A

APPENDIX A. STUDIES ON THE COSTS OF MOTOR VEHICLE FUEL ECONOMY REGULATION

This Appendix to the comments of the Alliance of Automobile Manufacturers on the proposed adoption of the California motor vehicle greenhouse gas regulations supplements the discussion in the comments of studies that evaluate the total costs of motor vehicle fuel economy regulations for consumers.

As indicated in the Alliance's comments, the economic analysis of the California greenhouse gas standards has ignored opportunity costs of a mandated increase in fuel economy standards. From the perspective of many consumers, the total costs of compliance with the California will include the lost opportunity to purchase a vehicle which may be less fuel-efficient but has other features that a consumer desires more than enhanced fuel efficiency. Such features include vehicle performance, safety, capacity, comfort and aesthetics. Mainstream economic studies on the subject of fuel economy regulation consider such costs. Several leading studies in this area are summarized below.

1. Congressional Budget Office.

A study of federal fuel economy standards by the nonpartisan Congressional Budget Office ("the CBO") has identified two types of costs that must be compared with fuel economy savings flowing from a mandated increase in fuel economy levels. *See* Congressional Budget Office, "The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax," (December 2003), Chapter 2, pages 1 to 5 These are (1) the "higher prices paid by purchasers of new vehicles and [(2)] a loss in the well-being of consumers who would be discouraged from buying a new vehicle because of the higher prices." Applying estimates of the engineering or hardware costs and fuel savings that were assumed in the National Research Council's study of fuel economy standards, the CBO found that a proposal to increase the nation's fuel economy standards by 3.8 miles per gallon for both cars and light trucks over the next 14 years (far short of the proposal before the Board) would cost the nation's consumers some $2.4 billion per year, or $153 per vehicle and 33 cents per gallon of fuel conserved.

2. Portney, Parry, Gruenspecht and Harrington.

In a survey article, the former Chair of the National Research Council (NRC) and several co-authors examine the issue of consumer costs as it should be examined, by including the opportunity costs of not using fuel saving technologies for other vehicle enhancements that consumers would prefer over increased fuel economy. *See* Portney *et al.*, Comment, in *Journal of Economic Perspectives*, vol. 18 at 273 (Spring 2004). Those opportunity costs include the value of the improved performance, increased weight and carrying capacity and other vehicle attributes that a consumer must forego when she purchases or operates a vehicle designed to meet a regulatory fuel economy target that is higher than what she would choose for herself.

The authors of the survey article conclude that those opportunity costs must be compared with the fuel economy savings achieved by fuel economy standards. The authors of the survey write:

"[E]ngineering studies [may] underestimate the true economic costs of actually adopting fuel-saving technologies. The true economic cost is probably larger than ... engineering cost estimates ... for two reasons. First, it ignores the possible opportunity cost of not using fuel saving technologies for other vehicle enhancements. That is, by forcing automakers to apply their technical expertise to more fuel-efficient engines, tighter [fuel economy] standards could mean fewer of the improvements to which consumers have responded enthusiastically in the past—including such things as enhanced acceleration, towing capacity and so on. It is the implicit values of these foregone improvements that ought to be compared with the fuel economy savings that tighter [fuel economy] standards would bring. A second point is that engineering studies may exclude various costs of actually implementing a new technology that are difficult to observe—for example, marketing, consumer unfamiliarity and retraining of mechanics."

Id. at 274.

The survey concludes that the costs of any further regulation of fuel economy, when fully considered to comprehend consumers' opportunity costs, are likely to "significantly" exceed any benefits associated with reduced fuel consumption. Elsewhere, several of the authors of the survey article have stated:

"Engineering studies alone may give a very unreliable guide to the actual costs of mandated increases in fuel economy. They may not capture many important costs of actually implementing a new technology . . . Moreover, auto manufacturers have for the past several decades devoted their technological skills principally to the introduction of technologies that improve vehicle performance (like acceleration and towing capacity) rather than fuel economy; therefore, the real cost of devoting technology to improving fuel economy is the foregone performance enhancements that might have resulted. . . . *When we account for the existing taxes on gasoline and the likelihood of a rebound effect, it appears that tightening CAFE could significantly reduce social welfare overall.*"

See Paul Portney, Ian W. H. Parry, Howard K. Gruenspecht and Winston Harrington, "The Economics of Fuel Economy Standards," *Journal of Economic Perspectives* (Fall 2003), pages 209, 212 (emphasis added).

3. Kleit, Lutter, and Kravitz.

The same basic points about the economics of vehicle regulation involving fuel consumption and fuel economy are mirrored by two other recent studies. Andrew Kleit, at the time a member of the faculty of The Pennsylvania State University, found that a "long-range" CAFE increase of 3 miles per gallon for both cars and light trucks would impose consumer and producer welfare losses summing to about $4 billion per year, for a "hidden tax" of $0.78 per gallon of fuel conserved. Andrew N. Kleit, "Impacts of Long-Range Increases in the Fuel Economy (CAFE) Standard," *Economic Inquiry* (April 2004), pages 279-294.

Randall Lutter of the American Enterprise Institute and Troy Kravitz of the Brookings Institution found that "mandatory fuel economy standards cannot benefit informed consumers" and "that there is little reason to believe that consumers systematically underestimate the price of gasoline." Lutter and Kravitz also note that engineering-based estimates overstate the net benefits of fuel economy standards because they "exclude the foregone value to the consumer of the declines in performance associated with better fuel economy." Randall Lutter and Troy Kravitz, "Do Regulations Requiring Light Trucks To Be more Fuel Efficient Make Sense? An Evaluation of NHTSA's Proposed Standards," AEI-Brookings Joint Center for Regulatory Studies, Regulatory Analysis 03-2, (February 2003), pages 6, 7, and 10.

* * * *

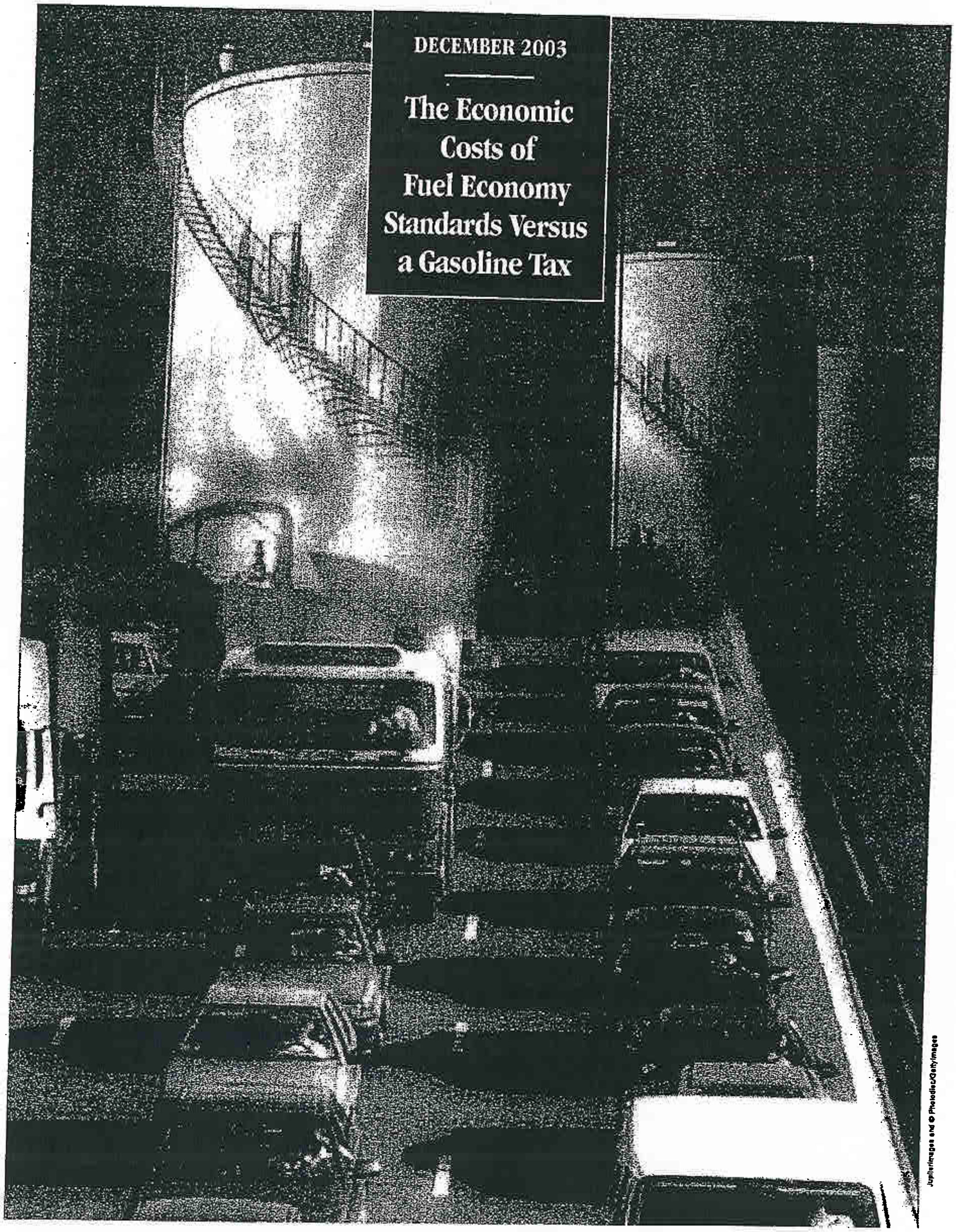
The referenced studies are attached to this Appendix. The Department should consider them fully in determining the true costs of compliance with the California greenhouse gas regulation.

CONGRESS OF THE UNITED STATES
CONGRESSIONAL BUDGET OFFICE

A CBO STUDY

DECEMBER 2003

The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax



JupiterImages and © PhotoDisc/GettyImages

A

CBO

STUDY

The Economic Costs of Fuel Economy Standards Versus a Gasoline Tax

December 2003

The Congress of the United States ■ Congressional Budget Office

Preface

In recent years, there has been renewed interest in the Congress in policies that would reduce gasoline consumption in the United States. That interest has been motivated primarily by concerns about the nation's energy security and about the risk that carbon emissions, 20 percent of which come from gasoline consumption, may affect the Earth's climate. This Congressional Budget Office (CBO) study—prepared at the request of the Senate Committee on Environment and Public Works—compares the economic costs of two methods for reducing gasoline consumption: raising the corporate average fuel economy (CAFE) standards for passenger vehicles and increasing the federal tax on gasoline. In analyzing CAFE standards, the study also estimates the potential cost savings from allowing automakers to trade fuel economy credits with one another as a way of complying.

The study breaks down the costs that each of the alternative policies would impose on both producers and consumers. Further, it discusses the prospects for CAFE standards to improve social welfare given that the existing gasoline tax also provides consumers an incentive to buy more-fuel-efficient vehicles. In keeping with CBO's mandate to provide objective, impartial analysis, this study makes no recommendations.

David Austin and Terry Dinan of CBO's Microeconomic and Financial Studies Division wrote the study, under the supervision of Roger Hitchner. CBO's Robert Dennis, Richard Farmer, Arlene Holen, Deborah Lucas, and Tom Woodward provided valuable comments, as did Robert Carroll (formerly of CBO); Andrew Kleit of Pennsylvania State University; Kenneth Small of the University of California, Irvine; and Ian Parry of Resources for the Future.

John Skeen edited the study, and Juyne Linger proofread it. Cecil McPherson provided research assistance. Angela Z. McCollough typed the tables in the draft. Maureen Costantino designed the cover and prepared the study for publication, and Annette Kalicki prepared the electronic versions for CBO's Web site (www.cbo.gov).

Douglas Holtz-Eakin
Director

December 2003

Tables

Figures

Boxes

CONTENTS

Summary

Some Members of Congress and public interest groups have recently proposed raising the corporate average fuel economy (CAFE) standards for automobiles. Proponents of CAFE standards see them as a way to decrease the United States' dependence on oil and its emissions of carbon dioxide (the predominant greenhouse gas). In this study, the Congressional Budget Office (CBO) estimates the costs that raising CAFE standards would impose on automobile producers and consumers. This study also extends previous research by examining the potential cost savings from instituting a system in which producers could trade "fuel economy credits." Under that system, producers with high costs of complying with CAFE standards could meet the new standards by applying credits bought from producers that exceeded the standards. CBO also compares the costs of CAFE standards with those of a higher gasoline tax, an alternative policy for reducing gasoline consumption. Finally, CBO examines the available evidence on whether changing CAFE standards or the gasoline tax could improve social welfare, a general measure of society's well-being that includes not only the value derived from the goods and services that people consume but also factors that diminish the quality of life, such as pollution and traffic congestion.

CAFE standards are currently set at 27.5 miles per gallon (mpg) for cars and 20.7 mpg for light trucks. The standard for cars has not changed since 1990; the truck standard, fixed since 1996, is due to increase to 22.2 mpg by 2007. The federal gasoline tax, which dates from 1932 and is earmarked for mass transit and the construction and maintenance of highways, is currently 18.4 cents per gallon. The average tax on gasoline—including federal, state, and local taxes—is 41 cents per gallon.

The Costs of Alternative Policies

CBO estimates the costs borne by producers and consumers resulting from various increases in CAFE standards and various increases in the tax on gasoline—which effect different levels of reduction in gasoline consumption. A 10 percent reduction in gasoline consumption is used as a benchmark for the purpose of comparing the costs of the alternative policies.

According to CBO's estimates, CAFE standards designed to meet the benchmark 10 percent reduction—about 31.3 mpg for cars and 24.5 mpg for light trucks—would impose costs on producers and consumers of new vehicles totaling approximately $3.6 billion per year, over and above the value of fuel savings (*see Summary Table 1*). Those costs average about $228 per new vehicle sold. The costs are measured in the long run—that is, once the vehicles currently on the road are retired.

Instituting fuel economy credit trading along with the higher standards would reduce the costs of raising the CAFE standards by shifting the adoption of fuel economy measures away from higher-cost firms to lower-cost firms. CBO estimates that trading would cut the costs of achieving the benchmark target by 16 percent, to about $3.0 billion per year, or $184 per vehicle.

The gasoline tax would achieve the 10 percent reduction at the lowest cost of the three policy alternatives examined. Under the demand and supply responses that CBO assumed, a 46-cent-per-gallon tax increase would achieve the targeted reduction and would impose a welfare cost of $2.9 billion per year—3 percent less than the cost of CAFE standards with trading and 19 percent less than the cost of the standards without trading.

Summary Table 1.

Total Long-Run Annual Costs to Achieve a 10 Percent Reduction in Gasoline Consumption Under Alternative Policies

(Billions of dollars)

	CAFE Standards		
	Without Trading	With Trading	Gasoline Tax
Policy Modeled	31.3 mpg for cars 24.5 mpg for light trucks		46-cent-per-gallon increase
Total Welfare Costs[a]	3.6	3.0	2.9
Producers' costs	1.2	0.8	0.5
Consumers' costs	2.4	2.2	2.4

Source: Congressional Budget Office.

Note: CAFE = corporate average fuel economy; mpg = miles per gallon.

a. For producers, costs are measured as reductions in total profits, while for consumers, they are measured as reductions in the amount that consumers value their new vehicle over and above the purchase price.

The advantage of a gasoline tax over CAFE standards is much greater in the short run. Neither the higher tax nor higher CAFE standards would achieve full effectiveness until all existing vehicles were replaced, or after about 14 years in CBO's analysis. But over the initial 14 years, the tax would save 42 percent more gasoline than would CAFE standards with trading, while costing 27 percent less (*see Summary Figure 1*). The gasoline tax would outperform the CAFE standards because, while both policies would improve the fuel economy of new vehicles, the tax would produce greater immediate gasoline savings by inducing owners of both new and existing vehicles to drive less. In contrast, by making new vehicles cheaper to operate, higher CAFE standards would encourage owners of new vehicles to drive more (and would not affect the driving incentives of existing-vehicle owners at all).

Consumers would bear the brunt of the costs under all of the policies considered, according to CBO's estimates. Achieving the 10 percent reduction through higher CAFE standards would cost new-vehicle buyers about $2.4 billion per year if automakers were not allowed to trade fuel economy credits, or $2.2 billion if they were allowed. In either case, consumers would bear more than two-thirds of the total long-run costs. Consumers' costs would vary across vehicle types. In some cases, buyers of vehicles with poor fuel economy would be subsidizing the purchase of fuel-efficient vehicles. Finally, if policymakers chose to achieve the 10 percent reduction through a 46-cent increase in the tax on gasoline, gasoline consumers would bear nearly 85 percent of the total long-run costs, or $2.4 billion per year, CBO estimates.

Fuel economy credit trading would significantly reduce producers' costs of complying with CAFE standards, from roughly $1.2 billion per year to $0.8 billion per year. Credit trading would reduce compliance costs for firms that bought credits (projected to be primarily the "Big Three" domestic automakers), while boosting revenue for firms that sold credits.

Some Key Assumptions and Limitations

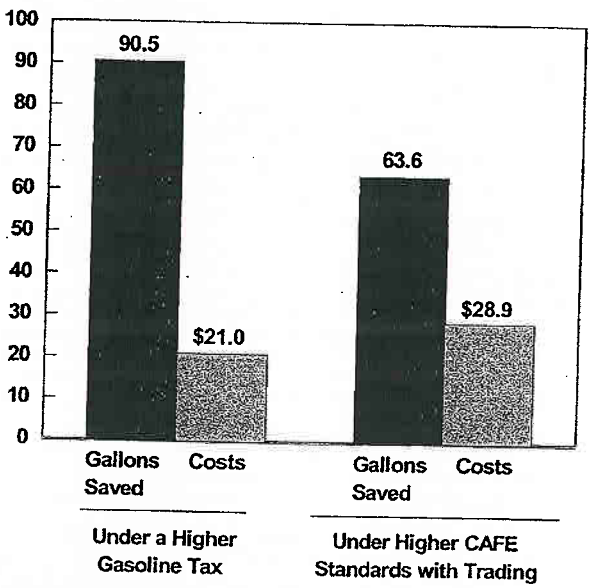
To study the effects of alternative policies, CBO developed a detailed simulation model of the U.S. passenger vehicle market. That model extends previous research by capturing firms' competition on both price and fuel economy and by measuring the potential savings due to instituting fuel economy credit trading. In CBO's model, firms' responses to policy changes are motivated by the desire to maximize profits given the costs of improving fuel economy[1] and the response of consumers to changes in vehicles' prices and fuel economy.

1. Cost estimates come from National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Washington, D.C.: National Academy of Sciences, 2002).

Summary Figure 1.

The Effects of CAFE Standards with Trading Versus a Gasoline Tax Over the First 14 Years

(Billions)



Source: Congressional Budget Office.

Notes: CAFE = corporate average fuel economy.

The figure depicts effects over the first 14 years (after which all current vehicles are assumed to be retired) from policy changes that would bring about a 10 percent reduction in gasoline consumption.

A key assumption is that firms will not voluntarily use future new technologies to produce fuel savings. CBO made that assumption because consumers' preferences over the past 15 years have induced automakers to increase vehicles' size and weight (for safety or other reasons) and horsepower, while holding gasoline mileage ratings steady. Given that pattern, CBO believes that regulatory intervention would be required to raise average mileage ratings and that any increase in the standards would reduce the welfare of automobile producers and consumers.

One of the main contributions of this study is its comparison of CAFE standards and the gasoline tax on the basis of a consistent set of assumptions. For instance, in calculating how demand responds to an increase in the price of gasoline resulting from a tax hike, CBO uses the same assumptions about consumers' behavior and technology costs as in its analysis of higher CAFE standards.

Several factors that could reduce the direct costs of increases in CAFE standards or the gasoline tax are not considered in this study. The costs that CAFE standards would impose on producers and consumers could be considerably lower if the real price of gasoline rose—making fuel economy a more desirable attribute for vehicles. Further, the costs imposed by higher CAFE standards or by a higher gasoline tax would be reduced if future fuel-saving technologies were significantly less costly than the ones anticipated or if consumers' preferences shifted to smaller, less powerful vehicles.

On the other hand, other factors could result in costs that are higher than those estimated in this study. For example, this study estimates only costs that CAFE and gasoline tax policies might impose on the sellers and buyers of vehicles and gasoline, although both policies have the potential to impose costs in other parts of the economy. Including those additional costs could significantly boost CBO's estimates of the costs of all of the policies considered.

Given those limitations, the costs reported in this study should not be viewed as precise estimates. Nonetheless, CBO believes that its conclusions about the relative cost-effectiveness of the alternative policies discussed are sound.

Could Increases in CAFE Standards or the Gasoline Tax Improve Social Welfare?

Increasing CAFE standards or the gasoline tax would impose costs on both producers and consumers of, respectively, vehicles and gasoline—direct costs that are estimated by CBO's modeling. An important question, therefore, is whether those costs would be worthwhile—that is, would they be justified by the accompanying benefits? The primary benefit from reducing gasoline consumption would be the decrease in the external costs that such consumption creates—in particular, the costs stemming from the United States' dependence on oil and the carbon dioxide emitted during gasoline combustion. In its recent report, the National Research Council suggested that a reasonable, albeit uncertain, estimate of those external costs would be 26 cents per gallon.[2]

Determining whether the costs of higher CAFE standards would be justified requires accounting for the effect that existing taxes have on gasoline consumption. The existing state, local, and federal taxes on gasoline already provide an incentive for consumers to reduce their consumption of gasoline: consumers will buy more-fuel-efficient cars and drive less as long as the costs of doing so are less than the tax-induced increase in the price of gasoline.

If the existing tax was equal to the external costs associated with consuming a gallon of gasoline—that is, if it reflected the total costs that gasoline consumption imposes on society—then consumers would have an incentive to reduce their consumption by an amount that took those external costs fully into account. In that case, there would be no need to increase CAFE standards.

Given that the existing tax on gasoline currently averages 41 cents per gallon, consumers have an incentive to buy fuel-efficient vehicles and to reduce driving up to a cost of 41 cents per gallon saved.[3] If the National Research Council's 26-cent estimate for the external costs of consuming a gallon of gasoline is correct, then the existing tax on gasoline already provides new-car buyers with an incentive to pursue fuel economy up to a cost that exceeds the benefits of reducing gasoline consumption by 15 cents. In that case, raising the CAFE standards would impose unwarranted costs on automakers and buyers of new vehicles and would reduce social welfare.

Estimating the external costs associated with consuming gasoline is not part of this study, and CBO does not endorse the National Research Council's estimate—indeed, that organization itself considers its estimate to be tentative. However, given the magnitude of the existing tax on gasoline, higher CAFE standards would have the potential to improve social welfare only if the external costs associated with consuming a gallon of gasoline exceeded 41 cents, a figure that is significantly higher than the National Research Council's estimate.

