, but extended and revised in a few key areas. Costs were assumed based on participation in the program by four key state agencies, based on their current responsibilities and what seems to be a potentially efficient way to manage the program. These responsibilities are as follows:

- Air Resources Board (ARB): Initial program design and implementation; periodic program modifications; program enforcement; public education; development of online training programs.

- Board of Equalization (BOE): Develop and implement process for collecting net fees collected by dealers, depositing those revenues, and making rebate payments to those dealers (or individual purchasers).

- Dept. of Motor Vehicles (DMV): Collect and process surcharges for out-of-state vehicle registered in California when new or nearly new (e.g., with vehicles with less than 7,500 miles considered "new").

- Department of Finance (DOF): Provide audit function and management of additional ARB state budget authority associated with the program (*pro rata* share collected for "central government costs" associated with programs not covered by the state general fund).

There are of course various other ways a program could be structured, and the responsibilities for designing and managing it divided among the responsible agencies. For example, the original California "Drive+" program of the early 1990s proposed that the DMV would manage the fee/rebate fund rather than the BOE. This could make small to significant differences to these estimated costs. We note that for actual implementation, some care should be taken to structuring the program in a way that (ideally) takes advantage of existing revenue and vehicle sales reporting requirements to the extent possible, in order to minimize duplications of effort.

The following table summarizes the estimates of program administrative costs for key representative program designs. Also included are some of the variations in costs that might be expected as a result of program uncertainties, particularly with regard to the level of cost.

One important note with regard to program administrative costs is that unless legislatively capped, administrative costs can increase over time, especially when state budgets are strained. Thus it may be important to restrict the ability of state agencies to "reach into" the feebate program revenues and to increase their share by, for example, limiting administrative costs to an absolute maximum of 2 or 3% of total program revenues collected. This could potentially help in the effort to maintain the revenue neutrality of the program.

Table 10.5 Approximate Administrative Costs of Example Feebate Program Designs

Program Design	Responsible Agency	Startup Costs (One time)	Annual Costs	Notes/ Uncertainties
Dealer Locus	ARB	$1 million	$340,000/yr	Annual costs based on 2 FTEs at $170K/yr ea.
	BOE	$2 million	$2 million/yr	Subject to negotiation between the agencies and their exact roles and responsibilities
	DMV	$250,000	$170,000/yr	Annual costs based on 1 FTE at $170K/yr ea.
	DOF	N/A	$3 million/yr	Would be based on gross fees collected and could be as high as $10-20M/yr if not limited
Total		**$3.25 million**	**$5.5 million/yr**	
OEM Locus	ARB	$1 million	$255,000/yr	Annual costs based on 1.5 FTEs at $170K/yr ea.
	BOE	$1.5 million	$1.2 million	Many fewer transactions to manage (but similar total $ amount)
	DMV	$250,000	$170,000/yr	Annual costs based on 1 FTE at $170K/yr ea.
	DOF	N/A	$3 million/yr	Would be based on gross fees collected and could be as high as $10-20M/yr if not limited
Total		**$2.75 million**	**$4.6 million/yr**	
Dealer Locus for Fees + Rebates by Mail	ARB	$1 million	$340,000/yr	Annual costs based on 2 FTEs at $170K/yr ea.
	BOE	$2.5 million	$3 million/yr	Assumes BOE processes rebate requests
	DMV	$250,000	$170,000/year	Annual costs based on 1 FTE at $170K/yr ea.
	DOF	N/A	$3 million/yr	Would be based on gross fees collected and could be as high as $10-20M/yr if not limited
Total		**$3.75 million**	**$6.5 million/yr**	

10.5.3 Issues Associated with Program Revenue Neutrality

Assessments of previous feebate programs suggest that achieving/maintaining revenue neutrality for the program can be challenging in some cases, and some flexibility in program design needs to be considered to allow changes to be made over time. As has been noted in some research, feebate programs can relatively quickly turn cash negative (or cash positive) if left un-corrected (for example, see Ford, 1995). The French example, described above, also indicates that changing economic conditions (e.g., increases in gasoline prices) can cause greater than expected interest in higher fuel economy/lower emission vehicles, making the program starved for revenue over time.