Higher CAFE standards could further reduce social welfare by worsening traffic congestion and increasing the number of traffic accidents. That undesirable outcome could occur because higher CAFE standards would lower the per-mile cost of driving, providing new-vehicle owners with an incentive to drive more. While the increase in driving associated with higher CAFE standards may be relatively small, some studies suggest that the resulting costs of the increased congestion and traffic accidents may nevertheless be large.

Although the existing tax on gasoline exceeds the NRC's estimate of the external costs associated with consuming gasoline, the tax is not necessarily too high. The gasoline tax serves purposes other than encouraging gasoline buyers to take the external costs of gasoline consumption into account. It also discourages driving. Determining the "optimal" tax on gasoline is beyond the scope of this study, but such a determination could take into account the external costs associated with driving—beyond those specifically associated with consuming gasoline (the costs of increased dependence on oil and higher carbon emissions)—such as traffic congestion and accidents. Depending on the outcome of such an assessment, increases in the existing tax on gasoline could improve social welfare.

2. See National Research Council, *Effectiveness and Impact of CAFE Standards*. Also, note that improving fuel efficiency would not necessarily reduce other pollutants emitted by passenger vehicles—such as carbon monoxide, nitrogen oxides, and hydrocarbons—because the Environmental Protection Agency's maximum emission rates for those pollutants are defined in terms of grams per mile rather than per gallon. Thus, those pollutants are, in principle, independent of gasoline mileage. (In practice, though, cars with better mileage ratings may pollute less than the agency's standards allow.)

3. Producers of gasoline might bear part of the tax. In that case, the price of gasoline would increase by less than the amount of the tax. In either case, however, the incremental cost of the tax (borne by producers and consumers) would be 41 cents.

CHAPTER

1

Introduction

Recently, there has been much discussion, in the Congress, in the press, and among public interest groups, about fuel economy standards for cars and light trucks. The average fuel economy of new vehicles has been declining for more than a decade, as consumers have increasingly switched from cars to trucks or more powerful cars. At the same time, there has been increasing concern about the energy security of the U.S. economy and about the role of carbon dioxide emissions in global climate change.[1] Proponents of higher fuel economy standards hope that reducing gasoline consumption will help address those concerns.

A recent Congressional Budget Office (CBO) study provided a qualitative comparison of the effects of three policies that could decrease gasoline consumption: an increase in the corporate average fuel economy (CAFE) standards that govern passenger vehicles, an increase in the federal tax on gasoline, and a "cap-and-trade" program for the carbon dioxide emissions that result when gasoline is burned.[2] That study weighed those policies against four major criteria: whether they would minimize costs to producers and consumers; how reliably they would achieve a given reduction in gasoline use; what implications they would have for the safety of driving; and what effects they would have on factors such as traffic congestion, requirements for highway construction, and emissions of air pollutants other than carbon dioxide.

This study extends CBO's previous work by providing a quantitative comparison of the costs that producers and consumers would bear as a result of two of the policies: an increase in CAFE standards and an increase in the federal tax on gasoline. A significant feature of this study is that it compares the costs of those policy options on the basis of a consistent set of assumptions—in particular, assumptions about consumers' preferences concerning fuel economy and about the costs of technologies for improving fuel economy. Higher CAFE standards would reduce gasoline consumption by raising vehicles' fuel economy, while an increase in the federal gasoline tax would discourage consumption by raising the price of gasoline.

The study considers two alternative designs for the CAFE program. The first, based on the existing design, would require each manufacturer individually to meet the standards. Under the second design, manufacturers could trade "fuel economy credits"; that is, firms exceeding the standards could sell credits to firms that would otherwise fall short of the standards. The trading of fuel economy credits would lower the costs of raising the CAFE standards; this study estimates the resulting savings.

The Rationale for Decreasing Gasoline Consumption

Proponents of higher CAFE standards point out that the standards are a way of improving energy security and reducing climate change. The energy-security cost of gaso-

---

1. For a discussion of the scientific consensus and economic issues related to climate change, see Congressional Budget Office, *The Economics of Climate Change: A Primer* (April 2003).

2. See Congressional Budget Office, *Reducing Gasoline Consumption: Three Policy Options* (November 2002).

   Burning a gallon of gasoline releases 8.9 kilograms of carbon dioxide into the atmosphere. See National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Washington, D.C.: National Academy of Sciences, 2002), p. 85.

line consumption can be measured as the risk of macroeconomic losses from higher oil prices due to disruptions in the world oil supply. Some analysts argue that the United States would be less vulnerable to such disruptions if it used less oil.[3] The use of motor gasoline (which is derived from oil) accounts for about 43 percent of U.S. petroleum use and about 11 percent of world petroleum use.

Gasoline consumption can contribute to climate change because it produces emissions of carbon dioxide, the predominant "greenhouse gas." Although climate change might benefit some regions, it could ultimately cause extensive physical and economic damage in others. That damage is uncertain, but it could include higher sea levels; wider ranges for tropical diseases; disruptions to farming, forestry, and natural ecosystems; and greater variability and extremes of regional weather. Carbon emissions make up about 84 percent of U.S. greenhouse gas emissions, with motor vehicles accounting for approximately 20 percent of U.S. carbon emissions.

Reducing gasoline consumption could cut the amount of oil that the United States consumes and the greenhouse gases that it emits. But, as this study discusses, determining whether or not increases in CAFE standards would have the potential to improve social welfare—that is, including not only the value derived from the goods and services that people consume but also factors that diminish the quality of life, such as pollution—requires considering the role that the existing tax on gasoline plays in reducing gasoline consumption. Further, one must consider the increase in driving that could result from higher CAFE standards (as people enjoyed the lower operating costs of higher-mileage vehicles) and the resulting social costs—such as greater traffic congestion and an increased risk of accidents.

3. Because oil prices are determined in the world market, vulnerability does not depend on where the oil is produced. Foreign disruptions would cause price shocks in the United States, even if the country produced all of its oil domestically.

The Existing CAFE Standards and Gasoline Taxes

The Energy Policy and Conservation Act of 1975 mandated CAFE standards. Currently, those standards are 27.5 miles per gallon (mpg) for cars and 20.7 mpg for light trucks (which is due to increase to 22.2 mpg by 2007). All manufacturers that sell more than 10,000 passenger vehicles per year in the United States must comply with the standards.

Firms must comply by ensuring that the average fuel economy of the vehicles that they sell each year meets or exceeds the applicable CAFE standard. Compliance is determined separately for each firm's domestic and imported car fleets (a distinction no longer made for light trucks). Producers that fail to meet a CAFE standard must eventually pay a penalty of $5.50 per vehicle for every tenth of a mile per gallon that their fleet average falls short. Firms have some leeway in complying over time, as they can undercomply in one year provided that they overcomplied by an equivalent amount during the three preceding years or that they overcomply within the next three years. Actual compliance, then, depends on firms' fleet averages over several years.

The federal government began levying a tax on gasoline in 1932. Historically, the tax has supported the Highway Trust Fund, providing a dependable source of funding for the Interstate highway system. Today, gasoline tax receipts are also earmarked for mass transit projects. The federal tax has increased gradually over the years, from an initial rate of 1 cent per gallon to today's 18.4 cents per gallon. Including state and local taxes on gasoline, which average 22.6 cents per gallon, the average tax in the United States is about 41 cents per gallon.

Three Policy Alternatives

Increase CAFE Standards

CBO has modeled the effects of raising the car and light-truck CAFE standards in half-mpg increments up to 38 mpg and 31.2 mpg, respectively. This study estimates the resulting reductions in gasoline consumption, estimates the overall costs of raising the standards and breaks out those costs for producers and consumers, and explores the concomitant changes in the composition of the new-vehicle fleet.

An increase in CAFE standards would directly affect automobile producers and indirectly affect automobile consumers. Producers would face higher manufacturing costs from adopting new fuel-saving technologies in their vehicles and a reduction in profits if they adjusted their pricing to increase the sales of their higher-mileage vehicles. While consumers with a relatively strong preference for fuel economy could come out ahead, on average consumers would face higher vehicle prices and, in effect, share compliance costs with the manufacturers.

The CAFE program analyzed in this study differs from the actual program in several ways. First, while in theory manufacturers are free to pay a penalty in lieu of complying with CAFE standards, in fact, U.S. manufacturers invariably choose to comply. They do so, according to an automobile industry representative, to avoid or reduce the possibility of legal or public relations ramifications. As a result, this study presumes compliance annually. Second, because relevant data are unavailable, this analysis does not distinguish between domestic and imported automobiles. Thus, CBO considers compliance based on the fuel economy of each firm's domestic and imported vehicles combined. Finally, in CBO's analysis, firms' compliance is defined in terms of their production in a single year. The actual CAFE program's flexibility in allowing firms to comply on a multiyear basis is largely a response to the uncertainty inherent in sales forecasts and related production decisions and thus need not be a focus of CBO's analysis.

Increase CAFE Standards and Introduce Credit Trading

Allowing firms to trade fuel economy credits would lower the costs of improving fuel economy for any given increase in CAFE standards. Under a credit-trading system, firms that exceeded one of the CAFE standards would generate credits that they could sell to firms that fell below that standard. The selling and buying of credits would be voluntary. A credit would be denominated in gallons of gasoline saved,[4] and its price determined by the dynamics of demand and supply. Each firm's compliance would be based on the average fuel economy of the vehicles that it sold plus the fuel economy credits that it held.

Aggregate cost savings would result when automakers with lower marginal compliance costs (the additional costs of achieving incremental increases in average fuel economy) exceeded the CAFE standards and sold the resulting credits to firms with higher marginal compliance costs. A firm would buy a credit as long as the price was less than the cost of an equivalent increase in the firm's average fuel economy. Essentially, firms would choose the means of complying that was least expensive for them.

Increase the Federal Gasoline Tax

The gasoline tax could also be used as a policy tool for reducing gasoline consumption. By raising the price of gasoline, a tax increase would give drivers an incentive to undertake a broad range of gas-saving activities—including purchasing more-fuel-efficient vehicles; retiring gas-guzzlers earlier than they otherwise would have; driving less; driving more slowly; and maintaining their vehicles better.

The costs of increasing the gasoline tax would be borne by both consumers and producers, the former by reducing the amounts they purchased as prices increased at the pump, and the latter by diminishing their net revenues. Indirectly, an increase in the gasoline tax would also affect automobile manufacturers by raising the demand for fuel economy in new vehicles. The size of those effects, and thus the costs of achieving a given reduction in gasoline consumption via a tax increase, would depend crucially on how responsive consumers were to changes in the price of gasoline and on the share of the tax that was borne by gasoline producers.

4. Savings would be calculated relative to the CAFE standard, per hundred miles of driving. For example, if the standard was 30 mpg, a car with a mileage rating of 31 mpg would save 0.1 gallons per hundred miles relative to a car rated at 30 mpg and would therefore generate one-tenth of a credit.

CHAPTER

2

Methods and Data

To properly estimate the costs of raising corporate average fuel economy standards, it is necessary not only to have information on the expected technology costs, but also to anticipate how automakers and consumers would respond to the new standards. Similarly, to estimate the costs of an increase in the gasoline tax, it is necessary to have information about how consumers and producers would respond to that tax.

For this study, the Congressional Budget Office has developed an economic simulation model to predict how automakers would respond to increases in fuel economy standards. Firms' responses are governed by their motivation to maximize profits, which depend on the fuel economy of their vehicles, the prices that they charge, and in turn the consumer demand for those vehicles; the technology costs of increasing fuel economy; and the actions of other firms. CBO also uses this simulation model to predict changes in consumer demand for fuel economy as gasoline prices rise, an important component in analyzing the costs of a higher gasoline tax.

Analyzing CAFE Standards

Methods

CBO's simulation model for the automobile market describes activity in the U.S. passenger vehicle market, relying on information about current production and pricing, estimated technology costs for raising fuel economy, and estimated consumer demand for different types of vehicles. The model distinguishes vehicles by type and manufacturer, price, and fuel economy.

In such a setting with differentiated products, firms set prices and fuel economy levels so as to maximize their profits, subject to complying with CAFE standards. (By contrast, in a perfectly competitive market, each individual firm represents such a small share of the market that its actions have no influence on the product's price.) The firms' behavior in setting prices is disciplined by consumers' freedom to switch from one type of vehicle to another and from one firm to another. So while a firm could increase its profit per vehicle by raising its prices, it would sell fewer cars and may reduce its overall profits. The firm must also respond to its rivals' pricing decisions, as consumers' choices are determined by relative as well as absolute prices.

In its model, CBO simulates the effects of higher CAFE standards by imposing new fuel economy constraints on the firms and letting them optimize their prices and fuel economy levels again. In an iterative fashion, each firm in turn makes those adjustments, given the values the other firms have chosen, until a unique equilibrium is reached. At that point, every firm has maximized its profits, and none wishes to make further adjustments. Vehicle supply and demand are by definition equal at that point.

In CBO's analysis, all firms face identical costs of technology for increasing vehicles' fuel economy, with costs differing for each vehicle type. Boosting a vehicle's fuel economy increases its production costs because the vehicle must be redesigned. This analysis assumes that new CAFE standards would allow manufacturers sufficient lead time to incorporate new technologies into their products.[1] Firms' final technology costs depend on the actual increases in fuel economy that they adopt. Differ-

1. According to the recent study of the CAFE program by the National Research Council, achieving widespread use of even existing technologies would probably require five to 10 years. See National Research Council, *Effectiveness and Impact of CAFE Standards*, p. 4.

ences in the mix of vehicles that firms sell, in the baseline fuel economy of those vehicles, and in firms' manufacturing costs and profits ensure that their responses to new standards will be diverse.

Given the complexity of the interactions between firms and consumers, firms have several ways to comply with new fuel economy standards. The most direct way, of course, is to increase the fuel economy of their vehicles. Firms could also alter their pricing to draw consumers toward their more-fuel-efficient vehicles, lowering the prices of those vehicles while raising the prices of their less-fuel-efficient ones, a strategy called mix-shifting.

In CBO's analysis, raising a vehicle's mileage rating lowers its effective price, as consumers take into account the present discounted value of the fuel savings when they make their purchase decisions.[2] In CBO's model, the effects of price changes depend on the elasticities of demand across six vehicle makes and 10 types, that is, consumers' propensity to change their choice of vehicle because of a change in price.[3] The model includes elasticities for every possible pairing among 60 different vehicles (including pairings of each vehicle with itself), providing the percentage change in the quantity demanded of one vehicle due to a 1 percent increase in the price of the other. Thus, the analysis requires a 60-by-60 elasticity matrix describing how consumers would respond to an incremental change in any price.

Data

The simulation model that CBO has created for this analysis is a detailed but stylized version of the market, incorporating pricing and production data for General Motors, Ford, DaimlerChrysler, Toyota, and Honda, including all divisions and wholly owned subsidiaries with vehicle sales in this market. Those are the five largest firms in the U.S. passenger vehicle market in terms of unit sales.[4] The model also includes data on a composite sixth firm representing most of the remainder of the industry.[5] Consequently, the model covers about 95 percent of the U.S. market.

Each firm produces both cars and light trucks. In CBO's analysis, they are classified as follows:

Types of Cars:

- Subcompact (including sports cars),
- Compact (including sedans and wagons),
- Midsize (including sedans and wagons),
- Large (including sedans and wagons),
- Luxury small (subcompacts and compacts with a price above $31,000), and
- Luxury large (midsize and large cars with a price above $35,000).[6]

Types of Light Trucks:

- Minivan,
- Small sport utility vehicle (SUV) (with six or fewer cylinders),
- Large SUV (with eight cylinders), and
- Pickup (including small and standard sizes).

The baseline data used in this analysis reflect the prices, unit sales, and fuel economy ratings of vehicles sold in the United States in 2001.[7] Information on sales came from *Automotive News*; wholesale and suggested retail prices for the available configurations of every vehicle came from

2. CBO calculates the present value of fuel savings relative to a vehicle's baseline fuel economy, with savings accumulating over time as the vehicle is driven.

3. An elasticity gives the percentage change in one variable in response to a 1 percent change in another. For example, a price elasticity of demand of -1.5 means that a 1 percent price increase leads to a 1.5 percent decrease in the quantity demanded.

4. Their subsidiaries include Saab (owned by General Motors), Jaguar and Volvo (owned by Ford), and Mercedes-Benz (owned by DaimlerChrysler).

5. The sixth firm includes BMW, Daewoo, Hyundai, Isuzu, Kia, Mazda, Mitsubishi, Nissan, Subaru, and Volkswagen.

6. The particular dollar thresholds used to define small and large luxury cars separate traditional luxury brands (for example, BMW, Cadillac, Jaguar, Lincoln, Mercedes) from other brands.

7. Total U.S. sales were 16.6 million in 2001, which is 4 to 5 percent less than occurred in 2000 or 2002. See *Automotive News* data center, at www.autonews.com. CBO's estimates of welfare losses would be slightly higher if data from those years were used instead.

Edmunds.com; and fuel economy data, for multiple configurations of engine size, transmission type, and drive wheels, came from the Environmental Protection Agency.[8]

Each vehicle is identified by its type and manufacturer. For example, CBO has combined the data for Ford's two nonluxury midsize models in 2001, the Taurus and the Mercury Sable, into information on a vehicle called the "Ford midsize car," with a quantity sold equal to total U.S. sales of the Taurus and the Sable, and a price and fuel economy equal to the median price and median fuel economy rating for Taurus and Sable's available configurations of engine size, type of transmission, and other attributes not included in CBO's analysis.

The Cost of Fuel Economy. The findings of this analysis depend critically on the estimated direct cost of improvements in fuel economy. CBO uses cost estimates developed in the recent National Research Council (NRC) study. The NRC considered fuel-saving technologies that are either already available or are anticipated within 10 to 15 years,[9] ordering them from lowest to highest cost. The NRC estimated the incremental costs of reducing gasoline consumption for each of 10 different types of vehicles.[10]

Consumers' preferences over the past 15 or 20 years have led automakers to increase vehicles' size and weight (for safety and other reasons) and horsepower, while holding gasoline mileage more or less constant. Consequently, in its model, CBO assumes that firms will not voluntarily use the fuel-saving technologies identified by the NRC to increase their average fuel economy. That is, to reduce gasoline consumption, regulatory intervention would be required. Thus, because some firms are currently just complying with the CAFE standards, CBO assumes that any increase in the standards would reduce the welfare of vehicle producers and consumers.[11] CBO implemented that assumption by first running the model with all of the new technologies available, but with no increase in CAFE standards. CBO then eliminated the technologies that the model predicted firms would use, implicitly assuming that firms would prefer to offset the resulting mileage gains by increasing their vehicles' power or weight (which are held constant in the model). The remaining technologies are those that the automakers would not use voluntarily, meaning that using them to comply with higher CAFE standards would impose costs on them or on their customers (*see Box 2-1*).

CBO's calibration method thus implies that increases in CAFE standards would impose costs on producers and consumers. One recent study goes further and assumes that the *current* CAFE standards are binding—implying that average fuel economy would fall if the standards were

8. For model-year prices, see "New Car Pricing" at www.edmunds.com. For quantities sold, see "Sales, U.S. Car—2001" and "Sales, U.S. Light Truck—2001" at www.autonews.com. For model-year fuel economy, see "Fuel Economy Guide Data" for the 2001 model year at www.epa.gov/otaq/fedata.htm. Data on prices and fuel economy are reported by model year, which begins in October; data on sales are by calendar year. Thus, the overlap of the information is nine months.

9. See National Research Council, *Effectiveness and Impact of CAFE Standards.* This recent, publicly funded study was produced by an independent panel of engineers, physical scientists, and economists, in consultation with the U.S. Department of Transportation. The final report reflects the panel's consideration of public comments from representatives of the automobile industry, environmental advocacy groups, and other interested parties.

10. The NRC assumes that firms would not reduce the weight of their vehicles to improve fuel economy, in fact, that weight will increase 5 percent because of additional requirements for emissions and safety equipment. The NRC holds vehicles' performance (for example, horsepower) constant and adjusts for interactions between fuel-saving technologies that could otherwise result in the double counting of some savings. The 10 vehicle types included in the analysis are subcompact, compact, midsize and large cars; small, midsize, and large SUVs; minivans; and small and large pickup trucks. CBO uses slightly different vehicle types in some cases for consistency with the demand elasticity estimates that it uses. CBO uses the NRC's cost estimates for "compact" and "large" cars in its "luxury small" and "luxury large" categories, respectively; it uses the average of the NRC's estimated costs for midsize and large SUVs in its "large SUV" category; and it averages the NRC's estimated costs for small and large pickups.

11. If producers satisfied new CAFE standards by reducing vehicles' performance or weight, consumers' costs would be in the form of reduced satisfaction from owning a new vehicle.

Box 2-1.

Can Higher CAFE Standards Be "Free"?

In 2002, the National Research Council (NRC) published a study of the corporate average fuel economy (CAFE) program and of fuel-saving technologies for light-duty passenger vehicles.[1] It found that the value of the fuel savings from installing the lowest-cost technologies would exceed the costs by between 12 and 27 percent for new cars, depending on the vehicle's size, and between 25 and 42 percent for light trucks.[2]

The Congressional Budget Office's (CBO's) analysis extends the NRC study by estimating losses in producers' profits and consumers' welfare from tightened CAFE standards, given the NRC's estimates of technology costs. The NRC analysis could be misinterpreted as suggesting that employing the new technologies to boost fuel economy would improve welfare as long as the resulting fuel savings exceeded the cost of the technologies. If that were so, there might be no need to raise the CAFE standards.

However, without regulatory intervention, the new technologies may not be used for fuel economy. As the NRC report notes, "given the choice, consumers might well spend their money on other amenities ... rather than on ... fuel economy...." Indeed, between 1981 and 2003, according to the Environmental Protection Agency's calculations, average fuel economy changed very little (increasing from 20.5 to 20.8 mpg),[3] yet average horsepower nearly doubled (from 102 to 197), weight increased by almost 25 percent (from 3,201 to 3,974 lbs), and the time for acceleration from 0 to 60 mph fell by nearly 30 percent.[4] Further technological advances, such as those described in the NRC report, could be used to continue that trend. Therefore, increases in CAFE standards or in the gasoline tax may be necessary if policymakers want average fuel economy to rise.

Forcing manufacturers to use new technologies to improve fuel economy would reduce carbon emissions and decrease the United States' oil dependency but would not necessarily make automobile (or fuel) producers or consumers better off. Those groups would be better off only if consumers have been incorrectly valuing fuel economy by overly discounting savings at the pump or if consumers have been receiving inadequate information about the fuel savings offered by different cars. CBO does not think that either of those conditions holds.[5]

Given that consumers have not demonstrated a preference for fuel economy at current prices, the average fuel economy of the U.S. new passenger vehicle fleet should not be expected to rise unless forced to through government action. Absent that, gasoline consumption may fall only if future technologies lower the price of improvements in fuel economy, the real price of gasoline rises significantly,

1. See National Research Council, *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards* (Washington, D.C.: National Academy of Sciences, 2002).

2. The NRC compared the cost of improvements in fuel economy with the projected fuel savings over an expected vehicle life of 14 years, assuming 15,600 miles of driving in the first year, declining by 4.5 percent per year thereafter. The NRC assumed a real (inflation-adjusted) price of gasoline of $1.50 per gallon and a discount rate of 12 percent for consumers. Finally, the NRC assumed that fuel economy would be 15 percent less than indicated by the Environmental Protection Agency's test results and that future safety and emissions standards would reduce gasoline savings by 3.5 percent.

3. These are adjusted ratings that reflect actual driving conditions.

4. See Environmental Protection Agency: "Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003," EPA420-R-03-006 (April 2003). In the report, EPA asserts that "based on accepted engineering relationships, ... had the new 2003 light vehicle fleet had the same average performance and same distribution of weight as in 1981, it could have achieved about 33 percent higher fuel economy."

5. See Congressional Budget Office, "Reducing Gasoline Consumption: Three Policy Options," (November 2002).

Box 2-1.

Continued

or consumers place a higher value on fuel economy at any price of gasoline. Because the technologies described in the NRC study do not lower the costs of improving fuel economy (they merely extend the scope of current fuel-saving technologies to offer further savings at greater costs)[6] and because CBO's analysis assumes that consumers' preferences remain the same and that gasoline prices are constant, increasing the CAFE standards or the gasoline tax in the simulation model imposes costs on producers and consumers of new vehicles (or of gasoline); that is, their welfare (producers' profits and the value consumers receive from their purchases of new vehicles or gasoline) falls.

The figure shows the effect of including in CBO's model a realistic assumption about the adoption of fuel-saving technologies. The dashed curve shows the results of the simulation model run with all of the new technologies available. Those results show an average voluntary (that is, "free") fuel economy increase of approximately 3.2 mpg for cars, which would bring the least fuel-efficient firm's fleet average up to 30.7 mpg. The corresponding "free" increase for the light truck CAFE standard is 3.7 mpg. Raising the standards by those amounts would raise the industry average fuel economy levels to 32 mpg for cars and 24.4 mpg for light trucks, meaning that CAFE standards would not be necessary unless even higher average fuel economy was desired.[7]

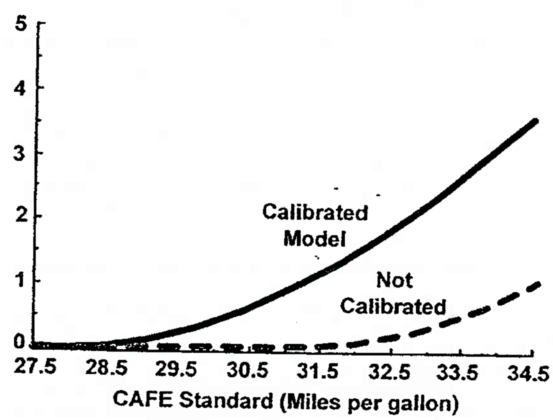
6. Personal communication with K.G. Duleep, who served on the National Research Council panel on CAFE, 2003.

7. The industry average fuel economy would be above the CAFE standard as long as some firms overcomplied (as Toyota and Honda currently do). In recent years, the annual industry averages have exceeded current CAFE standards by an average of about one mile per gallon for cars and a third of a mile per gallon for light trucks.

But CBO regards those unconstrained results as unrealistic. They do not account for automakers and their customers' demonstrated preferences over the past 15 years. They fail to acknowledge that the gains from cost-effective fuel-saving technologies have been offset by other design changes and have not translated into fuel savings. Therefore, CBO has calibrated its model to incorporate those facts; the model eliminates the technologies that provide those "free" increases in fuel economy. In the calibrated model, which is the source of the results presented in this report, any increase in CAFE standards would, by assumption, yield welfare losses for producers and consumers. As indicated by the solid curve in the figure, a car standard of 32 mpg in the calibrated model would result in losses to producers and consumers of nearly $2 billion per year; an increase in the light-truck standard would impose additional costs.

The Effects of Calibration in CBO's Model on the Welfare Loss from a Higher CAFE Standard for Cars

(Welfare loss in billions of dollars)



Source: Congressional Budget Office.

Note: As described in the text of this box, CBO calibrated its model to include what it believes is a realistic assumption about the adoption of fuel-saving technologies.

relaxed.[12] If CBO had made a similar assumption, its estimates of the costs of raising CAFE standards would have been greater than those presented in this study; however, CBO does not feel that sufficient data exist for estimating the extent to which the existing standards constrain producers' and consumers' choices.

The Discount Rate and Valuation of Future Fuel Cost Savings. The value that consumers place on reductions in gasoline consumption can also affect the costs of CAFE standards. Higher fuel economy translates directly into dollars saved at the gas pump. Consumers' valuation of fuel economy depends, however, on how much they expect to drive and on how heavily they discount future savings. Dollars saved in the future are worth less than dollars saved today because current savings can be invested to grow in value over time.

CBO discounts consumers' fuel savings at a rate of 12 percent per year. That rate, used in other recent studies of CAFE standards, including the NRC report, is slightly higher than the interest rate that consumers reported for used-car purchases in the most recent Consumer Expenditure Survey.[13] For further comparability with the NRC report, CBO assumes the same values for gasoline price ($1.50 per gallon); vehicle-miles driven (15,600 in the first year); and average years of operation (14).[14]

The particular discount rate that CBO assumes has less influence on predictions of costs than it would in the uncalibrated model. The lower the discount rate in the uncalibrated model, the more consumers would value improvements in fuel economy, and thus the more firms would use technologies to increase fuel economy. But because CBO's calibration method eliminates freely chosen technologies, a lower discount rate would also make it more costly for firms to achieve additional improvements. As explained above, CBO's decision to calibrate the model in that way was based on the observation that firms have used available technologies to increase power and weight rather than fuel economy.

Demand Elasticities. The costs that new CAFE standards would impose on producers and consumers would depend on how responsive consumers are to changes in vehicle prices. Consumers' CAFE costs are measured as reductions in the net value of their new-vehicle purchases, that is, the value that consumers attach to their vehicles over and above the price they pay for them. Welfare would fall after a price increase, not only for consumers that purchased a vehicle but also for those who would have bought a new vehicle except for the rise in price. Producers also bear CAFE costs in two ways: reduced profit margins on the cars that they sell and forgone profits from reduced sales.

The less that a price increase would affect consumers' purchasing decisions—that is, the more inelastic the demand for cars—the better able producers would be to pass along the costs of complying with CAFE standards, in the form of higher vehicle prices. If demand is relatively inelastic, consumers would bear most of the economic costs of higher CAFE standards.

12. See Andrew N. Kleit, *Impacts of Long-Range Increases in the Corporate Average Fuel Economy Standards*, AEI-Brookings Joint Center for Regulatory Studies, Working Paper 02-10 (October 2002). Kleit estimates that in the absence of CAFE standards, the average fuel economy ratings of General Motors, Ford, and DaimlerChrysler would be 1.05, 1.42, and 0.55 mpg lower, respectively, for their cars and 0.59, 0.5, and 0.4 mpg lower for their light trucks. He estimates the cost of the existing standard at $1,652 per mpg per vehicle, meaning, for example, that the existing CAFE standard for cars costs General Motors $1,734 per car, or (1.05)*($1,652). Further, he finds that the cost of a 3 mpg increase in the CAFE standards would be 33 percent higher if the existing CAFE standards are binding.

CBO's analysis assumes that current standards are just short of binding, so there would be an economic cost to any increase in the standards, but a small increase would come at a small cost. (Note that consumption-reducing policies that impose no costs on producers and consumers also do not save any gasoline.)

13. Consumers can be expected to discount the value of future fuel savings at a rate at least as high as their cost of borrowing funds. At a 12 percent discount rate, consumers would be unwilling to spend an extra dollar on fuel economy improvements that would lower their fuel costs by, say, 10 cents per year because the cost savings would be less than the annual interest on that dollar.

14. The NRC assumes that the vehicle-miles driven decline at a rate of 4.5 percent annually. In CBO's analysis, the decline is slightly more gradual, corresponding better to the National Household Travel Survey's vehicle usage data, available at http://nhts.ornl.gov/2001/index.shtml.

In this study, CBO uses estimated demand elasticities that originate from a consumer survey developed by General Motors.[15] From industry-level elasticities and estimates of manufacturers' markups of wholesale prices over cost, CBO developed firm-level elasticities that preserved what the survey data implied about the overall market elasticity and the elasticities indicating consumers' propensity to switch vehicle types in response to price changes. The firm-level elasticities further describe consumers' propensity to respond to changes in vehicle prices by switching firms and reflect firms' ability to maintain prices above their marginal costs.[16]

Analyzing the Gasoline Tax

In contrast to the market for automobiles, the gasoline market features substantially undifferentiated products. Retail firms distinguish themselves primarily by mixing proprietary additives with essentially identical gasoline. Each firm's products come in several grades (octane ratings) that may vary in price by 5 to 10 percent, though consumers' choices are governed largely by the fuel requirements of their particular vehicles.

In a market with undifferentiated products, producers have little flexibility in setting retail prices. CBO's analysis therefore does not need to account for strategic pricing by firms and can gauge the effects of a gasoline tax directly from the aggregate supply and demand for gasoline, that is, from the respective price elasticities.

The more inelastic the demand for gasoline—that is, the more that consumers sustain the quantities they purchase when the price rises—the bigger a tax increase would have to be to achieve a given reduction in gasoline consumption, and the greater the associated welfare losses to gasoline producers and consumers.[17] Similarly, the more inelastic the supply—that is, the smaller the increase in the quantities supplied by producers when the market price goes up—the smaller the share of the gasoline tax consumers would pay. Because producers would be absorbing more of the cost in that case, the tax increase would be less effective at reducing consumption.[18]

CBO assumes that the price elasticity of the gasoline supply is 2. That is, a 1 percent increase in the price that producers receive for gasoline would lead to a 2 percent increase in the quantity produced. That value comes from comparing the effects of changes in gasoline prices on the quantities supplied, according to the Energy Information Administration's 2010 forecast.[19]

15. See Kleit, *Impacts of Long-Range Increases in the Corporate Average Fuel Economy Standards*.

16. *Edmunds.com* reports manufacturers' invoice prices to dealers and the manufacturers' suggested retail prices—the difference between which CBO takes as the dealer markup. On the basis of research by Pinelopi Goldberg, CBO assumes that manufacturers' markups are twice as large as dealers'. See Pinelopi K. Goldberg, "Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry," *Econometrica*, vol. 63, no. 4 (July 1995), pp. 891-951. That assumption yields estimates of firms' manufacturing costs and suggests the elasticities indicating consumers' propensity to switch firms. CBO assumes that firms' costs rise with the number of vehicles they produce. Thus, a change in a vehicle's price affects unit costs because it affects the quantity sold.

17. For taxes, welfare losses comprise forgone profits for producers and, for consumers, lost surplus due to a reduction in the amount of gasoline sold. That lost surplus reflects the difference between the price that consumers would have been willing to pay for the gallon that they purchased and the price that they actually paid. Note that for the gasoline actually sold, the higher prices paid by consumers due to a tax, and the lower prices received by producers, are not counted in the measure of welfare loss. The difference between the price paid and the price received, that is, the tax, constitutes a transfer to the public sector and is not considered a cost to the economy. Thus, producers' and consumers' welfare losses under a tax arise solely from decreased sales.

18. According to the Energy Information Administration's projections and CBO's analysis, the cost of producing gasoline would rise somewhat as the quantities supplied increased.

19. See Energy Information Administration, *Annual Energy Outlook*, (January 2003), Appendix B, Tables B11 and B12, available at www.eia.doe.gov/oiaf/archive/ae003/pdf/appb.pdf. CBO found little published information on the supply elasticity of gasoline. Some analyses of gasoline taxes assume a perfectly elastic supply curve—with the costs of supplying gasoline independent of the quantities supplied. If CBO had made a similar assumption, then the gasoline tax would appear to be less costly.

In the short run, consumers respond to a change in the price of gasoline primarily by adjusting their driving behavior. A tax increase would achieve its full effect only in the long run, as consumers replaced their vehicles and fully adapted to the gasoline tax. Specifically, after an increase in the tax, consumers would value fuel economy more, and the average fuel economy of new vehicles could rise.

Those two effects divide the price elasticity of demand into distinct components. One indicates the percentage change in vehicle-miles traveled due to a 1 percent increase in the price of gasoline. The other component indicates the percentage change in the average fuel economy of the vehicle fleet from a 1 percent increase in the price of gasoline. The overall gasoline price elasticity of demand is the sum of those two effects.[20] In the short run, the elasticity of vehicle-miles traveled predominates. In the long run, the elasticity of fuel economy plays a larger role as more consumers purchase new vehicles.

Increasing the price of gasoline in the model—while holding CAFE standards at their baseline levels—causes consumers to seek better fuel economy and permits a direct calculation of the fuel economy elasticity implicit in the analysis. That elasticity depends on technology costs, the value of fuel savings, the propensity of consumers to change their choice of new vehicle in response to a change in vehicle prices, and other factors relevant to the analysis.

By that method, CBO estimates a fuel economy elasticity of about +0.22, meaning that a 10 percent increase in the price of gasoline would eventually result in improvements in fuel economy that would reduce gasoline consumption by 2.2 percent. On the basis of available data, CBO assumes an elasticity of vehicle-miles traveled of –0.2.[21] Thus, the elasticity value that emerges from CBO's simulation model is –0.39, meaning that a 10 percent increase in the price of gasoline would reduce the quantities sold by 3.9 percent. That estimate allows CBO to compare the effects of a gasoline tax increase and of more stringent CAFE standards on the basis of a consistent set of assumptions. The value is in line with more recent estimates of long-run elasticities, which tend toward the low end of the range between –0.3 and –0.9 in the empirical literature.[22] The estimates vary in part because they are sensitive to the type of econometric model used and to the time period covered.

Limitations

CBO's analysis examines the effects of higher corporate fuel economy standards in a market that is based on actual, current conditions. If new types of vehicles are introduced or if consumers' tastes change significantly, the costs of new standards or of a higher tax could be higher or lower than CBO predicts.

---

20. The overall price elasticity of gasoline consumption can be written as $\beta_Q = \beta_{VMT}(1-\beta_{FE}) - \beta_{FE}$, where the β_x are price elasticities, Q is demand for gasoline, FE is fuel economy, and VMT is vehicle-miles traveled. Thus, the total decrease in gasoline consumption from a permanent increase in the gasoline tax is due to driving less (β_{VMT}, a direct result of the price increase) and buying more-fuel-efficient vehicles ($-\beta_{FE}$, where the minus sign indicates that fuel economy and consumption move in opposite directions), with an adjustment ($-\beta_{VMT}\beta_{FE}$) for the increase in driving due to improved gas mileage and thus lower vehicle operating costs. That (small) adjustment is referred to as the take-back, or rebound, effect.

21. On the basis of a review of the literature, David Greene concluded that the elasticity for vehicle miles traveled in the long run is about -0.2. See David Greene, "Why CAFE Worked," Oak Ridge National Laboratory (November 6, 1997), p. 12.

22. The range of –0.3 to –0.9 comes from a 1991 survey of 97 estimates of gasoline price elasticity. See Carol Dahl and Thomas Sterner, "Analyzing Gasoline Demand Elasticities: A Survey," *Energy Economics* (July 1991). More recently, the Department of Energy, on the basis of a review of newer studies, suggested an estimate of long-run elasticity of –0.38. See Department of Energy, Office of Policy and International Affairs, *Policies and Measures for Reducing Energy-Related Greenhouse Gas Emissions: Lessons From Recent Literature*, DOE/PO-0047 (July 1996).

For instance, while recent history suggests that producers have not found it profitable to raise average fuel economy, their conclusion could change if higher gasoline prices caused consumers to place a greater value on fuel savings.[23] A shift in preferences toward smaller vehicles could reduce the costs of complying with CAFE standards below the estimates offered in this study. Or to similar effect, manufacturers could introduce vehicle types not included in CBO's analysis (such as smaller, higher-mileage SUVs that handled more like cars). The assumption that increases in CAFE standards would impose costs on consumers and producers—which is consistent with consumers' preferences and producers' decisions over the past 15 years—is a key determinant of CBO's cost estimates.

CBO's analysis is limited to technologies that would improve the fuel economy of gasoline-powered vehicles. It thus excludes vehicles powered by alternative means, such as fuel cells and gas/electric hybrid engines. Such vehicles as yet constitute an insignificant portion of the market. To the extent that their rate of adoption grows and that firms do not offset the resulting fuel economy gains by boosting the performance of their vehicles, the costs of complying with CAFE standards would shrink.

Furthermore, the analysis considers only compliance strategies that do not involve reductions in vehicle weight or performance (such as acceleration). CBO's predictions of costs pertain to a vehicle fleet resembling that actually existing today. Should consumers become willing to sacrifice some weight or performance in their vehicles in exchange for higher fuel economy, compliance costs as measured in this analysis would be reduced, but the true costs would also include the value of the surrendered attributes. Given consumers' current tastes, however, modeling the effects of CAFE standards holding fixed those vehicle attributes other than fuel economy is not a major limitation.

In addition, this analysis does not account for the effects of existing CAFE standards. To the extent that existing standards currently constrain production decisions and the choices that consumers face, the costs of increases would be higher than CBO estimates. In that case, the existing standards would already be requiring producers to sell more-fuel-efficient vehicles than consumers want: therefore, small increases in the standards would add to that existing distortion, creating larger losses for producers and consumers than if there were no existing constraints.

Accounting for the existing tax on gasoline would also raise the predicted costs that a tax increase would impose on producers and consumers of gasoline. The existing tax does not impose a net cost on society, however, if it is justified by the extent to which it discourages driving (thus lowering the social costs of driving, such as traffic congestion) and gasoline consumption. Some research indicates that the social benefits created by taxing gasoline may justify a tax rate significantly higher than the existing rate.[24]

Assumptions about the price elasticity of vehicle-miles traveled affect CBO's prediction of the relative costs of an increase in the gasoline tax and an increase in CAFE standards. If a lower elasticity value were assumed for vehicle-miles traveled, the implied gasoline price elasticity would also be lower, and a tax would appear to be less effective at reducing gasoline consumption. In contrast, CAFE standards would appear to be relatively more efficient because raising the standards—and reducing vehicles' operating costs—would have a smaller (though still positive) predicted effect on the amount people drive, thus enhancing the standards' ability to reduce gasoline consumption.

23. CBO assumed a constant real price of gasoline when calculating the value that consumers would attach to improvements in fuel economy. The real price of gasoline spiked in the early 1980s but it hovered between $1.20 and $1.35 (measured in 1996 dollars) in 11 of the 15 years from 1986 to 2000.

24. See Ian W.H. Parry and Kenneth A. Small, "Does Britain or the United States Have the Right Gasoline Tax?" Discussion Paper, Resources for the Future (Washington D.C.: Resources for the Future, 2001).

CHAPTER

3

Results

The biggest firms in the U.S. passenger vehicle market currently achieve average fuel economy ratings about equal to the existing corporate average fuel economy standards for cars and light trucks. Consequently, increasing the standards would force those firms—or, if the increases were large enough, all firms—to raise the average fuel economy of the vehicles they sell, imposing costs on both producers (in the form of reduced profits) and consumers (in the form of higher vehicle prices, net of the value of gasoline savings).

If firms were permitted to trade fuel economy credits, it would lower the incremental cost of reducing gasoline consumption by transferring the adoption of fuel-saving technologies from firms with higher costs of improving fuel efficiency (that is, firms with lower fuel economy ratings) to firms with lower costs. Given the choice of improving average fuel economy or buying credits, firms would pursue the means of complying that was least expensive for them. As a result, every firm would end up with the same marginal cost per gallon saved.

An increase in the gasoline tax would be an even less costly way to reduce gasoline consumption. In fact, a tax increase would have a significant advantage over more stringent CAFE standards in the initial years because, while consumers would only gradually buy new, more-fuel-efficient vehicles, they would reduce their driving immediately in response to the tax. That change would not only reduce gasoline consumption, but it would also lower other social costs of driving, such as traffic congestion and the frequency of accidents. In contrast, higher CAFE standards would tend to encourage driving (by lowering the per-mile cost) and would thus increase those social costs.

Measurement Concepts

The costs that higher CAFE standards would impose on consumers have two components: higher prices paid by purchasers of new vehicles and a loss in the well-being of consumers who would be discouraged from buying a new vehicle because of the higher prices. In measuring the vehicle price increases that would result from mandated improvements in fuel economy, the Congressional Budget Office subtracts the value of the gasoline savings that purchasers would derive over the lifetime of their vehicles, reflecting the assumption that consumers take fuel savings into account in their decisions about purchasing new vehicles.

A tax increase would, similarly, raise gasoline prices and reduce the quantity sold, which would also reduce the welfare of gasoline consumers. They would adjust to a higher tax by driving less as well as by potentially choosing more-fuel-efficient vehicles.

CBO measures producers' lost welfare as the reduction in their net revenues, or profits. With an increase in CAFE standards, average vehicle production costs would rise more than prices would as firms added fuel-saving technologies. Thus, firms' vehicle profit margins would decline, as would total vehicle sales. In the case of a gasoline tax increase, while the retail price of gasoline would rise, the price received by gasoline producers and suppliers would fall—with the tax increase making up the difference.[1]

1. Aggregate welfare losses may not be the sole criterion for favoring one policy over another. Other considerations could include fairness (a policy's effect on different income, demographic, and/or geographic groups) and certainty (the likelihood that a given policy would achieve its target). See Congressional Budget Office, *"Reducing Gasoline Consumption: Three Policy Options."*

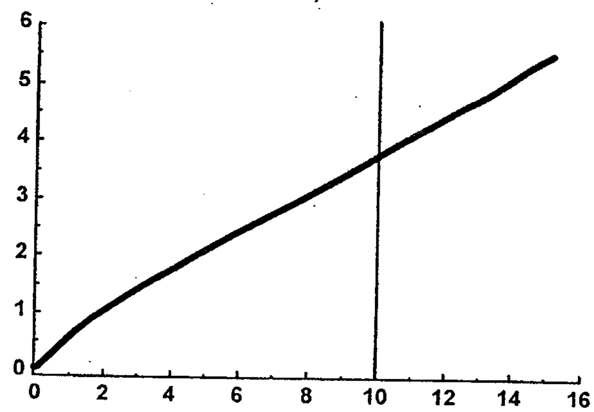
The Relationship Between Increases in CAFE Standards and Reductions in Gasoline Consumption

CBO considered various ways that CAFE standards could be raised or restructured. With separate standards for cars and for light trucks, the standards could be raised in equal or unequal increments, in either nominal or percentage terms, of miles per gallon or of gallons per mile (gpm). Here CBO analyzes the effects of raising both standards in equal-mpg increments and of introducing fuel economy credit trading.