The detailed program implementation plans for any feebate program should thus include allowances for how the program can be fairly rapidly modified over time to maintain a positive balance of funds, potentially with a "buffer" established initially to allow program changes at prescribed intervals, and reduce uncertainty and "surprises" for both the auto industry and consumers.

10.5.4 Potential Rebound Effects

One potential secondary effect that should be considered in a feebate program is that its effectiveness will be undermined to some extent by the fact that as consumers purchase more fuel-efficient vehicles, they will face lower per-mile costs of driving than they would have faced in an alternate, lower fuel-economy vehicle. This may cause them to drive somewhat more miles (i.e., "increase VMT"), thus eroding back some of the gains in GHG emissions that otherwise might have been expected from the placement of lower emitting cars on the road.

This "rebound effect" of fuel cost changes to drivers has been well studied (Greene, 1992; Jones, 1993; Schimek, 1996; Pickrell and Schimek, 1999; Small and Van Dender, 2007, others), but with a lack of consensus on the "correct" values for the U.S. especially in the long run. Estimating rebound effects using time-series data is difficult because there are confounding effects. These include, for example, changing levels of urbanization, the imposition of the CAFE standards, changes in other demographic trends, etc., that may be difficult to control for.

Recent data suggests that VMT is clearly sensitive to fuel prices, based on the run-up in gasoline prices in mid-2008. And based on historical responses to decreases in gasoline prices, there could be an opposite effect (where VMT increases rather than declines) should the fleet average fuel economy of vehicles be improved over time. We note however, that there is some evidence that consumers may respond more strongly to relative gasoline price increases than decreases (Puente and Tomer, 2008; Sallee and West, 2008), a finding that if true would suggest that rebound effects from feebates programs could be relatively modest. See Figure 10.9 below, for gasoline price and VMT trends in the U.S. from 1991 to 2008.

Following earlier studies and attempting to improve on their deficiencies, one careful analysis was conducted recently of the rebound effect in the U.S. (Small and Van Dender, 2007). The study used a longer time series than had previously been used -- from 1966-2001 – enabling a high level of precision in the study. The study also used an analysis model with fuel efficiency as an endogenous variable, distinguished between autocorrelation and lagged effects, included a measure of the stringency of fuel-economy standards, and allowed the rebound effect to vary with income, urbanization, and the fuel cost of driving. Based on the time series studied, the authors found rebound effects of 2.2-4.5% in the short run and 10.7-22.2% in the long run, depending on fuel price assumptions and household incomes. The lower estimates of 2.2% and 10.7% reflect household incomes from 1997-2001, rather than for the whole period.