Because of the difference in the average fuel economy for cars and light trucks, an equal-mpg increase in the CAFE standards for both would reduce the average rate of fuel consumption (measured in gallons per mile) more for light trucks than for cars. For example, raising both standards by 3.8 mpg (to 31.3 mpg for cars and 24.5 mpg for light trucks) would lower the average rate of gasoline consumption for light trucks by 15 percent, from (1/20.7) gpm to (1/24.5) gpm, while the rate for cars would fall by 12 percent. Because not all firms would have to improve their average fuel economy by this much to comply with the new standards and because the higher fuel economy would encourage additional driving, the overall reduction in gasoline consumption would be 10 percent (*see Figure 3-1*). Small increases in the standards would not require any actions by manufacturers with CAFE ratings above the current standards (thus explaining the initial, steeper portion of the curve).

Figure 3-1.

Gasoline Savings from Raising CAFE Standards by an Equal Number of Miles per Gallon for Both Cars and Light Trucks



Source: Congressional Budget Office.

Total Long-Run Costs

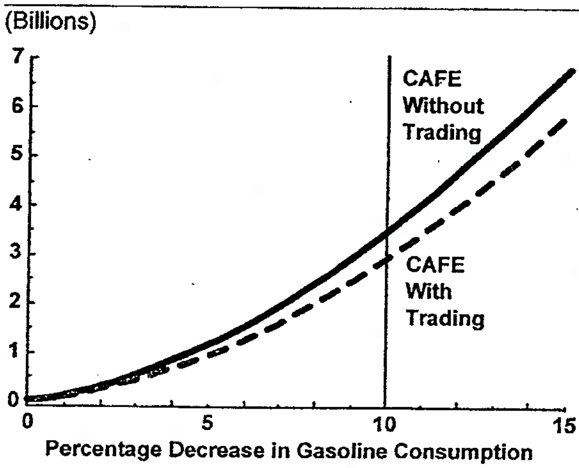
CBO measures the total annual private welfare losses (ignoring benefits) of an increase in CAFE standards in the long run—that is, once all of the existing vehicles are retired (or after 14 years, by CBO's assumption). CBO considers any increase in CAFE standards to be binding, meaning that some firms in CBO's simulation model are currently just compliant and that any increase in the standards would therefore force them to raise the average fuel economy of their new-vehicle fleet. Consequently, higher standards would necessarily reduce the welfare of producers and consumers of new vehicles.

The total costs associated with setting car and truck standards so as to reduce gasoline consumption by the benchmark target of 10 percent would reduce producers' and consumers' welfare by about $3.6 billion per year (*see Figure 3-2 on page 17 and Table 3-1 on page 18*). If firms were allowed to trade fuel economy credits in order to comply, the costs of achieving the benchmark target would fall to about $3.0 billion per year, representing a savings of 16 percent.[2] Greater reductions in gasoline consumption would result in increasingly higher costs.

2. All results in this report, including the costs described here, are annual and are for vehicles produced in a single model year. For this analysis, CBO assumes that the new CAFE standards would allow sufficient lead time for firms to redesign their products as necessary, in particular so that the relevant fuel economy technologies would be available.

Figure 3-2.

Costs of Reducing Gasoline Consumption Through More Stringent CAFE Standards, With and Without Credit Trading



Source: Congressional Budget Office.

As with CAFE standards themselves, a credit-trading program could be structured in various ways. The most important consideration is whether to give credits to firms whose baseline fuel economy would already be above the new standards or to award credits only for further improvements. Rewarding preexisting overcompliance would allow firms to sell some credits based on fuel economy gains made before the standards were raised, so as the CAFE standards were raised, gasoline consumption would not actually drop until those credits were used up. Awarding credits only for improvements made after the standards were raised, though, would effectively penalize firms for voluntarily overcomplying with the existing standards. For that reason, CBO's results are based on awarding credits for preexisting overcompliance.

The costs of achieving a given reduction in gasoline consumption via a tax increase depend on the price elasticities of the demand for and supply of gasoline. The lower the price elasticity of demand is, the less responsive consumers are to price changes, and thus the greater the tax increase (and associated welfare cost) that would be necessary to save a given amount of gasoline. The higher the supply elasticity is, the greater the share of a gasoline tax that would be borne by consumers and thus the more effective the tax and the lower its cost. CBO's assumptions about the demand and supply elasticities in the gasoline market imply that consumers' share of a tax would be about 85 percent. If the supply was perfectly elastic, consumers' share of the tax would be 100 percent. In that case, producers' costs would be unaltered by the change in demand due to the tax—and the full amount of the tax would be passed on to consumers in the form of higher prices.

The long-run annual costs of a gasoline tax increase designed to achieve the benchmark reduction in consumption would be $2.9 billion under CBO's assumptions about the demand and supply elasticities for gasoline (*see Table 3-1 on page 18*). That figure would fall to $2.5 billion if the gasoline supply is perfectly elastic. Importantly, although the long-run annual costs of the tax would be only slightly less than those of higher CAFE standards with credit trading, the tax would have a significant advantage over CAFE standards in the initial years of the policies, before the stock of existing vehicles was replaced (see the upcoming discussion in the section "Cost Savings and Gasoline Savings in the First 14 Years"on page 20).

CBO's analysis considers only the direct effects that increases in CAFE standards or a gasoline tax would have on the vehicle and gasoline markets. Including effects on other markets—such as capital and labor markets—could significantly increase the total welfare losses of each of the policies analyzed (*see Box 3-1 on page 19*).

Consumers' and Producers' Shares of the Total Long-Run Costs

By CBO's estimates, consumers would bear the majority of the costs of higher CAFE standards and, relative to automakers, would share in few of the gains from credit trading. For example, meeting the benchmark target with CAFE standards would impose costs on vehicle producers of about $1.2 billion without trading and about $0.8 billion with trading, or roughly 1.4 percent and 1 percent, respectively, of their total annual net revenues (*see Table 3-1*). But costs to consumers would be roughly $2.4 billion and $2.2 billion, respectively.

Table 3-1.

Total Long-Run Annual Costs to Achieve a 10 Percent Reduction in Gasoline Consumption Under Alternative Policies

(Billions of dollars)

	CAFE Standards		
	Without Trading	With Trading	Gasoline Tax
Policy Modeled	31.3 mpg for cars 24.5 mpg for light trucks		46-cent-per-gallon increase
Total Welfare Costs[a]	3.6	3.0	2.9
Producers' costs	1.2	0.8	0.5
Consumers' costs	2.4	2.2	2.4

Source: Congressional Budget Office.

Note: CAFE = corporate average fuel economy; mpg = miles per gallon.

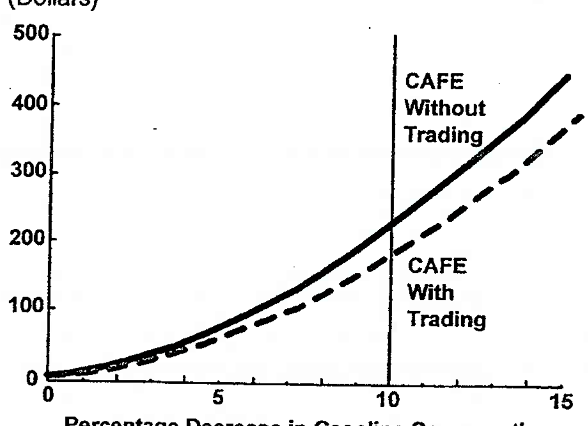
a. For producers, costs are measured as reductions in total profits, while for consumers, they are measured as reductions in the amount that consumers value their new vehicles over and above the purchase price.

The ratios of consumers' costs to producers' costs—about 2 to 1 without trading and nearly 3 to 1 with trading—depend on the demand for and the supply of new passenger vehicles and on the degree of product differentiation among them. The latter helps producers set prices above marginal costs without losing many sales. On the basis of the empirical evidence described previously, CBO assumes that consumer demand for new passenger vehicles is somewhat elastic at about −1.4 (so a 10 percent price increase for all vehicles would reduce unit sales by 14 percent) and that producers have some market power, allowing them to maintain profit margins that, in CBO's simulation model, range from about 17 percent for compact cars to 26 percent for large SUVs.

Figure 3-3.

Costs per Vehicle of More Stringent CAFE Standards, With and Without Credit Trading

(Dollars)



Source: Congressional Budget Office.

On a per-vehicle basis, the simulation model predicts that the average total welfare loss associated with using CAFE standards to reduce gasoline consumption by 10 percent would be about $228, of which roughly $153 would come from consumers. Under the credit-trading system, the average per-vehicle cost is predicted to be $184, with consumers bearing $142 of that amount (*see Figure 3-3*). Producers' costs for that level of gasoline savings would be about $75 per vehicle, or about $42 with credit trading. As mentioned, those costs reflect higher vehicle prices (net of the value of the discounted gasoline savings), lower vehicle sales, and reduced profit margins. Consumers' costs are averages of the lost welfare for consumers who purchase new vehicles under the higher CAFE standards and for those who would have purchased but for the higher new-vehicle prices; the size of the latter group is a small fraction of that of the former.

Box 3-1.

Effects on Markets Not Included in This Analysis

One limitation of the Congressional Budget Office's (CBO's) study is that it measures the costs that increases in the corporate average fuel economy (CAFE) standards or gasoline taxes would impose on producers and consumers of vehicles and gasoline but does not measure costs in other affected markets. Accounting for effects on, for instance, the labor and capital markets would require using a "general-equilibrium" approach—modeling the entire economy, not just the markets directly affected. Including the effects on other markets could substantially increase estimates of the costs of both policies. However, CBO does not believe that including those effects would alter the basic conclusion that an increase in the tax on gasoline would be a more cost-effective way to reduce gasoline consumption than an increase in CAFE standards would, because it would not change the fact that a gasoline tax would achieve much greater reductions in gasoline consumption—at a much lower cost—in the initial years of the policy. Furthermore, a higher gasoline tax would generate revenues that policymakers could use to offset inefficiencies in other markets, but higher CAFE standards would not offer that possibility.

Many analysts have concluded that pollution-reducing policies could generate significant welfare losses in labor and capital markets by exacerbating the discouraging effect that existing taxes on labor and capital have on economic activity.[1] By raising the prices of new passenger vehicles and of gasoline, an increase in CAFE standards or in the gasoline tax would lower the real (inflation-adjusted) returns to labor and capital. Those effects, in turn, would reduce the incentive of households to work and to save and invest. While the change in the amount of labor or capital supplied as a result of the gasoline-saving policies would be small, the welfare loss could be large because capital and labor markets are already heavily taxed.[2] Small changes in the supply of factors in heavily taxed markets can create relatively large welfare costs—a result referred to as the tax interaction effect.

Increases in the CAFE standards or in the gasoline tax could generate a tax interaction effect. The policies would differ, however, in other ways that they affected the economy. An increase in the CAFE standards would decrease revenue (by reducing gasoline sales and hence the amount of taxes collected at the current rate), while an increase in the gasoline tax would raise additional revenues (outweighing the loss in revenue associated with declining gasoline sales). If they chose to, policymakers could use the additional revenues generated by an increase in the gasoline tax to decrease taxes on labor and/or capital, thereby offsetting some of the tax interaction effect. In contrast, maintaining the level of revenue following an increase in CAFE standards would necessitate increasing taxes.

1. For a survey of the literature, see A. Lans Bovenberg and Lawrence H. Goulder, "Environmental Taxation and Regulation," in Alan Auerbach and Martin Feldstein, eds., *Handbook of Public Economics*, 3rd ed. (Amsterdam: Elsevier, 2002).

2. Researchers have proposed a formula that can determine the increase in the total welfare cost that commodity taxes, such as a gasoline tax, would have if effects on the labor market were considered. See Lawrence H. Goulder and Roberton C. Williams III, "The Substantial Bias from Ignoring General Equilibrium Effects in Estimating Excess Burden, and a Practical Solution," *Journal of Political Economy*, vol. 111, no. 4 (August 2003), pp. 898-927. On that basis, the total welfare cost of a 46-cent increase in the gasoline tax could be more than twice as high as CBO estimates. Unfortunately, no such formula is available for environmental standards, such as CAFE standards, so CBO compares the two policies on a partial-equilibrium basis.

Total Long-Run Costs for Firms Buying Credits and Firms Selling Them

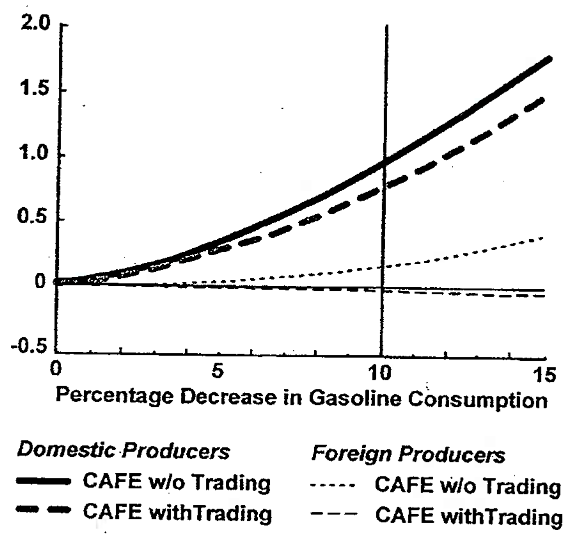
Although most automakers are now multinational entities, the distinction between "domestic" and "foreign" reflects the firms' corporate histories and is useful here in identifying the buyers and sellers of credits. Most of the demand for credits would come from domestic firms, and virtually all of the supply would come from foreign firms.

Both domestic and foreign firms would benefit from trading, according to CBO's analysis. Domestic firms would have reduced welfare losses because buying credits would lower their costs of complying. Foreign firms could be better off than they would have been in the absence of an increase in CAFE standards because, in the aggregate, the extra revenue that they would get from selling the credits they earned by going beyond the new standards could more than cover their costs of doing so (*see Figure 3-4*).[3] The disparity between domestic firms' and foreign firms' total costs partly reflects differences in compliance costs per vehicle but occurs primarily because domestic firms sell more vehicles in the United States than foreign firms do.

Figure 3-4.

Domestic and Foreign Producers' Costs for More Stringent CAFE Standards, With and Without Credit Trading

(Billions of dollars)



Source: Congressional Budget Office.

Cost Savings and Gasoline Savings in the First 14 Years

Depending on consumers' responses to an increase in the price of gasoline, the annual long-run costs of reducing gasoline consumption via higher CAFE standards as opposed to an increase in the gasoline tax may not differ very dramatically. Because both policies would promote fuel economy in new vehicles, they would not reach their full effectiveness until all existing vehicles were replaced with newer ones manufactured after the policies were enacted.

However, until the long run has been reached, that is, until the 14 years constituting the average life of a vehicle have passed, a gasoline tax would save much more gasoline, at a much lower cost, than would an equivalent increase in CAFE standards. Both policies would gradually increase average vehicle fuel economy, as older vehicles were retired. But that changeover would account for only about half of the total effect of a gasoline tax. The other half of the effect would occur immediately, as consumers responded to higher retail gasoline prices by driving less. Because all vehicles, not just new ones, would be driven less, a tax would be initially much more effective than an equivalent increase in CAFE standards. In fact, over the initial 14 years, a tax designed to reduce gasoline consumption by 10 percent would save an additional 27 billion gallons of gasoline, or 42 percent more, and would cost nearly 30 percent less (*see Figure 3-5*).[4] The costs of the CAFE standards would be the same in all 14 years. The costs of the gasoline tax would increase annually, as improvements in fuel efficiency further reduced gasoline consumption, until the steady state was reached.

3. CBO's predicted division of gains from trading between buyers and sellers of fuel economy credits assumes that the credit market would be perfectly competitive, implying a single market-clearing price equal to the cost of supplying the "last" (and most expensive) credit. But with relatively few agents, as in the automobile market, sellers could realize greater gains at the expense of buyers, or vice versa. However, because both parties would have an incentive to continue trading until all possible gains were realized, the number of credits traded and the gains available from trading need not depend on whether the trading market is competitive.

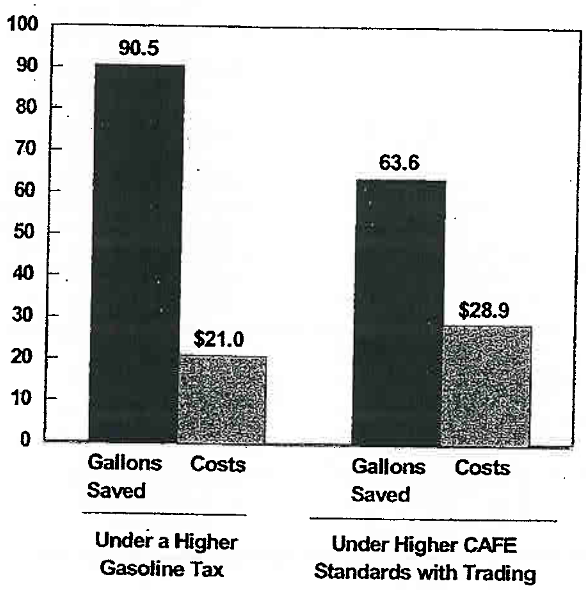
4. The costs and savings have been discounted to present-value terms at an annual rate of 6.2 percent, reflecting the relative price volatility of petroleum.

The advantage of a tax stems from its greater scope for reducing gasoline consumption: only the tax would encourage behaviors such as carpooling, relying on public transportation, or combining trips. By contrast, higher CAFE standards could encourage driving by lowering the operating costs of new vehicles, thus offsetting some of the potential gasoline savings from raising the standards. Under CBO's assumptions, in its first year the tax would save about seven times as much gasoline as the equivalent CAFE standards would. That advantage would decline in each subsequent year, and in the long run, that is, after 14 years, both policies would, by design, save the same amount of gasoline per year.

Figure 3-5.

The Effects of CAFE Standards with Trading Versus a Gasoline Tax Over the First 14 Years

(Billions)



Source: Congressional Budget Office.

Notes: CAFE = corporate average fuel economy.

The figure depicts effects over the first 14 years (after which all current vehicles are assumed to be retired) from policy changes that would bring about a 10 percent reduction in gasoline consumption.

The Long-Run Effects of Increasing CAFE Standards on the Passenger Vehicle Market

The size of the passenger vehicle market could shrink by several percent if CAFE standards were raised significantly (*see Figure 3-6*). On a percentage basis, unit sales of light trucks would ultimately decline about twice as much as would those of cars, primarily reflecting the particular CAFE policies that CBO modeled—that is, car and light-truck standards raised in equal-mpg increments but from different starting points. As noted earlier, because the current standard for light trucks is lower than that for cars, a given mpg increase would require a greater percentage reduction in gasoline consumption by trucks than it would by cars.

Moderate increases in CAFE standards would not have a very large effect. The benchmark increase of 3.8 mpg in the standards would result in a predicted decline of only 1.3 percent in unit sales of light trucks and a 0.2 percent decline in car unit sales (as indicated in Figure 3-6). Those declines result from an increase of approximately 0.5 percent in average vehicle prices, after accounting for the value of the resulting gasoline savings.

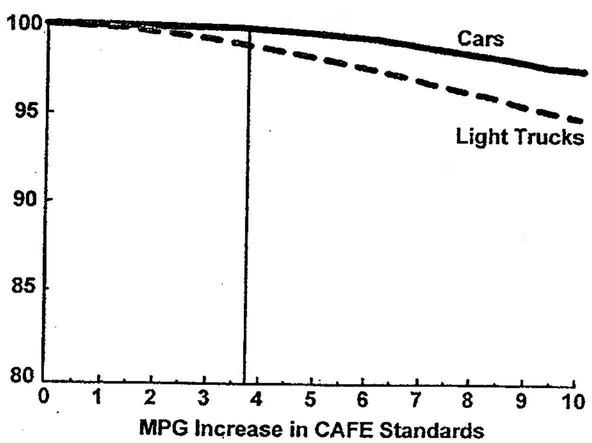
According to CBO's simulation model, the price increases of fuel-efficient cars and light trucks would tend to be less than the costs of the fuel-efficiency technologies installed by the manufacturers. Buyers of those vehicles could enjoy benefits (in terms of better mileage) worth well in excess of the increase in purchase price, while price increases for low-mpg vehicles could exceed the added cost of the new technologies. The difference could occur because higher CAFE standards would give firms an incentive to draw consumers toward more-fuel-efficient vehicles. In effect, buyers of vehicles with poor fuel economy would be subsidizing buyers of fuel-efficient vehicles.

Not all of the decline in the unit sales of cars and light trucks would be permanent. Some of the depicted decline represents delayed purchases: faced with higher vehicle prices, some consumers would simply drive their current vehicles an extra year or two before replacing them. The simulation model captures both delayed and permanently lost sales, and it is not possible to say how much of the decline is due to which effect. It is likely, though, that

Figure 3-6.

The Effect of More Stringent CAFE Standards on Sales of Cars and Light Trucks

(Percent)



Source: Congressional Budget Office.

because some of the "lost" sales are merely delayed, the true long-run effects of higher CAFE standards on unit sales would be slightly lower than predicted by CBO's model.

Could Increases in CAFE Standards or the Gasoline Tax Improve Social Welfare?

Because raising CAFE standards would impose costs on both producers and consumers, an important question is whether those costs would be outweighed by the benefits that they would bring about.

In the absence of existing policies to discourage the use of gasoline (and other complications described below), the optimal increase in CAFE standards could be determined by balancing the costs of tightening the standards against the resulting benefits stemming from the reduction in gasoline consumption. The fact that existing policies—such as federal, state, and local taxes on gasoline—already discourage gasoline consumption complicates the picture.

If the existing per-gallon tax was equal to the existing external costs associated with consuming a gallon of gasoline (or, alternatively, the social benefits associated with reducing consumption by one gallon), then there would be no need to increase the CAFE standards. The tax on gasoline would give buyers just the right incentive to change their behavior to reflect the costs that consuming gasoline imposes on society.

If the tax on a gallon of gasoline was less than the external costs associated with consuming that gallon, then higher CAFE standards could potentially benefit society. In that case, one would need to weigh the additional benefit associated with reducing gasoline consumption—a benefit equal to the external costs less the existing tax—against the costs that the higher standards would impose on producers and consumers of vehicles (costs that are quantified by CBO's model).