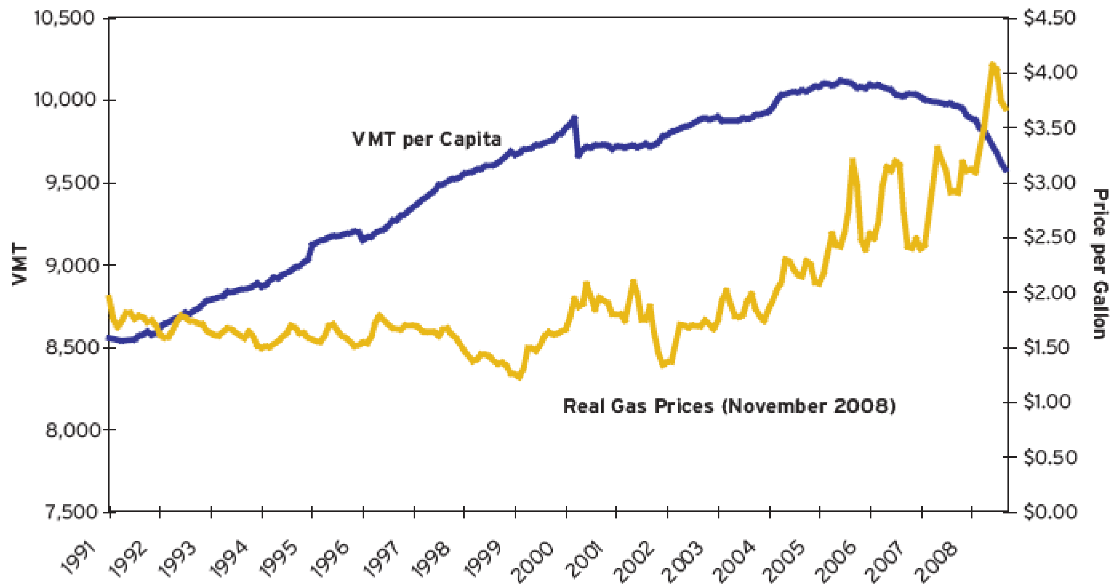

Figure 10.9 Vehicle Miles Traveled and Real Gasoline Prices in the U.S. (1991-2008)
Source: Puentes and Tomer, 2008

These values are lower than sometimes assumed in transportation policy analysis, but also generally consistent with some other studies that have found rebound effects to be on the lower side of the range of estimates in the literature (e.g., Greene, 1992 and Pickrell and Schimek, 1999). A particularly interesting finding is that the rebound effect is found to decline over time with increases in real incomes and slow declines in real fuel prices -- trends that may continue. If so, the authors hypothesize, the rebound effect may continue to decline in the future (Small and Van Dender, 2007).

The implications of this effect for feebate programs are that this effect should be considered and the program administrators should recognize that the ultimate GHG reductions from the program may be reduced about 10% as a result. This would suggest that in order to more fully achieve the level of desired emission reduction, the goals of the program could be set to approximately 110% of the desired goal, to allow for the potential erosion of benefits from a modest level of rebound in VMT after the lower emitting/higher fuel economy vehicles are purchased.

11. SUMMARY AND CONCLUSIONS

Based on the collection of results, we provide an overall summary of some conclusions along with brief discussion. These reflect the outcomes of individual project tasks as well as interactions among the tasks. They represent the key take-away messages from the project efforts.

1. There is evidence from case studies in four European countries to suggest that feebate programs *can* be effective in lowering the average emissions rates of new vehicles.

- This finding is based on average vehicle emissions data from both before and after the introduction of feebate systems.
- At the same time, this finding should be viewed with some caution for a number of reasons.
  - There are important differences between the policy and cultural environment of Europe versus California.
  - Introduction of these systems overlapped with fuel price increases in most cases. At the same time, even taking into account fuel price volatility, the data seem to indicate that feebates did have a measureable effect.

2. Quantitative models suggest that, under the right conditions, feebates can be used to reduce greenhouse gas emissions from new vehicles in California below national emissions standard levels. In addition, results indicate that feebates yield net positive social benefits aside from greenhouse gas reductions.

- A California feebate program could reduce average emissions from new vehicles by 3 to 5 percent, producing 3 to 5 $MMTCO_2E$ of reductions in California in 2020, depending on the design of the policy.
- Results are subject to base case modeling assumptions on consumers' value for fuel savings, their responsiveness to price changes, fuel prices, and vehicle technology costs.
- If consumers were to value fuel savings over the full lifetime of the vehicle, the market would yield emissions levels below currently discussed targets without policy intervention.

3. The ability to affect vehicle design decisions is one of the frequently stated benefits of feebate programs. However, because California is about 10% of the domestic market, feebate policies based in California alone would only have a limited effect on vehicle design decisions.