Finally, if the existing tax on gasoline was greater than the external costs associated with consuming gasoline, then increasing CAFE standards could make society worse off. Higher CAFE standards would force further reductions in gasoline consumption, even though the existing tax was already causing consumers to reduce their consumption by a greater amount than was justified by the external costs that the consumption imposed on society.[5] In that case, the social "benefit" associated with saving one more gallon of gasoline through higher CAFE standards would be negative.

Two key questions, therefore, are, What is the existing tax on gasoline, and, What are the costs that consuming a gallon of gasoline imposes on society? The first question is easy to answer. The average federal, state, and local tax paid on a gallon of gasoline is 41 cents. The second question, however, is very difficult to answer.

In its recent report, the National Research Council suggested that there are two primary external costs associated with gasoline consumption that could be addressed by increasing the CAFE standards. First, gasoline combustion releases carbon into the atmosphere, and those emissions are thought to lead to a gradual warming of the Earth.

5. Having a gasoline tax that was greater than the external costs associated with consuming a gallon of gasoline could be justified on other grounds. It could be an efficient means of raising revenues, or it could reflect external costs associated with driving—such as traffic congestion or an increased risk of accidents—that would be diminished by a higher gasoline tax but not by higher CAFE standards.

Second, gasoline consumption adds to the United States' dependency on oil and, therefore, increases the country's vulnerability to disruptions in the world supply of oil.

While acknowledging uncertainty, the NRC tentatively suggested an estimate of 12 cents to reflect the cost of carbon emissions resulting from a one gallon decrease in gasoline consumption (which corresponds to a cost of $50 per metric ton of carbon). Further, it suggested an energy-security cost associated with consuming one gallon of gasoline of 12 cents (which corresponds to a cost of $5 per barrel of oil). Finally, the NRC estimated a cost of 2 cents per gallon due to emissions of air pollutants associated with the production and distribution of gasoline, resulting in total external costs of 26 cents per gallon.[6]

If the NRC's estimate of 26 cents for the external costs of consuming a gallon of gasoline is correct, then the existing tax on gasoline of 41 cents already provides buyers of new vehicles with an incentive to pursue fuel economy up to a cost that exceeds by 15 cents the benefits associated with reducing gasoline consumption.[7] In that case, higher CAFE standards would impose unwarranted costs on automakers and new-vehicle buyers—and thereby would reduce social welfare.[8]

Estimating the external costs associated with consuming gasoline is beyond the scope of this study, and CBO does not endorse the NRC's estimate. However, given the existing gasoline tax of 41 cents per gallon, higher CAFE standards would have the potential to improve social welfare only if the external costs associated with consuming gasoline exceeded 41 cents per gallon—a figure significantly higher than the external costs suggested by the NRC.

Higher CAFE standards could further reduce social welfare by worsening traffic congestion and increasing the number of traffic accidents.[9] That undesirable effect could occur because higher CAFE standards would lower the per-mile cost of driving, providing owners of new vehicles with an incentive to drive more. While the increase in driving associated with higher CAFE standards might be relatively small, some studies suggest that the resulting costs of the increased congestion and traffic accidents may nevertheless be large.[10]

A complete determination of the potential for higher CAFE standards to improve social welfare requires accounting for both the effect of the existing gasoline tax as well as the CAFE-induced increase in driving-related costs. Increased CAFE standards have the potential to improve social welfare only if the reduction in the costs of climate change and oil dependency due to higher CAFE

6. See National Research Council, *Effectiveness and Impact of CAFE Standards*, p.8.

7. Producers of gasoline might bear part of the tax. In that case, the price of gasoline would increase by less than the amount of the tax. In either case, however, the incremental cost of the tax (borne by producers and consumers) would be 41 cents.

8. CBO estimates that for CAFE standards with trading, the marginal cost of reaching the benchmark target (that is, the cost of saving the "final" gallon of gasoline) is 33 cents per gallon saved (with the external costs resulting from the increase in driving ignored).

9. In addition to increasing the risk of an accident occurring, according to some analysts, higher CAFE standards could increase the harm that accidents cause by leading to lighter, smaller vehicles. That claim is controversial, however. Some members of the NRC panel argue that the "relationships between vehicle weight and safety are complex and not measurable with any degree of certainty at present." See National Research Council, *Effectiveness and Impact of CAFE Standards*, p.117.

10. For example, one study estimates that the external cost of each additional mile driven is $0.035 from the additional congestion and $0.03 from the additional accident risk. See Parry and Small, "Does Britain or the United States Have the Right Gasoline Tax?"

standards is greater than the existing tax on gasoline plus the CAFE-induced increase in congestion and accident costs.[11]

While the existing tax on gasoline exceeds the NRC's estimate of the external costs associated with consuming gasoline, the tax is not necessarily too high. Gasoline taxes serve other purposes besides encouraging gasoline buyers to take the external costs of gasoline consumption into account. Gasoline taxes also discourage driving. Determining the "optimal" tax on gasoline is beyond the scope of this study, but such a determination might take into account the external costs that are associated with driving—but that are independent of the amount of gasoline consumed—such as traffic congestion and accident risk.[12] Finally, a determination of the optimal tax might include the external costs associated with consuming gasoline (the costs of oil dependency and carbon emissions, discussed above). Such an assessment could conclude that increases in the existing tax on gasoline could improve social welfare.[13]

11. The authors of a forthcoming study have attempted to make this complete assessment. They find that the existing tax on gasoline, as well as the costs associated with CAFE-induced increases in driving, make it appear that increases in CAFE standards could significantly reduce overall welfare. However, the authors cannot agree on whether increases in CAFE standards would be preferable to no gasoline-saving policy. They indicate that higher CAFE standards would have the potential to improve social welfare if the benefits of reduced oil consumption and carbon emissions increased over time, if technologies to improve fuel economy turned out to be less expensive than anticipated, or if the current market fails to provide optimal incentives for fuel economy innovation. See Paul R. Portney et al., "The Economics of Fuel Economy Standards," *Journal of Economic Perspectives* (forthcoming).

12. Some researchers have proposed a gasoline tax as a means of addressing those externalities, provided that other, more direct means are not feasible. More direct methods of addressing such externalities could involve using congestion pricing (tolls that rise with traffic density as a way of controlling highway congestion) or tying insurance premiums to the number of miles driven.

13. One study concludes that the optimal tax on gasoline would be $1.01. See Parry and Small, "Does Britain or the United States Have the Right Gasoline Tax?"

Journal of Economic Perspectives—Volume 18, Number 2—Spring 2004—Pages 271–276

Comments

To be considered for publication in the Comments section, letters should be relatively short—generally fewer than 1,000 words—and should be sent to the journal offices at the address appearing inside the front cover. The editors will choose which letters will be published. All published letters will be subject to editing for style and length.

Inequality and Poverty

In "Halving Global Poverty," Tim Besley and Robin Burgess (Summer 2003, pp. 3–22) note that, conditional on mean real per capita national income, higher inequality (as measured by the standard deviation of income) is correlated across countries with higher absolute poverty as measured by the headcount of those with less than $1 a day (see their Table 3). This result is not surprising. Indeed, as stated, the observation might be little more than tautological. After all, the more of total national income is taken by the rich and mean income is held constant, then the less is available for the rest, and as such there are likely to be more absolutely poor people.

Is there more to the inequality-poverty link than this tautology? In fact, there is. Consider a regression in which the poverty headcount is the dependent variable, and the two explanatory variables are the mean income of the lower 90 percent of the income distribution and the share of income going to the top decile. One might expect that after taking into account the mean income of the bottom 90 percent of the income distribution, the share of income going to the top percentile should not affect the poverty headcount.

However, when I carried out this regression for using data for 89 countries and territories—that is, all for which these variables are available using the World Bank GPID database and World Development Indicators—I found that the share of income going to the top decile is large and statistically significant. In an ordinary least squares regression, if the share of income going to the decile rises by 1 percentage point, the percentage of the population below the $1 per day poverty line rises by about half a percentage point, after including the mean income level of the bottom 90 percent as another explanatory variable and adding a constant term. This finding survives inclusion of other variables such as financial depth, and measures of institutional quality (Honohan, 2004). Almost equivalent results are obtained by substituting the mean income of the top decile for their share in total income. These results can be found at ⟨http://econ.worldbank.org/programs/finance/library/⟩.

It is by no means clear why making some rich people richer should increase the number of absolutely poor people: as an empirical fact, this is rather startling. Admittedly, it is consistent with most of the functional forms that are used to fit the statistical distribution of incomes in any country. Two-parameter functional forms for income distribution (such as the log-normal) almost necessarily imply such a relationship, in the sense that mean-preserving parameter changes for any given functional form will send the share of the top decile and the poverty headcount in the same direction. Even a more flexible functional form such as the widely favored three-parameter Singh-Maddala (McDonald, 1984) tends to predict the positive association in this sense. However, this insight only pushes the question back one further step inasmuch as these statistical models lack any serious economic rationale. Besides, the empirical fit of these curves near the ends of the distribution have traditionally been their weak point; thus, there was no *a priori* assurance that this prediction would have been empirically robust.

Of course, there is no surprise that increasing mean national income reduces the poverty headcount. But what is it about societies where the rich are rich that tends to result in more people falling into poverty? This appears to remain something of an unresolved puzzle.

Patrick Honohan
The World Bank
Washington, D.C.

■ *Without implicating him, I am grateful to Aart Kraay for helpful suggestions. This note reflects the views of the author alone and not those of the World Bank.*

References

Honohan, Patrick. 2004. "Financial Development, Growth and Poverty: How Close are the Links," in *Financial Development and Economic Growth: Explaining the Links.* Charles Goodhart, ed. London: Palgrave, forthcoming.

McDonald, James B. 1984. "Some Generalized Functions for the Size Distribution of Income." *Econometrica.* 53:3, pp. 647–63.

Fuel Economy Standards

In their article "The Economics of Fuel Economy Standards," Paul Portney, Ian W.H. Parry, Howard K. Gruenspecht and Winston Harrington (Fall 2003, pp. 203–217) note that engineering studies suggest a substantial opportunity to improve the energy efficiency of new vehicles using demonstrated, cost-effective technologies and that the failure of markets to exploit this potential is difficult to reconcile with economic theory. Given the gap between evidence and theory, the authors express skepticism about the evidence; that is, they criticize the use of engineering studies in justifying more stringent fuel economy standards. The authors do not, however, note that important econometric evidence also points to significant inefficiencies in markets for energy-using equipment.

In a seminal paper on home appliance purchases, Hausman (1979) found that consumers employ an implicit discount rate of 25 percent per year in evaluating the net benefits of improved energy efficiency. A subsequent literature found discount rates ranging from 25 percent to 300 percent in markets for refrigerators, heating and cooling systems, building shell improvements and a variety of other technologies (Frederick et al., 2002). These anomalously high discount rates provide reason to reject the hypothesis that markets for energy-using equipment are characterized by substantive rationality and efficient resource allocation. In a study that is directly relevant to the fuel economy debate, Dreyfus and Viscusi (1995) undertook a hedonic price analysis of the U.S. automobile market to assess consumers' willingness to pay for improved safety and energy efficiency. On the assumption that consumers use a common discount rate in evaluating both safety and fuel economy, the study calculates an implicit discount rate that ranges from 11 to 17 percent in alternative specifications. More tellingly, Dreyfus and Viscusi conclude that only 35 percent of the present-value cost savings provided by improved energy efficiency is capitalized in the purchase price of vehicles.

Attempts to interpret the so-called "energy efficiency gap"—the failure of real-world markets to implement energy-efficient technologies that are cost-effective at prevailing energy prices—have focused mainly on issues of information asymmetries (Howarth and Andersson, 1993), bounded rationality (Conlisk, 1996) and inefficiencies in the structure of large organizations (DeCanio, 1993). These explanations are consistent with empirical work in behavioral economics, which finds that a wedge often exists between observed behavior and the model of substantive rationality in the context of intertemporal decisions (Loewenstein and Thaler, 1989). A contrasting approach is taken by Hassett and Metcalf (1993), who seek to explain the use of high discount rates as a rational response to issues of risk and irreversibility. Sanstad et al. (1995), however, show that these effects are too small to account for the empirical magnitude of the efficiency gap.

Although Portney and his co-authors reason that car buyers are well-informed about fuel economy tradeoffs by the energy labels required for new vehicles, behavioral studies suggest that providing consumers with technically accurate information often has little influence on their decision making (Gardner and Stern, 2002, chapter 4). This observation does not imply that consumers are fundamentally irrational. As Conlisk notes, limitations on people's cognitive capabilities imply that (boundedly) rational agents must rely on simple decision heuristics that are subject to systematic bias. In the context of automobile purchase decisions, energy costs (a) constitute only a small fraction of the total cost of owning and operating a vehicle; and (b) are not tangibly apparent to consumers at the point of decision. These conditions match the circumstances under which bounded rationality most typically prevails, explaining why consumers fail to optimize fuel economy choices as they would given perfect information and infinite cognitive capabilities (Kempton and Layne, 1994).

Portney, Parry, Gruenspecht and Harrington are on firm ground when they note the importance of taxing gasoline to reflect the social costs of fuel consumption. The imperfections that appear to exist in vehicle markets, however, weaken the force of the authors' critique of enhanced fuel economy standards. As the authors note, the National Research Council (2002) found that strengthening the Corporate Average Fuel Economy (CAFE) standards could substantially raise the energy efficiency of new vehicles while maintaining or enhancing consumer welfare. Although this conclusion seems difficult to reconcile with the traditional theory of efficient markets, it is arguably consistent with recent developments in information and behavioral economics.

Richard B. Howarth
Dartmouth College
Hanover, New Hampshire

References

Conlisk, John. 1996. "Why Bounded Rationality?" *Journal of Economic Literature.* June, 34, pp. 669–700.

DeCanio, Stephen J. 1993. "Barriers within Firms to Energy-Efficient Investments." *Energy Policy.* September, 21, pp. 906–14.

Dreyfus, Mark K. and W. Kip Viscusi. 1995. "Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency." *Journal of Law and Economics.* 38:1, pp. 79–98.

Frederick, Shane, George Loewenstein and Ted O'Donoghue. 2002. "Time Discounting and Time Preference: A Critical Review." *Journal of Economic Literature.* 40:2, pp. 351–401.

Gardner, Gerald T. and Paul C. Stern. 2002. *Environmental Problems and Juman Behavior.* Boston: Pearson Custom Publishing.

Hassett, Kevin A. and Gilbert Metcalf. 1993. "Energy Conservation Investment: Do Consumers Discount the Future Correctly?" *Energy Policy.* 21:4, pp. 710–16.

Hausman, Jerry. 1979. "Individual Discount Rates and the Purchase and Utilization of Energy-Using Durables." *Bell Journal of Economics.* 10:1, pp. 33–54.

Howarth, R. B. and B. Andersson. 1993. "Market Barriers to Energy Efficiency." *Energy Economics.* 15:4, pp. 262–72.

Kempton, Willett and Linda Layne. 1994. "The Consumer's Energy Analysis Environment." *Energy Policy.* 22:10, pp. 857–66.

Loewenstein, George and Richard H. Thaler. 1989. "Anomalies: Intertemporal Choice." *Journal of Economic Perspectives.* 3:4, pp. 181–93.

National Research Council. 2002. *Effectiveness and Impacts of Corporate Average Fuel Economy (CAFE) Standards.* Washington: National Academy Press.

Sanstad, Alan H., Carl Blumstein and Steven E. Stoft. 1995. "How High are Options Values in Energy-Efficiency Investments?" *Energy Policy.* 23:9, pp. 739–43.

Reply from Paul Portney, Ian Parry and Winston Harrington

Unfortunately, one of the most crucial issues in assessing the economic merit of tighter fuel economy standards is also one of the most contentious. A number of engineering studies suggest that there is a wide range of fuel-saving technologies that could be adopted by auto manufacturers for which the discounted fuel saving benefits over the vehicle lifetime would exceed the costs of vehicle production—see in particular NRC (2002). If so, tightening Corporate Average Fuel Economy (CAFE) standards on new passenger vehicles can easily be welfare-improving overall; if not, tightening CAFE could be welfare-reducing, due to its perverse effects on increasing the incentive to drive and on compounding distortions from pre-existing fuel taxes (Parry, 2004).

Is there a market failure that prevents auto manufacturers from installing fuel-saving technologies that consumers should be willing to pay for? The most common hypothesis is that auto buyers have very high discount rates and undervalue the true social benefits from future fuel savings. Richard Howarth draws our attention to a number of econometric studies suggesting that consumers may in fact discount future fuel costs at high rates. Howarth's underlying explanation is that when fuel costs are a small portion of total vehicle owning and operating costs and are not tangibly apparent to consumers at the point of purchase, then "...[boundedly rational] consumers fail to optimize fuel economy choices as they would given perfect information and infinite cognitive capabilities."

Maybe. But some of the evidence Howarth cites relates to energy savings from home appliances, and it is not necessarily clear that discount rates from these studies are applicable to automobiles, largely because the energy savings are so difficult for consumers to observe. Of most relevance is the Dreyfus and Viscusi (1995) hedonic analysis of car purchases, which finds a discount rate of 11 to 17 percent. The discount rate used in the NRC (2002) report is 14 percent—exactly the midpoint of this range.

Perhaps it is not that consumers misperceive or overly discount fuel-saving benefits, but rather that engineering studies underestimate the true economic costs of actually adopting fuel-saving technologies. The true economic cost is probably larger than the engineering cost estimates used by the NRC for two reasons. First, it ignores the possible opportunity cost of not using fuel saving technologies for other vehicle enhancements. That is, by forcing automakers to apply their technical expertise to more fuel-efficient engines, tighter CAFE standards could mean fewer of the improvements to which consumers have responded enthusiastically in the past—including such things as enhanced acceleration, towing capacity and so on. It is the implicit values of these foregone improvements that ought to be compared with the fuel economy savings that tighter CAFE standards would bring. A second point is that engineering studies may exclude various sosts of actually implementing a new technology that are difficult to observe—for example, marketing, consumer unfamiliarity and retraining of mechanics.

While it would be extreme to assume all manufacturers incorporate fuel saving technologies that pay for themselves the instant they become available, basing the case for substantially tightening fuel economy standards purely on results from engineering studies is also on rather shaky ground. Until a greater consensus emerges on the extent to which the true economic costs of tightening fuel economy standards differ from engineering costs, policymakers would be well advised to focus on other initiatives that are on firmer ground. We would advocate a moderate (economy-wide) carbon tax to reduce greenhouse gases, a broad oil tax (of perhaps $3 per barrel) to help reduce the economy's dependence on imported oil, encouragement of per-mile insurance (rather than annual lump-sum payments) to reduce driving and reforming the CAFE program by allowing manufacturers to trade fuel economy credits.

References

Dreyfus, Mark K. and W. Kip Viscusi. 1995. "Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency." *Journal of Law and Economics.* 38:1, pp. 79–98.

National Research Council. 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.* Washington, D.C.: National Academy Press.

Parry, Ian W. H. 2004. "Welfare Effects of Tightening the Corporate Average Fuel Economy (CAFE) Standards." Discussion paper, Resouces for the Future, Washington, D.C.

Exchange Rate Regimes

Guillermo Calvo and Frederic S. Mishkin's article "The Mirage of Exchange Rate Regimes for Emerging Market Countries" (Fall 2003, pp. 99–118) illustrates a problem that has plagued discussion of exchange rate regimes: lack of precision, especially regarding fixed exchange rates. Like many other economists, Calvo and Mishkin use the terms "fixed" and "pegged" interchangeably. It is confusing to have two terms for the same thing.

Their definition of one type of fixed exchange rate, a currency board, is vague in a key respect. Calvo and Mishkin (p. 100) say only that a currency board has "enough" reserves "to exchange domestically issued notes for the foreign [anchor] currency on demand." A currency board does not hold just any amount of foreign reserves that may be "enough." Rather, it holds net foreign reserves equal to 100 percent of the monetary base. A currency board does not let its reserves fall below 100 percent, nor does it accumulate excess reserves beyond at most an additional 10-percent. The excess reserves, if any, serve as a cushion against possible losses in the capital value of assets, not as a source of funds for discretionary monetary policy. A currency board holds no significant financial assets other than its foreign reserves, hence it does not hold domestic financial assets.

Their vague definition leads Calvo and Mishkin to say that Argentina's monetary system of April 1991 to January 2002, known locally as "convertibility," was a currency board. However, the central bank held large amounts of domestic financial assets, and over the life of the convertibility system, the ratio of net foreign assets to the monetary base was often quite far above or below 100 percent. It is more accurate to view the convertibility system as the latest of Argentina's many attempts to combine a hard pegged exchange rate with central banking.

Calvo and Mishkin claim that the choice of exchange rate regime "is likely to be of second order importance" in developing good overall economic policies (p. 115). Here again, I think it is possible to be more precise, in a way that is useful for economic policy. Even the best exchange rate regime (whatever you may consider that to be in a particular case) is not enough by itself to ensure economic growth, but a very bad regime is enough by itself to reverse growth. A good exchange rate regime enlarges the potential scope for mutually beneficial trades, but high tax rates, insecure property rights or other factors may still discourage people from actually making the trades. A very bad regime shrinks the scope for mutually beneficial trades, in extreme cases making barter more attractive than monetary exchange. The difference between a good exchange rate regime and the best regime may be small in terms of its effect on economic growth, but there is abundant evidence that the difference between a good regime and a very bad regime is large.

Kurt Schuler
Senior Economist to the Vice Chairman
Joint Economic Committee, U.S. Congress
Washington, D.C.

■ *The views expressed here are the personal views of the author, not necessarily the views of the Joint Economic Committee.*

School Accountability

In their excellent article on "The Promise and Pitfalls of Using Imprecise School Accountability Measures" (Fall 2002, pp. 91–114), Thomas J. Kane and Douglas O. Staiger point out that many accountability systems treat small schools in a capricious fashion. Because a small school has greater sampling variation, its average scores, or average gains, are likely to be volatile and occasionally extreme, even if the school itself is steady and average. Quite ordinary schools, if they are small, are likely to be praised in some years and censured in others.

To address this problem, Kane and Staiger suggest setting "different thresholds for schools of different sizes. For example, grouping schools according to size . . . and giving awards to the top 5 percent in each size class." This proposal solves the problem of comparing small schools to large schools, but it does not change the fact that, within the small school group, schools in the top 5 percent are likely to be there because of luck. Kane and Staiger's other suggestion—lowering the threshold so that more schools win rewards—has the same problem.