- For scenarios involving California-only feebate programs, manufacturers' technology decisions are largely determined by national emissions standards.
- Because California-only feebates have limited impact on vehicle design decisions, they are also limited as a source of "spillover" and produce minimal co-benefits for non-feebate regions.
- *If feebates were implemented over a larger geographical area, the potential for spillover would increase*. If other states or the entire country adopted California's feebate policies, the impact could significantly increase.
- A nationwide feebate system could have a very large impact on emissions reductions from passenger vehicles due to its much greater impact on vehicle design decisions. Average emissions from new vehicles would be lowered by about 10 percent, and roughly three-fourths of these reductions would result from vehicle redesign as opposed to changes in purchasing behavior.

4. Quantitative models suggest that a single benchmark system (i.e. one that is not indexed to vehicle size or class) would yield the largest reduction in greenhouse gas emissions, but also the largest reduction in consumer welfare (measured by Consumer Surplus). However, when future fuel savings are taken into account, a single benchmark system would yield the largest net social benefit.

- Quantitative results were obtained to provide comparisons among three different benchmark systems: single, two benchmarks (one for cars, one for trucks), and a footprint based system.
- In comparing these systems, no one system dominates on all evaluation criteria. Selecting among these systems requires tradeoffs to be decided on by policy makers.
- As noted, the single benchmark system is best if the criterion is to maximize reduction of greenhouse gasses. It also yields the largest fuel savings.
- If the criterion is to minimize the loss in Consumer Surplus, then a footprint-based benchmark is best. This system minimizes the impetus to shift sales toward smaller vehicles. At the same time, it yields a situation where a larger, higher emitting vehicle might receive a rebate while a smaller, lower emitting vehicle might pay a fee. It also yields the smallest reduction in greenhouse gas emissions.
- A dual-benchmark system (one for cars, one for trucks) represents a compromise between the single and footprint-based systems.

5. Quantitative models suggest that, under the right conditions, feebates could be used to reduce greenhouse gas emissions in lieu of more stringent performance-based standards beyond 2016. A properly designed feebate program could be used as a substitute for increasingly stringent GHG standards for new vehicles beyond 2016 (i.e. LEV III-GHG). This would require raising the feebate rate over time, from $5/g/mi up to $40/g/mi by 2025.

6. Although a single benchmark system would yield the largest net social benefit, issues of equity and fairness perceived by stakeholders could require consideration of alternatives, e.g., a footprint-based system.

- In the project focus groups, there was sensitivity to the issue of "fairness" and a belief that a class-based (or footprint) system would be "fairer" than a single benchmark for people who "need big vehicles."
- This concern is consistent with experience with France's single benchmark system. The system was recently modified to provide subsidies to large families who "need" larger vehicles.
- Some focus group participants understood that, under a class-based (or footprint) system, there would be instances where some large, higher emission vehicles would receive rebates while other lower emission vehicles would receive fees. This is confusing, and seems inconsistent with the stated purpose of feebate systems.
- This view is consistent with recent experience in the Netherlands, who introduced a footprint-based system. Consumer sentiment about the complexity of the system, and the possibility of higher emitting vehicles receiving rebates, caused the Netherlands to *abandon* its footprint system in favor of a *single benchmark* system.

7. Model results suggest that there would be a decline in new vehicle sales under all feebate programs, with an associated 1% drop in industry revenue for the California market. Although this is small in percentage terms, it is significant in terms of dollar amounts.

8. Feebate systems have an impact on sales patterns. All systems increase the demand for non-prestige cars (particularly small ones) and decrease the demand for all other vehicle types, particularly SUVs. However, there are differences across systems. A footprint-based system yields the smallest increase in small car demand, the single benchmark yields the largest, and a two-benchmark (car/truck) system lies in between.

9. Because product portfolios vary across manufacturers, they are affected differently by sales-mix shifts.

- Although evaluating impacts on individual manufacturers would be unreliable, grouping manufacturers using two dimensions (prestige versus non-prestige, domestic versus Asian versus European) reveals shifts in revenue shares due to feebate systems.
- Revenue shares for non-prestige vehicles with Asian nameplates ("Asia-Standard") increase for all feebate systems, and decrease for all other groups. The increase for Asia-Standard is smallest for a footprint-based system, and largest for a single benchmark system.
- These results assume that vehicle portfolio offerings across manufacturers remain unchanged from those projected for the period 2008-2013.