What Kane and Staiger overlook is that at least one government recognizes the small-school problem and has taken steps to avoid it. The danger is addressed by Sanders's influential value-added methodology, which is a mixed model focused on year-to-year gains. In Tennessee and other systems that have adopted Sanders's suggestions, school effects are treated as random and estimated using a "shrinkage" estimator known as the empirical Bayes (EB) residual or the best linear unbiased predictor (BLUP). This estimator "shrinks" school averages toward the system mean, with greater shrinkage for schools with smaller enrollments (Sanders, Saxton and Horn, 1996; Robinson, 1991; Raudenbush and Bryk, 2002). Kane and Staiger (2001) allude to empirical Bayes methods in describing their complex "filtered" estimates of school effects, but do not mention that empirical Bayes methods, with their shrinkage properties, are already part of the simpler accountability system in Tennessee.

Shrinkage ensures that a small school is unlikely to have a large estimated effect. For example, suppose that sampling variation made average scores 75 percent reliable for large schools, but only 50 percent reliable for small schools. If both a small school and a large school reported average scores that were two standard deviations above the mean, the large school's estimate would be shrunk to 2×75 percent $= 1.5$ standard deviations, while the small school's estimate would be shrunk to $2 \div 50$ percent $= 1$ standard deviation above the mean. The small school is shrunk more, because a smaller sample provides weaker evidence of extraordinary achievement.

A drawback of this approach is that shrinkage makes it hard for an exceptional small school to get much attention (Raudenbush and Bryk, 2002). From a policy perspective, however, it may be appropriate to focus attention on large schools, since large schools impact more students. In short, one of the pitfalls that Kane and Staiger have identified is something that certain governments have learned to sidestep. These governments should be commended, and others should be encouraged to follow their example.

Paul T. von Hippel
Department of Sociology and Initiative in Population Research
Ohio State University
Columbus, Ohio

References

Kane, Thomas J. and Douglas O. Staiger. 2001. "Improving School Accountability Measures." NBER Working Paper No. 8156; Available at ⟨http://www.nber.org/papers/w8156⟩.

Raudenbush, Stephen W. and Anthony S. Bryk. 2002. *Hierarchical Linear Models.* Thousand Oaks, Calif.: Sage.

Robinson, G. K. 1991. "That BLUP is a Good Thing: The Estimation of Random Effects." *Statistical Science.* 6:1, pp. 15–32.

Sanders, William L., Arnold M. Saxton and Sandra P. Horn. 1997. "The Tennessee Value-Added Assessment System: A Quantitative, Outcomes-Based Approach to Educational Assessment," in *Grading Teachers, Grading Schools: Is Student Achievement a Valid Evaluation Measure?* Jason Millman, ed. Thousand Oaks, Calif.: Corwin Press, pp. 137–62.

The Economics of Fuel Economy Standards

Paul R. Portney, Ian W.H. Parry, Howard K. Gruenspecht and Winston Harrington

November 2003 • Discussion Paper 03–44

RESOURCES
FOR THE FUTURE

Resources for the Future
1616 P Street, NW
Washington, D.C. 20036
Telephone: 202–328–5000
Fax: 202–939–3460
Internet: http://www.rff.org

The Economics of Fuel Economy Standards

Paul R. Portney, Ian W.H. Parry, Howard K. Gruenspecht, and Winston Harrington

Abstract

This paper discusses several rationales for the Corporate Average Fuel Economy (CAFE) program, including reduced oil dependence, reduced greenhouse gas emissions, and the possibility that fuel saving benefits from higher standards might exceed added vehicle costs. We then summarize what can be said about the welfare effects of tightening standards, accounting for prior fuel taxes, and perverse effects on congestion and traffic accidents through the impact of improved fuel economy on the incentive to drive. Implications of CAFE on local air pollution, and the controversy over CAFE, vehicle weight, and road safety, are also discussed. Finally, we describe ways in which the existing CAFE program could be substantially improved and identify a variety of alternative, and much superior, policy approaches.

Key Words: fuel economy, externalities, oil dependency, vehicle safety, climate change

JEL Classification Numbers: R48, Q48, H23

Contents

The Economics of Fuel Economy Standards

Paul R. Portney, Ian W.H. Parry, Howard K. Gruenspecht and Winston Harrington*

1. Introduction and Background

Public policy debates are often overheated, but those regarding government-mandated new-car fuel economy standards have been extreme. Proponents of more stringent standards allege that the declining fuel economy of the new-vehicle fleet in the United States plays into the hands of Al Qaeda; opponents claim that tighter standards would lead directly to smaller cars and, therefore, carnage on the highways. With important industries and public interests at stake, it is important to disentagle fact from fiction.

In the Energy Policy and Conservation Act of 1975 (EPCA), Congress created the Corporate Average Fuel Economy (or CAFE) program. Congress itself required each manufacturer of new passenger cars to meet a sales-weighted average of 18 miles per gallon (mpg) by Model Year 1978, increasing steadily to 27.5 mpg for Model Year 1985 and beyond. Congress also directed the National Highway Traffic Safety Administration (NHTSA) to establish fuel economy standards for what are called light-duty trucks—a category that includes pickup trucks, minivans and sport utility vehicles (or SUVs). Standards for light-duty trucks began with Model Year 1979, and today each manufacturer's fleet must average at least 20.7 mpg. Vehicle manufacturers have always had the option to pay $5.50 per vehicle sold for each 0.1 mile-per-gallon (mpg) that their fleet average falls short of the relevant standard. However, only a few European manufacturers of luxury cars (Mercedes and BMW, for example) have chosen this route; no Japanese or U.S. carmaker (prior to the merger of Daimler and Chrysler) has ever fallen short of the standards.

* *Paul Portney is President, Ian Parry a Fellow, and Winston Harrington a Senior Fellow of Resources for the Future; Howard Gruenspecht is Deputy Administrator, Energy Information Administration, Department of Energy. Gruenspecht was a Resident Scholar at Resources for the Future when this paper was written. Portney chaired the National Research Council report on the future of the Corporate Average Fuel Economy program. Please address all correspondence to portney@rff.org.

Together in concert with higher real gasoline prices, which began rising in 1973 (see Figure 1), the new standards had a significant effect on fuel economy. According to the U.S. Environmental Protection Agency (EPA), new passenger car fuel economy rose from 17 mpg in 1978 to more than 22 mpg in 1982, an increase of more than 30 percent. Light-duty truck fuel economy rose 35 percent during this same period; the combined fuel economy of the entire new vehicle fleet rose by an even third (see Figure 2).

Note that fuel economy for both the new passenger car and the new light duty truck fleets continued to improve until 1988, at which point they exceeded by 44 and 42 percent respectively their levels when the CAFE program went into effect. The improvements beyond 1982 are significant because that is the year in which the price of gasoline began its precipitous decline, never to recover. If the fuel economy improvements of the late '70s and early '80s were a response only to rising gasoline prices, we might have expected a gradual fall-off in fuel economy in the years following 1982; it is likely that the CAFE standards established a floor preventing such a decline. Note finally from Figure 2 that while average fuel economy for new light-duty trucks has remained flat for the last twenty years, and that for new cars has increased modestly, combined new vehicle average fuel economy has *declined* 6 percent since 1987. This is because the light-duty truck share of the new vehicle fleet has gown from less than a quarter of all new vehicles sold in 1975 to more than half in 2002.

This backdrop raises a number of interesting questions. Should the government intervene to stimulate the fuel economy of the new vehicle fleet, and if so, why? What are the likely benefits and costs of such efforts? If a case can be made for intervention, is the CAFE program the best way to do so? These questions are back on the political agenda again.

In the next section, several rationales for government intervention regarding fuel economy are spelled out. We then summarize what can be said about the welfare effects of tightening CAFE, accounting for prior fuel taxes, and perverse effects on congestion and traffic accidents through the impact of improved fuel economy on the incentive to drive. Implications of CAFE on local air pollution, and the controversy over CAFE, vehicle weight, and road safety, are also discussed. Finally, we describe ways in which the existing CAFE program could be substantially improved and identify a variety of alternative, and much superior, policy approaches.

2. Rationales for Fuel Economy Standards

The current discussion of CAFE standards takes place against renewed concerns about growing oil consumption in the United States, and particularly about the sources of that oil. As Figure 3 shows, U.S. oil consumption recently reached an all-time high, as did the fraction accounted for by imports (now more than half of oil consumption). Moreover, the OPEC cartel supplies the United States with slightly less than half of its oil imports, or about a quarter of all the oil it uses; gasoline accounts for just under half of oil use.[1] There are several alleged externalities or market imperfections associated with U.S. oil consumption: the macroeconomic impact associated with oil price "shocks"; market power in global oil markets; the environmental consequences of burning oil, especially the risk of greenhouse warming; and the possibility that consumer myopia, or technology spillover effects, may lead to insufficiently small investments in fuel efficiency. We take each of these in turn.

2.1 Macroeconomic Effects of Oil Price Shocks

A number of analysts have called attention to the significant and apparently causal negative relation between oil price volatility and macroeconomic performance (e.g., Brown and Yücel ,2002; for a contrary view, see Barsky and Killian in this issue). This relation has weakened over time; Americans now use 0.8 barrels of oil per $1000 dollars of (real) GDP compared with 1.5 barrels in the early 1970s (Energy Information Administration, 2002). One might imagine that the benefits of oil price reductions would offset the costs of price increases; but the empirical literature has identified an apparent asymmetry in response—rising oil prices seem to retard economic activity more than falling prices spur it (see Hamilton, 1996). To the extent that this asymmetry is due to adjustment costs elsewhere in the economy (e.g., transitory unemployment, costs incurred from re-optimizing capital stocks) that are not taken into account by energy consumers and producers, there can be an externality (see Bohi and Toman 1996 and Bernanke et al. 1997 for another explanation of this asymmetry). Importantly, neither the level of oil imports nor their countries of origin are germane to this argument. Even if the United

[1] Data on the sources and uses of energy in the United States can be found at http://www.eia.doe.gov.

States produced all the oil it used, it would still suffer from supply disruptions anywhere in the world because the price of oil is set in world markets. The only way to insulate ourselves from these disruptions is to further reduce the oil intensity of our economy or limit the size of the price spikes themselves.

2.2 Market Power

Another issue has to do with market power, possessed most obviously by the OPEC cartel. Production restraint by a few low-cost producers in the Middle East, notably Saudi Arabia, keeps the price of oil far above its marginal cost. On the demand side, no individual purchaser of imported oil buys enough to affect the price; however, through policies that affect the demand by all American users, the U.S. government can be said to have monopsony power in the oil market. Some observers have suggested that this power could be used to neutralize partly the anticompetitive behavior of OPEC and reduce the world price of oil. The policies most commonly discussed for this purpose include an oil import quota or tariff, although any policy that restricts oil use—such as CAFE—would very likely have the desired effect on imports. Again, the magnitude of these "externality" benefits is controversial, being sensitive to assumptions about how OPEC supply, and demand from other importing countries, would respond to a reduction in U.S. consumption (Leiby et al. 1997).

A recent panel of experts (National Research Council 2002) surveyed the literature and tentatively valued the combined macroeconomic and monopsony externalities at $5 per barrel of oil, or 12 cents per gallon of gasoline (with a range of 2–24 cents). Arguably, there are other costs of our oil dependency, such as the power that it gives to undemocratic governments in the Middle East, though these are very difficult to quantify.[2]

[2] It is sometimes argued that Middle East military expenditures constitute an external cost from oil consumption. This is questionable because these expenditures also serve other objectives, such as the security of Israel. Moreover, much of this spending might be regarded as a fixed cost that would not fall in proportion to a (moderate) reduction in US imports.

2.3 Environmental Concerns

The primary environmental justification for government intervention to reduce gasoline consumption is concern about future global climate change. Unlike other automobile emissions, abatement technologies do not exist for carbon dioxide so emissions are proportional to gasoline use. A number of studies have estimated the economic impacts of future climate change on agriculture, forestry, coastal activities, human health and so on. These estimates are highly speculative as there is controversy, among other things, over appropriate discount rates, how to value non-market effects such as species extinction, the likelihood and extent of instabilities within the climate system, the greater vulnerability of poor countries to climate change, and the possibility of catastrophic changes in climate.

Mainstream damage estimates tend to be fairly moderate because the bulk of world manufacturing and services is not especially sensitive to predicted changes in climate over the next century, and discounting greatly reduces the present value of distant costs. A wide range of estimates of the value of carbon abatement appears in the literature, from negative values to well over $100 per metric ton of carbon equivalent (MTCE), though most estimates are below $50 per MTCE (for discussion, see Nordhaus 1994, Tol et al, 2000, and the references cited therein). A value of $50 per MTCE, the value assumed by the National Research Council (2002), implies damages of 12 cents per gallon of gasoline. Combining this with the NRC's assumed value for oil dependency externalities, yields an external cost so far of 24 cents per gallon; since annual gasoline consumption in the United States is about 130 billions gallons per year, these external costs amount to about $30 billion annually, or about 15 percent of the value of all gasoline sales.

It is tempting to think that gasoline consumption may result in another negative environmental externality, namely emissions of carbon monoxide and the hydrocarbons and oxides of nitrogen that create smog and airborne particulates. In fact, however, local air pollution effects are both more subtle and ambiguous. First, tailpipe emissions from new vehicles are regulated in the U.S. on a grams-per-mile basis rather than a grams-per-gallon-of-gasoline basis. Thus, better fuel economy has no direct effect on pollutant emissions (aside from a minor impact on upstream emissions leakage during fuel refining and distribution).

Next, since tighter fuel economy standards will make it less expensive to drive an additional mile, to the extent people respond by driving more (as argued below in more detail), local pollution could actually *increase*. Moreover, if tighter fuel economy standards drive up the cost of new cars and light-duty trucks, the retirement of older vehicles will be delayed because these latter vehicles meet less stringent emissions standards. Also, emissions control performance deteriorates with age, an element that, when combined with tighter CAFE, could either increase or decrease emissions. But perhaps most importantly, the new vehicles potentially affected by tighter CAFE standards are already subject to increasingly more stringent limits on their per-mile emissions. It is our assessment that local pollution effects would probably play a minor role in any welfare assessment of proposed changes in the CAFE program.

2.4 Imperfect Markets for Improvements in Fuel Economy

A particularly contentious issue is whether, even in the absence of environmental or oil dependency externalities, the market would provide the efficient level of fuel economy. Many engineering studies suggest that there is a wide range of technological possibilities for improving new vehicle fuel economy, which could more than pay for themselves in terms of discounted fuel savings over vehicle lifetimes. For example, a thorough assessment by the National Research Council (2002) considered a range of technologies to improve both engine and transmission efficiency, reduce weight and aerodynamic drag and boost fuel economy in other ways. They concluded that the marginal value of fuel saving benefits might exceed the marginal costs of vehicle redesign for improvements in efficiency from anywhere between 0 and 50 percent above current standards, across a wide range of vehicle classes. Do these examples of technologies not offered to new vehicle buyers constitute a market failure, where more stringent government fuel economy standards could produce net economic benefits, before even counting external benefits?

Several hypotheses have been advanced to explain why vehicle manufacturers may not adopt so-called "no-regrets" technologies that would seem to pay for themselves. For example, consumers may undervalue future savings in gasoline purchases because they lack information, have short horizons, or are uncertain about future fuel prices. In addition, the automobile industry might be viewed as oligopolistic, in which case profit-maximizing manufacturers could undersupply vehicle attributes even when potential buyers would value them.

Others, however, view the new vehicle market as efficient, aside from the externalities described above (e.g., Kleit 1990). According to this view, manufacturers have incentives to provide improvements in fuel economy that consumers are willing to pay for, and buyers are reasonably well informed about fuel economy, thanks in part to stickers that must be displayed on all new cars. Moreover, consumers can already choose from a wide range of cars with exceptionally good fuel economy—ten 2003 models get better than 45 mpg in combined city and highway driving.

Engineering studies alone may give a very unreliable guide to the actual costs of mandated increases in fuel economy. They may not capture many important costs of actually implementing a new technology, such as marketing, maintenance, consumer unfamiliarity, and retraining of mechanics. Moreover, auto manufacturers have for the past several decades devoted their technological skills principally to the introduction of technologies that improve vehicle performance (e.g., acceleration and towing capacity) rather than fuel economy; therefore, the real cost of devoting technology to improving fuel economy is the foregone performance enhancements that might have resulted. Additionally, there is no guarantee that manufacturers would respond to tighter CAFE standards by adopting new, fuel-saving technologies. Instead, it may make more sense for them to lower the relative price of existing cars with high fuel economy to increase their market share, eliminate some of the performance enhancements that have been so attractive, or reduce the weight of new vehicles.

Another potentially significant market failure arises from possibly inadequate incentives for R&D into vehicle fuel economy. R&D will be sub-optimal if manufacturers cannot fully appropriate spillover benefits to other firms from their own innovation; for example, even if they obtain a patent, it may be easy for other firms to imitate around the patent by producing their own modified versions of the original technology. A number of empirical studies suggest that the social return to R&D may greatly exceed the private return (e.g., Mansfield et al. 1977); if so, this implies that innovation incentives are in fact sub-optimal. To the extent that tighter CAFE standards spur new innovation, this could lead to an additional source of welfare gain; however these gains may be limited if the added R&D effort in the vehicle sector comes at the expense of crowding out R&D efforts elsewhere in the economy.

3. Unintended Consequences of CAFE and the Controversy over Highway Safety

3.1 Prior Fuel Taxes

It is important to recognize that the welfare effects of induced changes in the demand for gasoline depend on the marginal external costs of gasoline, *net of any pre-existing gasoline taxes*. If fuel taxes perfectly correct for externalities, then a reduction in gasoline demand does not lead to any net welfare gain, as the source of market failure has effectively been eliminated; and if taxes over-correct for externalities, a reduction in the demand for gasoline will actually lower social welfare. For example, if we assume combined oil dependency and carbon externalities of 24 cents per gallon, then a reduction in gasoline demand by one gallon will save 24 cents in avoided externalities, but will cost federal and state governments the tax revenues on one gallon, which on average amount to about 40 cents.[3]

3.2 The Rebound Effect

Another possibly perverse effect of mandated higher fuel economy is that, by lowering the per-mile cost of driving, it may induce people to drive their vehicles more. Gasoline consumed is the product of gallons/mile times the number of miles traveled. While CAFE standards *reduce* gallons/mile, they *increase* the number of miles traveled by making driving cheaper. In fact, empirical estimates by Jones (1993) and Greene et al. (1999) suggest that this "rebound effect" offsets 10–20% or more of the initial fuel reduction from tighter CAFE standards. The significance of this rebound effect is its implications for the costs of other externalities that vary with the amount of driving, namely congestion and traffic accidents.

Economists measure congestion costs by the extra time it takes to drive under congested conditions, multiplied by the value of travel time (usually taken to be about half the market wage). Detailed analyses by the Texas Transportation Institute suggest that travel delays and the resulting extra fuel combustion now cost the nation around $70 billion annually (Schrank and Lomax 2002). A "best estimate" for the economy-wide marginal congestion cost, one that reflects the shares of driving in both rural and urban areas and at peak- and off-peak periods, as well as the smaller elasticity of demand for driving during congested periods, is 3.5 cents per mile (Parry and Small 2001).

Even congestion costs might be swamped by the societal costs of road accidents occasioned by increased driving, which are responsible for around 40,000 deaths each year; other costs include non-fatal injuries, property damage, and traffic holdups. Miller (1993) pegged aggregate accident costs in 1988 at more than $300 billion. However, we need to be careful in assessing what portion of accident costs is actually external—pedestrian injuries, travel delays, and a portion of property damage are probably external, but people presumably internalize injury risks to themselves. Whether one person's driving raises the accident risk to other drivers is unclear: the frequency of collisions rises with more road traffic but, if people drive more slowly in heavier traffic, a given accident will be less deadly. Parry and Small (2001) put the average accident externality at 3 cents per mile for the United States. Note that this accident effect is separate from and in addition to the well-publicized controversy about accidents attributable to CAFE's effect on vehicle size, which we take up below.

To add up the negative externalities associated with the possible additional driving that might result from tighter fuel economy standards, let's assume a rebound effect of 15% and on-road fuel efficiency of 20 miles per gallon. A "back-of-the-envelope" calculation would be that the rebound effect results in added congestion and accident externalities of 19.5 cents for each

[3] More generally, the resulting welfare cost per gallon of fuel reduction (ignoring externalities) equals the gasoline tax rate times the marginal social value of fuel tax revenue. If the social value of a dollar of tax revenue is assumed to be a dollar, the welfare loss is simply the tax rate. In practice, revenues finance highway maintenance and expansion; in this more general case the welfare loss is higher (lower) than the tax rate if the marginal social value of highway spending is greater (less) than a dollar.

gallon of mandated fuel economy improvement (= $6.5 \times 0.15 \times 20$), or perhaps 95% of the carbon and oil dependency benefits.[4]

3.3 Fleet mix effects and its implications for safety

Opponents of fuel economy standards often assert that they force people into lighter vehicles, and that more use of lighter vehicles will adversely affect road safety. We discuss each assertion in turn, though based on current evidence it is hard to draw definitive conclusions.

Vehicle manufacturers could meet tighter CAFE standards by adopting fuel-saving innovations, by lowering the relative price of small vehicles relative to big vehicles, or by reducing weight and other vehicle attributes. The first strategy has no first-round implications for vehicle safety, though the latter two do. However, economic studies on the likely choice of these strategies have come to mixed conclusions (for example, Kwoka 1983, Kleit 1990, and Greene 1991), depending in part on how much time carmakers are given to meet more stringent standards.

CAFE might also affect the average weight of the vehicle fleet by altering the sales mix of cars versus light-duty trucks, though again the magnitude of this effect is unclear. The CAFE standard is more stringent for cars than light trucks, though that may not greatly increase the price of cars relative to light trucks if achieving a given level of fuel economy is less costly for the former than the latter. The growth in demand for light trucks may be more of a reflection of changing consumer preferences than CAFE-induced price effects. Indeed the growth in the light truck market began well before the onset of CAFE in the late 1970s, and the share of trucks in new vehicle sales then declined sharply between 1978 and 1981—after CAFE—before resuming a steady upward climb (Davis 1999).

---

[4] This calculation assumes carbon and oil dependency costs of 12 cents per gallon each, scaled back by 15% to account for the rebound effect. The miles per gallon figure is obtained by splitting the mandated fuel efficiency for cars and light trucks (27.5 and 20.7 respectively) 50–50, and scaling back by 15% because on-road fuel economy is lower than recorded by EPA-required dynamometer testing.

Of course, the welfare cost of the rebound effect could be greatly diminished if other policies were to be implemented to address mileage-related externalities, such as peak period congestion charges, and per mile insurance reform.