10. Analyses of the impact of feebate policies on different income groups suggest that these policies are not regressive.

- In the new vehicle market, the majority of fees and rebates are applied to higher income groups because they purchase the majority of new vehicles.
- For households that purchase a new vehicle, the average feebate is negative (i.e. net fees) for all households except for those in the lowest income groups. For those income groups with a negative average feebate, the average gets more negative as income increases.
- Analysis of consumer surplus changes indicates that that lower-income households experience an *increase* in consumer surplus due to feebates, whereas higher income households experience a decrease. This is consistent with the pattern of feebates for new vehicle purchases, but also reflects a "ripple effect" from the diffusion of more fuel-efficient vehicles into the used vehicle fleet over time.

11. Results from a large statewide survey (sample size of 3,000) indicate that consumers in California are generally concerned with anthropogenic climate change and energy independence, and would be supportive of a feebate system.

- In the survey, a total of 76% of survey respondents either strongly agreed (26%) or agreed (50%) that they "would generally be supportive of this type of program to help slow the rate of climate change."
- Exploratory research using focus groups (total of about 100 participants) was conducted prior to the survey. The issue of program fairness was a major theme; for example, a household that really needs a large vehicle might be forced to pay a fee. We found that overall response to feebate programs was weakly or strongly negative in most groups. Although focus groups cannot yield statistically significant conclusions, this outcome is qualitatively different from the survey results and should not be summarily dismissed. One possible explanation is that, in the dynamic and interactive setting of focus groups, the presence of individuals with concerns about fairness or a dislike of government programs could influence the overall tenor and direction of discussions.

- With regard to program fairness, survey results generally indicate that the idea of providing feebate-like incentives is *not generally considered unfair* – although some respondents would rather see government programs targeted more directly at the automakers themselves.

12. Automobile dealers are generally opposed to feebate programs due to concerns about administrative burdens, lost revenues, and broader "ideological" opposition to government policies that are perceived to reduce consumer choice.

- Dealers have had mixed and often negative experiences with other types of grant and incentive programs (e.g., Cash for Clunkers) that come with state reporting requirements.
- Some (but not all) dealers are concerned with potential revenue losses under a feebate program. This concern is generally confirmed by quantitative modeling results.

13. Automobile manufacturers are mixed in their support or opposition to feebate programs, some citing it as being in line with their corporate stance for "environmental stewardship" but others being concerned about potential negative effects on sales revenues that also could impact dealers.

- The automakers are generally knowledgeable about feebate programs and have a preference for linear as opposed to "step based" programs.
- The automakers had a mixed response to footprint and class-based programs, some suggesting that a footprint-based system would be well harmonized with CAFE and others suggesting that either type would be too complicated for consumers to easily understand and thus not "transparent" enough.
- The automakers expressed a clear preference for a national rather than individual state programs, and worst of all a "patchwork" of differing state programs – some suggested that individual state programs should be at a minimum, harmonized with each other in the absence of a federal program.

14. Administrative costs for feebate programs are estimated to range from $4.6 to $6.5 million annually (plus $2-$4 million in startup costs). This cost is relatively small when compared to the volume of revenue flow in a feebate program, is on the order of 1% of total fees collected, and is consistent with the level of administrative burden that is typical of state programs of this sort.

15. The potential effectiveness of feebate programs is affected by future events that in some cases can be unpredictable, such as gasoline price changes, cost evolutions for new technologies, or changes in automobile market structure. The future stringency of fuel economy or greenhouse gas emission standards is also found to be a key factor in the incremental benefits of a California-level feebate program. Policymakers should be aware of the potential for these events to interact with feebate program implementation and potentially affect overall effectiveness.

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