Let us make the assumption that tightening fuel economy standards would result in at least somewhat lighter vehicles. How would this affect safety? In single vehicle accidents, which account for roughly half of vehicle occupant deaths, both vehicle size and weight are important factors in determining injury risks; size determines the "crush space" (i.e., the ability of vehicle components to absorb the energy impact rather than transmitting it to vehicle occupants). In multi-vehicle collisions it is not mass per se but rather the *disparity* in the masses of the vehicles that determines injury risk. Recent work by the National Highway Traffic Safety Administration (1997) shows that a 100-pound weight reduction increases fatalities by the same amount for cars and trucks in accidents involving stationary objects. For collisions between cars and light trucks, a 100-pound reduction in car weight increases the combined fatality risk for both cars by 2.6 percent, while a comparable reduction in light-truck weight reduces the combined fatality rate by 1.4 percent. Thus, if most of the downweighting occurred in cars, fatality risks would tend to increase; but the converse could be true if most of the downweighting instead occurred in light trucks.

From the perspective of pure economic efficiency, what matters is the implications of lighter vehicles for the overall external costs of traffic accidents, which is quite different from the effects on total highway deaths, not least because they exclude own-driver risk. Studies using detailed data on highway crashes find that external accident costs per mile driven tend to be about the same, or moderately lower, in most cases for lighter passenger vehicles (see Miller et al. 1998 and Parry and Gruenspecht 2003), though more research on this is required before we can draw conclusions with confidence.

3.4 Would Tighter CAFE Standards Increase or Decrease Social Welfare?

We would like to be able to sum up this discussion with a clear message about CAFE standards. Unfortunately, this is difficult to do with confidence until more consensus emerges on some key issues about which there is great controversy and little solid evidence.

When we account for the existing taxes on gasoline and the likelihood of a rebound effect, it appears that tightening CAFE could significantly reduce social welfare overall. Of course, there is a lot of uncertainty and differences in opinion about the nature and value of externalities. Moreover, assessments of marginal external damages may rise significantly in the future. For instance, the United States will become more dependent on oil imports over the next 25 years as world production becomes ever more concentrated in the Persian Gulf, where two-thirds of the world's reserves are located. Also, according to Nordhaus and Boyer (1999), marginal damages from carbon emissions may also increase several-fold over the course of the next century; climate change damages are a convex function of the atmospheric stock of greenhouse gases so that, as gases accumulate in the atmosphere over time, the marginal damage from further additions to the stock become progressively higher.

Nonetheless, at least based on currently available evidence, it appears difficult to make a watertight case for tightening fuel economy standards now, *based on externality grounds alone*. However, there are other important issues—particularly the possibility of sub-optimal incentives for fuel economy innovation—that need to be resolved and incorporated in a broader cost/benefit assessment. It seems plausible to us that tightening CAFE could still be welfare-improving overall—despite the rebound effect and prior fuel taxes—*if* the market does in fact provide too little incentive for fuel economy improvement.

4. Alternatives to the Current CAFE Policy[5]

The current CAFE policy is only one of many policies that could reduce petroleum consumption.

4.1 Improvements within the existing CAFE structure

Even if CAFE were kept basically intact, a number of modifications could be made to the program to make it more cost effective. One problem with the existing program is that the same fuel economy standard for both car and light-duty truck fleets is imposed across vehicle manufacturers, regardless of how costly it is for them to comply. Moreover, manufacturers who do better than their target in a given year in one segment (say light-duty trucks) can only use the

[5] For a more detailed discussion of some policy options related to fuel economy, see Congressional Budget Office (2002) and National Research Council (2002).

credits they earn to offset worse-than-required performance in that same vehicle segment, and only then for the next three years, after which the credits expire.

If manufacturers were allowed to trade fuel economy credits both between their own car and light-duty truck fleets, and also between one another, those with high marginal compliance costs could purchase credits from those with low marginal costs. This would allow a given (aggregate) target for fuel economy to be achieved at lower overall social cost. In the jargon of environmental economics, this is simply a replacement of the current "bubble" policy, which allows averaging within a manufacturer's own car and truck fleets, by a system of tradable allowances between cars and trucks and among manufacturers. Creating a market price for CAFE credits would also shed light on the real costs of improving fuel economy.

A system of tradable CAFE credits could also incorporate a cost cap. This could be implemented via a standing government offer to provide unlimited additional CAFE credits at a fixed price, providing an "escape valve" for manufacturers/consumers in the event that market or technological conditions would otherwise result in excessive price or performance penalties. Should the cap be triggered, the program becomes a "price-type" instrument that fixes compliance costs rather than a "quantity-type" instrument that sets average fuel economy regardless of cost.

4.2 Other policies to increase fuel economy

A variety of other approaches have been put forward that would have the effect of promoting greater fuel economy. For instance, current and proposed programs encourage the purchase of new fuel-efficient vehicles through federal tax deductions. Similarly, some have called for the imposition of fees on gas guzzlers that would be rebated to those purchasing gas "sippers." Such "feebate" programs generally have the same advantages and drawbacks as CAFE regulation. In particular, they do nothing to influence how much vehicles are driven and risks unintended consequences of additional driving.

4.3 Insurance Reform

It is worth mentioning one approach that could be both politically attractive, as well as providing significant incentives for reducing fuel demand, though that is not its primary motivation. We are referring to policies that encourage the transition from an automobile insurance system based on fixed annual charges to one where charges would be based on annual miles driven. Until recently, pay-as-you-drive (PAYD) insurance has been infeasible because there has been no inexpensive, reliable and tamper-proof way to monitor vehicle use, but the advent of global positioning systems (GPS) and on-board telemetering devices has reduced if not removed that obstacle. Political opposition to raising the cost of driving through pay-as-you-drive insurance may be lower than opposition to raising the gasoline tax, since it would not raise motoring costs for the average driver.[6] Its limitation is that it provides no incentives to improve fuel economy, as it penalizes miles driven rather than fuel use.

4.4 Gasoline taxes

On economic efficiency grounds alone, raising the gasoline tax would be a far better approach to reducing gasoline consumption than tightening CAFE standards, because it exploits all potential behavioral responses for reducing fuel use (e.g., Thorpe 1997, Congressional Budget Office 2002). Unlike CAFE, a fuel tax does not "work against itself" by encouraging people to drive more; instead it raises the cost of driving--and does so for both existing as well as new vehicles. Gasoline taxes encourage people to buy more fuel-efficient vehicles (and thus create incentives for automakers to produce them), to use more efficient vehicles if they have more than one, and to conserve fuel through their patterns of driving and maintenance.

The problem with gasoline taxes, of course, is not economic but political. In a country with low fuel prices and high fuel demand there is a powerful constituency lobbying against higher taxes (Goel and Nelson 1999). Nivola and Crandall (1995) have identified numerous obstacles to higher fuel taxes in the U.S. These include high levels of vehicle ownership, poorly developed mass transit systems, local land-use laws promoting low-density development and the

---

[6] Many motorists pay similar amounts for insurance each year as they do for gasoline. For example, the typical motorist drives 12,000 miles each year. At 20 miles per gallon, she buys 600 gallons annually; at $1.40/gallon, total expenditures are $840, just about the same as the $800 annual insurance premium that is typical. Suppose that only half one's annual insurance premium was based on miles traveled. Dividing $400 by 12,000 miles traveled gives an insurance cost per mile of $0.033. At 20 mpg, this is the same as a gasoline tax of nearly $0.67/gallon, or more than one and a half times the current combined federal, state and local taxes!

lack of a constituency for higher taxes which are, unlike in Europe, earmarked for ground transportation, primarily roadbuilding. Notwithstanding the intrinsic merit of a policy instrument that would simultaneously reduce oil use, global and local pollution, road congestion and accidents, it is difficult to envision a major increase in the federal gasoline tax for the foreseeable future. To the contrary, the federal tax has remained unchanged since 1993 even though the consumer price index has increased more than 20 percent since then.

4.5 Policies Addressing Specific Externalities

If our real concern is the externalities that attend gasoline consumption, such as greenhouse gas emissions, a tax on the carbon content of gasoline and all other carbon-based fuels, or a system of tradable carbon permits, would be a far more efficient way to address it than fuel economy standards. In addition to reducing gasoline consumption, a price-based or quantity-based approach to carbon would exploit options for emissions reductions from fuel substitution in electricity generation, adoption of electricity-saving technologies by firms and households, fuel conservation in industry, and so on. Indeed according to Energy Information Administration (1998), under an efficient policy to reduce carbon emissions, around two-thirds of the emissions reductions would come from the electricity sector alone; vehicle transportation does not appear to provide many low-cost options for reducing carbon emissions. Similarly, gasoline accounts for only 43% of oil consumption in the United States (Energy Information Administration 2002, Table 5.11). A broad-based oil tax would be a far more efficient policy than fuel economy standards for reducing economy-wide oil dependency as it would also encourage conservation of aviation fuel, diesel fuel, home heating oil, and other oil-based products.

5. Conclusion

There are several strong conclusions we can draw from the extensive literature pertinent to government-mandated fuel economy standards. First, there is no doubt that far more efficient tools exist for reducing oil consumption and greenhouse gas emissions. But the most efficient of these—taxes on gasoline or the carbon content of fuels, or tradable allowances for carbon emissions—face especially stiff opposition in the current political climate. Second, while it is a less efficient approach, the current regulatory edifice supporting CAFE standards would be greatly improved by making fuel economy credits transferable between passenger car and light-duty truck fleets and especially between different manufacturers. Such a change would engender much less political opposition than raising existing taxes or creating new ones.

However, if the *only* choice before us were tightening CAFE standards as they now exist or doing nothing at all, the authors of this paper could not reach agreement on a recommendation. More stringent standards would reduce oil consumption and carbon dioxide emissions, but not quite as much as one might expect because of the rebound effect. The social costs of this additional driving, moreover, could be about as large as the beneficial effects of CAFE. Throw in the pre-existing taxes on gasoline and it's quite possible that tightening CAFE could do more harm than good. This conclusion may change if the marginal benefits of reduced oil consumption and greenhouse gas emissions increase over time, or if technologies to improve fuel economy turn out to be relatively inexpensive.

Acknowledgements

We are most grateful to Brad De Long, John German, Richard Newell, Andrei Shleifer, Ken Small, Rob Stavins, Michael Waldman, Tom Walton and especially Tim Taylor for very helpful comments and suggestions on an earlier draft. Though we would prefer otherwise, the authors are responsible for all remaining errors.

References

Bernanke, Ben S., Mark Gertler, and Mark Watson. 1997. "Systematic Monetary Policy and the Effects of Oil Price Shocks." *Brookings Papers on Economic Activity*, pp. 91–157.

Bohi, Doug R., and Michael A. Toman. 1996. *The Economics of Energy Security.* Boston, MA: Kluwer Academic Publishers.

Brown, Stephen P.A., and Mine K. Yücel. 2002. "Energy Prices and Aggregate Economic Activity: An Interpretive Survey." *Quarterly Review of Economics and Finance* 42:193–208.

Congressional Budget Office. 2002. *Reducing Gasoline Consumption: Three Policy Options.* Washington, DC.

Davis, Stacy. 1999. *Transportation Energy Fact Book.* Edition 19. Center for Transportation Analysis, Oak Ridge, TN: Oak Ridge National Laboratory.

Energy Information Administration. 2002. *Annual Energy Review 2001.* Washington, DC: U.S. Department of Energy.

Energy Information Administration. 1998. *Impacts of the Kyoto Protocol on US Energy Markets and Economic Activity* (SR/OIAF/98-03). Washington, DC: U.S. Department of Energy.

Environmental Protection Agency. 2003. *Light-Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2003.* Available at: www.epa.gov/otaq/fetrends.htm.

Goel, Rajeev, and M. Nelson. 1999. "The Political Economy of Motor Fuel Taxation." *The Energy Journal* 20: 43–59.

Greene, David L. 1991. "Short-run Pricing Strategies to Increase Corporate Average Fuel Economy." *Economic Inquiry* 29 pp. 101-114.

Greene, D.L., J.R. Kahn, and R.C. Gibson. 1999. "Fuel Economy Rebound Effect for U.S. Household Vehicles." *The Energy Journal* 20: 1–31.

Hamilton, James D. 1996. "This is What Happened to the Oil Price-Macroeconomy Relationship?" *Journal of Monetary Economics* 38: 215–220.

Jones, C. 1993. "Another Look at U.S. Passenger Vehicle Use and the 'Rebound Effect' from Improved Fuel Efficiency." *The Energy Journal* 14: 99–110.

Kleit, Andrew N. 1990. "The Effect of Annual Changes in Automobile Fuel Economy Standards." *Journal of Regulatory Economics* 2: 151–172.

Kwoka, John E. 1983. "The Limits of Market-Oriented Regulatory Techniques: The Case of Automotive Fuel Economy." *Quarterly Journal of Economics* 98: 695–704.

Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee. 1997. "Oil Imports: An Assessment of Benefits and Costs." Oak Ridge, TN: Oak Ridge National Laboratory.

Mansfield, Edwin, J. Rappaport, A. Romeo, Samuel Wagner, and G. Beardsley. 1977. "Social and Private rates of Return from Industrial Innovations." *Quarterly Journal of Economics* 16: 221–240.

Miller, Ted R. 1993. "Costs and Functional Consequences of US.. Roadway Crashes." *Accident Analysis and Prevention* 25: 593–607.

Miller, Ted, David T. Levy, Rebecca S. Spicer, and Diane C. Letina. 1998. "Allocating the Costs of Motor Vehicle Crashes Between Vehicle Types." *Transportation Research Record* 1635: 81–87.

National Highway Traffic Safety Administration. 1997. *Relationship of Vehicle Weight to Fatality and Injury Risk in Model Year 1985–93 Passenger Cars and Light Trucks*. NHTSA Summary Report DOT HS 808 569. Springfield, VA.: National Technical Information Service.

National Research Council. 1992. *Automotive Fuel Economy: How Far Should We Go?* Washington, DC: National Academy Press.

National Research Council. 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*. Washington, DC: National Academy Press.

Nivola, Pietro, and Robert Crandall. 1995. *The Extra Mile*. Washington, DC: The Brookings Institution.

Nordhaus, William D. 1994. *Managing the Global Commons: The Economics of Climate Change*. Cambridge, MA: MIT Press.

Nordhaus, William D., and Joseph Boyer. 1999. *Roll the DICE Again: Economic Models of Global Warming*. Cambridge, MA: MIT Press.

Parry, Ian W.H., and Howard Gruenspecht. 2003. "Comparing Alternative Policies to Reduce Traffic Accidents." Washington, DC: Resources for the Future.

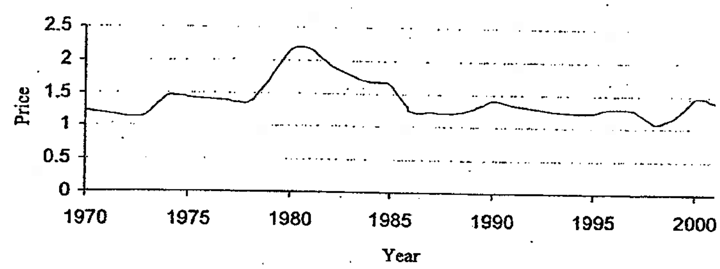
Parry, Ian W.H., and Kenneth A. Small. 2001. "Does Britain or The United States Have the Right Gasoline Tax?" Washington, DC: Resources for the Future.

Schrank, David, and Tim Lomax. 2002. *Urban Roadway Congestion: Annual Report*. Texas Transportation Institute, Texas A&M University.

Thorpe, Steven G. 1997. "Fuel Economy Standards, New Vehicle Sales, and Average Fuel Efficiency." *Journal of Regulatory Economics* 11: 311–326.

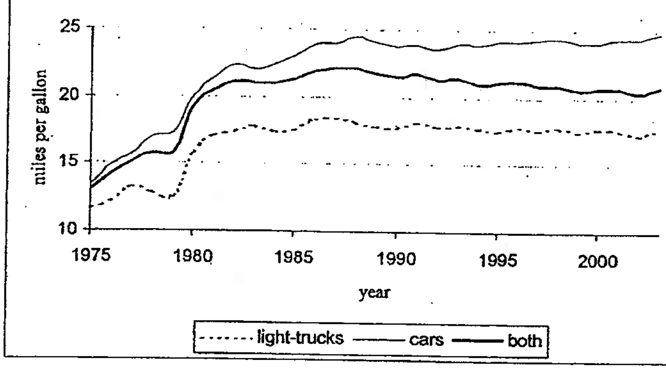
Tol, Richard S.J., Samuel Fankhauser, Richard Richels, and J. Smith. 2000. "How Much Damage Will Climate Change Do? Recent Estimates." *World Economics* 1: 179–206.

Figure 1. Gasoline Prices, 1970-2001
(all grades in $1996 per gallon)



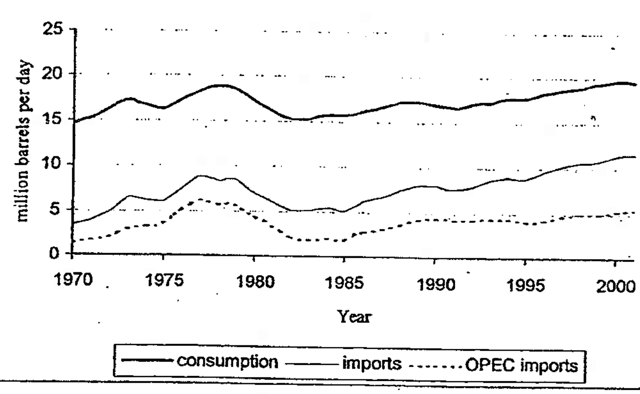
Source: Energy Information Administration (2002).

Figure 2. Fuel Economy by Model Year



Source: Environmental Protection Agency (2003).

Figure 3. Petroleum Consumption and Import Trends



Source: Energy Information Administration (2002).

IMPACTS OF LONG-RANGE INCREASES IN THE FUEL ECONOMY (CAFE) STANDARD

ANDREW N. KLEIT*

This work models the impact of higher CAFE standards on producer and consumer welfare, gasoline consumption, externalities from increased driving, and the emissions of traditional pollutants. In particular, a long-run 3.0 MPG increase in the CAFE standard is estimated to impose welfare losses of about $4 billion per year and save about 5.2 billion gallons of gasoline per year, for a hidden tax of $0.78 per gallon conserved. An 11-cent-per-gallon increase in the gasoline tax would save the same amount of fuel at a welfare cost of about $290 million per year, or about one-fourteenth the cost. (*JEL* L51, Q30)

I. INTRODUCTION AND BACKGROUND

In 1975 the U.S. government enacted legislation regulating the fuel efficiency of new motor vehicles. The apparent objective of this law is to reduce American dependence on foreign oil. After large increases in the price of petroleum in the late 1990s, and with continued conflict in the Middle East, corporate average fuel economy (CAFE) standards once again became a topic of interest. A number of proposals for changing the CAFE standards were discussed in Congress in early 2002, culminating in a defeat in the Senate of an amendment that would have required a 50% increase in the relevant CAFE standards. In place of that increase, the Senate voted to require the executive branch to examine the impact of further increases in the CAFE standard.

This work evaluates the long-term economic implications of raising the standard by 3.0 miles per gallon (MPG) above current levels. In industry parlance, this approach is sometimes referred to as "technology forcing." I choose 3.0 MPG because it reflects the focus of a May 2001 report by the vice president's task force on energy policy and because it reflects several legislative proposals in Congress.[1] The long term refers to a length of time such that manufacturers can adjust vehicle technologies and powertrain designs to reduce the amount of fuel required to move a given amount of mass or to achieve a given amount of performance or acceleration per gallon of fuel consumed. Previous work on CAFE standards, such as Kleit (1990) and Thorpe (1997), focused on short-term responses to higher CAFE standards, where technology forcing was not an option for manufacturers.

The analysis is conducted under two different scenarios. The first scenario is that CAFE standards are not binding in the current marketplace. The second scenario takes account of the current impact of CAFE standards and

*This report was funded by the General Motors Corporation. The views expressed herein are solely those of the author and not those of General Motors or of Pennsylvania State University. I thank General Motors economists Marc Robinson, Tom Walton, and Mike Whinihan and two anonymous referees for helpful comments and data, and graduate students Supawat Rangsuriyawiboon and Tina Zhang for excellent research assistance.

Kleit: Professor of Energy and Environmental Economics, The Pennsylvania State University, 507 Walker Building, The Pennsylvania State University, University Park, PA 16802-5010. Phone 1-814-865-0711, Fax 1-814-865-3663, E-mail ANK1@psu.edu

1. See "National Energy Policy," Report of the National Energy Policy Development Group (May 2001), available online at www.whitehouse.gov/energy, at pp. 4–10.

ABBREVIATIONS

CAFE: Corporate Average Fuel Economy
GM: General Motors
MPG: Miles Per Gallon
MY: Model Year
NHTSA: National Highway Traffic Safety Administration
NRC: National Research Council
OMB: Office of Management and Budget
SUV: Sport Utility Vehicle
VOC: Volatile Organic Compound

Economic Inquiry
(ISSN 0095-2583)
Vol. 42, No. 2, April 2004, 279–294

DOI: 10.1093/ei/cbh060

then analyzes the costs and benefits of increasing the standards. The costs of CAFE standards are broken down into two areas: the changes in consumer and producer surplus, and the increase in externalities caused by the increased driving that higher CAFE standards induce.

The plan of this article is as follows. Section II reviews the history of CAFE standards and briefly discusses the rationale for the regulation. Section III develops a model in which the current CAFE standard is assumed to be nonbinding. Section IV provides estimates of the impacts for a long-term 3.0 MPG CAFE increase under the assumption that the current standard is not binding. Section V then revises the model to take into account the arguably more realistic assumption that the existing CAFE standard was in fact binding. It then reports estimates for a long-term 3.0 MPG increase. Section VI provides a brief cost-benefit analysis of CAFE increases, and section VII provides a summary and conclusion.

II. BACKGROUND ON AUTOMOBILE FUEL ECONOMY STANDARDS

A Brief History of the CAFE Program

The CAFE program, as enacted in 1975, called for all manufacturers selling more than 10,000 autos per year in the United States to reach the mandated CAFE levels. CAFE levels rose from 19.0 MPG in 1978 to 27.5 MPG in 1985 and later years. A manufacturer's domestic and foreign cars are placed in separate CAFE categories, based on the domestic context of the vehicle. If a car has over 75% American context, it is considered domestic and placed in the domestic pool. Otherwise, it is placed in the foreign car pool (see Kleit 1990 for a discussion).

Light trucks (pickup trucks, sport-utility vehicles [SUVs], and minivans) were placed in a different CAFE pool than cars. When CAFE standards were originally passed, these vehicles represented a small fraction of the relevant market. By 2001, however, such vehicles made up approximately one-half of the sales of personal vehicles. In 2001, light trucks were required to reach 20.7 MPG. (There is no domestic and foreign division in the CAFE regulation for light trucks.)

If a review process finds that a manufacturer has not met the CAFE standard, that manufacturer is subject to a civil fine. The level of that fine is now set equal to $55 per car-MPG for each manufacturer. For example, if a manufacturer producers 1 million cars with an average MPG of 26.5, when the CAFE standard equals 27.5 MPG, that firm could be subject to a fine of $\$55 * 1{,}000{,}000 * (27.5 - 26.5) = \$55$ million. CAFE standards are calculated using harmonic averaging, as described below.

One important aspect of the impact of CAFE standards is that foreign firms appear to view the CAFE fine as a mere tax. Thus, several foreign firms, such as BMW and Mercedes-Benz, have routinely paid CAFE fines. In contrast, American firms have stated that they view CAFE standards as binding. Were they to violate the standards, American firms claim that they would therefore be liable for civil damages in stockholder suits. Even Chrysler, now owned by Daimler-Benz, has made it clear it is unwilling to pay CAFE fines. CAFE standards thus impose a shadow tax equal to the value of the relevant Lagrange multiplier on constrained domestic producers. Because the shadow tax of the CAFE constraint can be far higher than $55 per car-MPG, this implies that CAFE standards are not terribly binding on foreign firms and far more binding on U.S. firms.

As stated, higher CAFE standards were defeated in the U.S. Senate in early 2002. In addition, in the summer of 2002 the state of California passed legislation limiting the average output (by firm) from new automobiles of carbon dioxide per mile. Because the current method of reducing carbon dioxide emissions from vehicles is to raise fuel economy, California's law is effectively another form of CAFE regulation.

In 2003, the National Highway Traffic Safety Administration (NHTSA) issued rules-raising CAFE standards for trucks by 1.5 MPG by model year 2007. Congressional proposals to raise CAFE standards continue to be discussed in both houses of Congress.

If CAFE Is the Answer, Exactly What Is the Question?

At the margin, consumers equate the price of gasoline (the "internal" cost) with the marginal value of its consumption. In the absence of any externality, the marginal value of the use of a gallon of gas equals its price, and there is no public benefit from reducing the consumption of gasoline. Where externalities exist, economic theory is clear that the optimal policy is to set a level of stringency at which the marginal benefit of consumption of a gallon of gasoline equals the marginal cost plus the level of the relevant externality.

Thus the question becomes one of determining what the relevant externality is. A recent report of the National Research Council (NRC) attempted to quantify this externality.[2] The NRC concluded that the high level externality associated with the consumption of a gallon of gasoline amounts to $0.26 per gallon. (For the purposes of this work, I will assume this amount is both an average and a marginal benefit.)

The NRC divides the estimate into three components: $0.12 per gallon for adverse global climate effects, $0.12 per gallon for oil import effects, and $0.02 for changes in other pollution emissions at the refining level. Each estimate is subject to criticism. For example, there is a wide range of uncertainty about measuring the relevant externality for climate change. Several previous estimates imply that the climate change externality is between 1 and 4 cents a gallon, implying that the NRC may have overestimated this externality by a factor of at least three (see Toman and Shogren 2000).

The $0.12 per gallon estimate for oil import is also subject to criticism. The basis of this estimate is that the United States has market power in the purchasing of petroleum. Thus, if the United States were to reduce its demand for petroleum, the price of oil would decline. This estimate assumes, however, that CAFE changes can have a material influence on worldwide energy supply and demand. Because the United States only has about 26% of world oil consumption,[3] however, and there seems to be significant elasticity to the supply of oil, the United States does not appear to have any significant monopsony power in this market. Finally, it is unclear how reducing domestic consumption increases "oil security." Oil is traded in a world market, implying that it is difficult to insulate the United States from price shocks originating anywhere in the world. Reviewing such factors, Bohi and Toman (1996) conclude that there is no discernible oil import or energy security premium, though this question is subject to serious debate.

The NRC also allocates an externality of $0.02 per gallon for emissions of criteria pollutants from refiners. To the extent refiners are already under emission caps, it is unclear what effect higher CAFE standards would have on refinery emissions. CAFE standards, however, are not likely to reduce the emissions of traditional pollutants, volatile organic compounds (VOCs), oxides of nitrogen (NOx), and carbon monoxide (CO) from automobiles at the street level. These traditional pollutants are regulated by the Environmental Protection Agency on a per-mile basis. Thus CAFE does nothing to change the grams/mile emissions. However, if CAFE standards increase miles driven, via what is termed the rebound effect, they can be expected to increase emissions of traditional pollutants (see Espey 1997). Indeed, the results indicate that higher CAFE standards serve to increase the emissions of traditional pollutants.[4]

In addition, the gains to society from reducing the consumption of gasoline may be reduced or eliminated because gasoline is already a highly taxed good.[5] The question becomes one of how much of those funds are recycled back into funds to build and support roadways and therefore might better be viewed as user fees rather than attempts to combat externalities.

Greene (1997) asserts that a further rationale for CAFE standards is that purchasers of automobiles cannot truly estimate the fuel costs of their vehicles, and this is the "market failure" NHTSA alluded to in its 2003 truck proceedings. Nivola and Crandall (1995, 27) counter that fuel costs are prominently displayed for the consumer to read. Indeed, it is difficult to think of an automobile attribute that is better communicated to consumers. Even if consumers do have trouble obtaining and processing this information, however, it is unclear why the level of fuel economy offered in the market should be biased either above or below the efficient level.

2. See NRC, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," July 2001, online at http://books.nap.edu/html/cafe.

3. See Energy Information Administration, online at www.eia.doe.gov/emeu/ipsr/t24.txt.

4. In its 2003 rule-making procedure on CAFE standards, NHTSA calculated the relevant externality at a level for below that of the NRC value. NHTSA (2003, 44) estimated a total externality of 8.3 cents per gallon, with 4.8 cents attributed to monopsony power and 3.5 cents to supply disruption. Of course, this is subject to the same critiques made.

5. For the extent of such taxes, see www.energy.ca.gov/fuels/gasoline/gas_taxes_by_state.html.

TABLE 1
Initial Conditions—Prices and Quantities (Model Year 1999)

	Initial Totals by Class			Initial Quantities by Firms (millions of units)				Initial MPG by Firms (miles per gallon)			
Class	Prices ($000)	Quantity (million)	MPG	GM	Ford	Chrys.	Forgn.	GM	Ford	Chrys.	Forgn.
1	14.336	2.057	33.53	0.589	0.313	0.096	1.059	32.52	33.61	31.92	34.26
2	18.508	2.921	27.26	1.255	0.640	0.395	0.631	27.15	26.15	27.29	28.71
3	21.710	1.840	26.86	0.267	0.363	0.243	0.968	26.05	24.65	25.46	28.46
4	21.607	0.506	26.03	0.104	0.214	0.004	0.184	24.84	26.10	22.62	26.75
5	30.365	1.102	24.44	0.240	0.117	0.000	0.746	23.80	22.78	—	24.94
6	17.345	1.718	22.68	0.328	0.783	0.257	0.350	24.56	22.61	19.25	23.59
7	23.424	1.596	18.83	0.845	0.435	0.316	0.000	19.34	18.43	17.60	—
8	26.284	1.463	20.24	0.352	0.429	0.254	0.428	21.36	19.78	20.85	23.17
9	31.296	1.474	18.30	0.331	0.340	0.300	0.503	16.91	16.36	18.53	20.20
10	25.157	1.074	23.49	0.245	0.258	0.328	0.242	23.72	22.44	23.70	24.46
11	20.611	0.969	18.90	0.320	0.202	0.437	0.000	19.78	17.77	18.04	—

III. ASSUMPTIONS OF THE MODEL

Many of the theoretical details of this model are similar to what I used in my previous work on the impact of CAFE standards in the short run,[6] and I will not repeat that discussion here. The model begins with a set of supply and demand elasticities and initial conditions in prices and quantities. It assumes that demand and supply curves are linear. It then imposes a set of implicit CAFE taxes on each constrained firm such that in equilibrium each constrained firm reaches the relevant CAFE standard. I begin the analysis under the assumption that CAFE is not currently binding.

Base Year and Categories

Given the availability of data, model year (MY) 1999 was chosen as the base year (all dollar figures are therefore in 1999 dollars). Light vehicles were broken down into 11 categories. Cars are broken into five categories (1) small; (2) midsize; (3) large; (4) sports; and (5) luxury. Trucks are broken down into (6) small pickups; (7) large pickups; (8) small SUVs; (9) large SUVs; (10) minivans; and (11) vans.

For convenience, the data are broken down into four firms, General Motors (GM), Ford, Daimler-Chrysler (domestic production), and Other. The other firms consist of several foreign concerns, such as BMW, Honda, Mercedes-Benz, and Toyota. The relevant numbers and the MPGs for each firm/category, are presented in Table 1.[7]

Transaction prices are generated by taking the average price for each category in the GM model supplied by GM economists. Data on MPGs was also supplied by GM.

Demand Side

Elasticities and cross-elasticities between categories are calculated using the internal GM demand model. The GM model starts by using conjoint analysis (similar to, for example, Roe et al. 1996) of different vehicle attributes, based on the responses of about 4,000 "clinic" participants. These results are combined with estimates from market data and other clinics of the interactions between new and used vehicles in different segments to estimate the own-price elasticity for each nameplate. Thus one of the outputs of the model is an estimate of the change in sales for each vehicle nameplate (e.g., Chevrolet Cavalier) as its price changes.

This information is, in turn, combined with survey data on the second choices of about 90,000 new vehicle buyers from all manufacturers to estimate the cross-elasticities among nameplates in a method similar to Bordley

6. See Kleit (1990). For a similar model, see Thorpe (1997).

7. Categories are taken largely from internal GM documents, but most vehicle types fit easily into particular categories based on size, price, and whether the vehicle is a truck or a car.

(1993). These results are then aggregated into own- and cross-price elasticities for all vehicles in a given market segment. The estimates are updated every year.

The model given to me starts with base quantities and prices for MY 1999. In response to a new vector of auto prices, it will calculate a new vector of quantities sold. I therefore calculate elasticities and cross-elasticities by raising the price of all vehicles in a particular category by 1% and determining the resulting percentage change in demand, not only in that category but for all other categories as well. Because 10.0% of cars are placed in a category designated as Other in the GM model, all elasticities are multiplied by 0.90. (The calculated elasticities are presented in Table 14.)

Supply Side

Consistent with my previous work, I assume that the supply side is competitive with an elasticity of supply in the short run of 2.[8] In the longer run, supply is generally more elastic, as firms have a longer time to adjust to new conditions. Therefore, for the long-run model, I assume an elasticity of supply of 4. Because CAFE standards divide cars into domestic and foreign fleets, this essentially implies for the purpose of this model that (Daimler) Chrysler is two firms, one domestic and one foreign.

A competitive model is used for two reasons. First, the market is becoming more competitive over time. For example, in 1999 the Big 3 American firms had less than 50% of the small car market. Although the truck market in 1999 was apparently less competitive, all indications are that Asian firms will be entering these segments aggressively. Second, in the context of the 1999 market, where firms own both domestic and foreign production under the CAFE law, creating an Cournot-Nash equilibrium is more difficult. A Cournot equilibrium in this case is usually calculated by assuming that each firm has a fixed marginal cost and solving backward. In this case, however, that is unrealistic. Ford, for example, produces both Lincoln Continentals (domestic) and Jaguars (foreign). With the typical Cournot assumption and CAFE shadow taxes on Lincolns, Ford would simply shift all production out of Lincolns into Jaguars.

The differences between the results assuming a competitive model and using an oligopolistic model depend on the relative demand elasticities between larger and smaller cars (see Kleit 1990, 166–70). CAFE shadow taxes result in an increase in small car production and a decrease in large car production. When the demand for large cars is more elastic than the demand for small cars, this can reduce or even eliminate the deadweight loss associated with CAFE standards. The reason for this is that in such a market, relative to the production of large cars, there are too few small cars produced. In the demand structure employed here, however, the demand for large vehicles is generally less elastic than the demand for small vehicles.[9]

Treatment of Foreign Firms

As discussed in section II, CAFE standards call for a fine of $55 per car-MPG to be assessed to firms that do not meet the standard. Domestic firms have always asserted that for corporate policy and legal reasons, paying a fine is not an option. Therefore, the standard is modeled as binding on them. Foreign firms, however, appear to view the fine as equivalent to a tax. Several foreign firms with relatively small volumes over the years have paid this tax to the federal government. The larger foreign firms, however, have traditionally sold a mix of smaller, more fuel-efficient vehicle mixes and have not been bound by CAFE standards. This model therefore treats the foreign sector as unbound by standards.

The Technology Forcing Model

In my previous work (Kleit 1990), I assumed that manufacturers could not change the technology of their vehicles. This was done because the time period in question was short run, where technology innovation could not reach the market in time. In such circumstances, manufacturers must "mix shift" (sell fewer large cars and more small cars) to meet CAFE standards.

8. Later I will attempt to account for the likelihood that CAFE standards were already binding. I do this by first running the model "backward," employing the estimated tax as a subsidy and using short-run elasticities of supply. I then take the results as the free-market equilibrium and then run the model "forward" using the long-run elasticity of supply.

9. There are some caveats to this, as a review of Table 14 will make apparent. The own demand for medium and large cars is relatively elastic, but this is due to the high cross-elasticity of demand between the two segments. In addition, the own elasticity of demand for vans is very similar to the own demand elasticity for minivans.

The circumstances evaluated here, however, relate to the long run. In this case, firms can meet higher CAFE standards by either mix shifting or improving their fuel-efficiency technology. Therefore, in this section I present a model of technology forcing, in which firms increase the fuel efficiency of particular vehicles in response to CAFE standards.[10]

According to the method by which the statute defines a firm's average MPG, a firm that does not meet the CAFE standard has total CAFE fine equal to

$$(1)\quad F=\lambda\left(\sum_{i=1}^{T}Q_i\right)(S-MPG),\quad S>MPG,$$

where λ is the shadow cost of compliance, S is the CAFE standard, and Q_i is the quantity of each model type i sold by the firm. Under the CAFE standard, a firm's MPG is defined as a harmonic average,

$$(2)\qquad MPG=\sum_{i=1}^{T}Q_i\Big/\sum_{i=1}^{T}(Q_i/MPG_i),$$

where MPG_i is the mileage for each type of car sold by the relevant firm.

In this model, the firm faces total cost

$$(3)\qquad TC=\sum C_i(Q_i,MPG_i)+F,$$

where C_i represents the costs of one model and i is an index of models. Here the cost for MPG_i is net of consumer demand for MPG. Thus I assume that a firm will invest in fuel efficiency in a world without CAFE standards as long as the firm finds it profitable to do so, that is, consumers are willing to pay for fuel economy increases. Under this assumption, the free market net marginal cost of fuel economy is 0,[11] as the marginal cost of fuel economy will equal the marginal return of fuel economy to the consumer.

I define the cost function for any vehicle type i as

$$(4)\qquad TC_i=C_i(Q_i)+Q_iD_i(MPG_i),$$

where D_i represents the cost of fuel economy. Note that here and in following references D_i refers to the net cost of fuel economy. I will discuss how the marginal cost of fuel economy relates to the CAFE standard. Inserting the impact of fuel economy standards, total cost becomes

$$(5)\quad TC=\sum_{i=1}^{T}(C[Q_i]+Q_iD_i[MPG_i])+\left(\lambda\sum_{i=1}^{T}Q_i\right)\times\left(S-\left[\sum_{i=1}^{T}Q_i\Big/\sum(Q_i/MPG_i)\right]\right).$$

Minimizing total (net) costs with respect to MPG_i yields

$$(6)\qquad dTC/dMPG_i=Q_i(dD_i/dMPG_i)-\lambda MPG^2Q_i/MPG_i^2=O.$$

If the constraint is binding, $MPG=S$ and

$$(7)\qquad dD_i/dMPG_i=\lambda S^2/MPG_i^2.$$

This defines the level of technology forcing undergone by the firm.

Given this and MPG_i, a firm has marginal cost of production in type i of

$$(8)\quad dTC/dQ_i=dC/dQ_i+D_i(MPG_i)+\lambda\Big[(S-MPG)-\sum Q_i\Big(1\Big/\sum(MPG_i)-\Big(\sum Q_i\Big/\Big(\sum[Q_i/MPG_i]\Big)^2\Big)\times(1/MPG_i)\Big)\Big]$$
$$=dC/dQ_i+D_i(MPG_i)+\lambda[S-2MPG+(MPG^2/MPG_i)].$$

10. I note that my use of the phrase *technology forcing* may be slightly different than that generally used in the environmental literature. Here, by *technology forcing* I refer to manufacturers using technologies that they would otherwise not find profitable, rather than the standards actually inducing the creation of new technologies.

11. All of the costs of fuel efficiency used in this section and applied to subsequent sections refer to *net* costs, that is, the costs of fuel efficiency minus the benefits. The benefits are, of course, the reduced per mile cost of driving. Thus these represent economic rather than engineering costs.

TABLE 2
Gross Cost of Fuel Economy Improvement from Greene and Hopson (2003)

Data Source	Cars	Trucks
Sierra gross	$a=1097, b=7480$	$a=2102, b=6183$
Greene-Hopson-Duleep-Gross	$a=16, b=9025$	$a=219, b=8772$
NRC high cost	$a=4211, b=1430$	$a=3917, b=1020$
NRC average	$a=2461, b=2359$	$a=2529, b=1588$
NRC low	$a=1337, b=2404$	$a=1559, b=1689$

In equilibrium, $S=MPG$, which implies

$$(9)\quad dTC/dQ_i = dC/dQ_i + D_i(MPG_i) + \lambda S([S/MPG_i]-1).$$

This equation defines the CAFE-induced marginal cost of production, which is set equal to price in the next model. It also implies that an important element of the model is an estimate of λ, the shadow CAFE tax.

The model requires for both cars and trucks an estimated function

$$(10)\quad dD_i/dMPG = a\Delta MPG + b(\Delta MPG)^2,$$

where ΔMPG equals the change in MPG above the unconstrained market level. I expected both coefficients a and b to be positive. Consistent with the discussion, in this model, $D=0$ at the MY 1999 equilibrium level ($\Delta MPG=0$), making the assumption that at this point CAFE standards were just nonbinding. Without binding CAFE standards, firms should invest in fuel economy up to the point where consumers are willing to pay for it.

For estimates of the cost of fuel economy (the coefficient b above) I take up the results in from Table 1 of Greene and Hopson (2003), here presented as Table 2. Greene and Hopson assume a formula *Total Gross Costs* $= a(\Delta MPG/MPG_0) + b(\Delta MPG/MPG_0)^2$, where MPG_0 is the initial MPG. Of relevance are two curves Greene and Hopson estimated for the gross cost of fuel improvements. The curves are estimated from data from the Sierra Research Report and from 2002 data supplied by K. G. Duleep.[12] In addition, I take three curves estimated from NRC results, as presented in Greene and Hopson, although these have been subject to significant criticisms in the 2003 NHTSA truck proceedings.

To break these results down into net (of fuel economy) costs I assume MPG_0 is 27.5 for cars and 20.7 for trucks, and I assume gasoline costs $1.25 per gallon. Assuming a discount rate for fuel economy is more difficult. As Orazio et al. (2000) show, many automobile purchasers are liquidity constrained and therefore face implicit discount rates much higher than the market level. Following along this, Sutherland (2000) suggests that discount rates for these types of purchases should be raised far above market levels. The basic rationale for this is that auto purchases represent irrevocable commitments. Real options analysis, along the lines of Dixit and Pindyck (1994), implies that such commitments should attain higher interest rates. Given this line in the literature, I will take the medium point in Train's (1985) analysis and use a discount rate of 20% for consumer purchases.

Given a discount rate of 20%, I derive that drivers drive about 55,000 net present miles (this is taken from NHTSA's estimate of survival rates and miles driven for trucks) and gasoline costs $1.25 per gallon.[13] Therefore, the cost of gasoline to truck purchasers is $1.25 * 55{,}000/\text{MPG}$. The initial cost of gasoline is therefore $1.25 * 55{,}000 MPG_0$, and the change in gasoline costs is $(1.25 * 55{,}000/MPG_i) - (1.25 * 55{,}000 MPG_0)$. (Of course, a similar formula applies for cars.)

Consistent with the discussion, I then eliminate all the data where the net marginal cost (changes in the cost of innovation plus changes in the fuel cost of driving) of fuel improvement is negative. I then estimate the net cost of fuel economy as a function of $(\Delta MPG)^2$. The coefficients I derived are in Table 3.[14] For my base analysis, I take the median result from Table 3. However, I will also estimate the costs using the low and high cost scenarios from that table.

It should be noted that the long-term model implicitly assumes that the vehicle manufacturers have perfect foresight with respect to

12. See www.tc.gc.ca/envaffairs/subgroups1/vehicle%5Ftechnology%5Fold/study2/Final_report/Final_Report.htm.

13. Of course, many consumers will eventually sell their cars in the used car market. But the same reasons why the market for new cars should value fuel economy apply to the market for used cars.

14. The cost of fuel economy in Table 3 is not greatly dependent on the choice of interest rate used.

TABLE 3
Cost of Innovation Results

	Cars	Trucks
Sierra adjusted net	12.2	19.5
Greene-Hopson-Duleep adjusted net	14.2	21.93
NRC high cost	12.9	11.9
NRC average	5.81	15.35
NRC low	5.25	7.52
Median	10.07	15.24
Low	5.28	7.52
High	14.2	21.93

the demand for fuel economy several years into the future. With this perfect foresight, firms can reach all of the CAFE-mandated increases in fuel economy through technology forcing without the need to resort to far more expensive short-run mix shifting. Given the uncertainties inherent in the market for energy, which is crucial to the demand for fuel economy, the perfect foresight assumption would appear to result in a conservative estimate of the long-run cost of CAFE standards (see Kleit 1992).

The Gasoline Consumption Model

Once the relevant market equilibrium has been calculated, the impact of that market equilibrium on gasoline consumption must be estimated. Two important factors must be considered here. First, CAFE standards put some or most new car buyers in more fuel-efficient vehicles. This lowers their marginal cost of driving and causes them to drive more, a phenomenon referred to as the rebound effect. A recent study Greene et al. (1999), accepted by NHTSA in its 2003 proceedings and whose results I employ, finds that for every 10% that fuel economy is increased, driving increases 2%.

In addition, several studies imply that changing conditions in the new car market changes the actions of market participants in the used car market. Higher prices in new car markets makes used cars more attractive, reducing the scrappage rates of such cars. Here I adopt the empirical estimates I used in my 1990 article. (Because these estimates are in percentage terms, they are not obviously affected by the improvements in automobile durability.) As in my previous work, a (real) discount rate of 4% is used to analyze the net effect of gasoline savings in later years.

Pollution Impacts

To model pollution emissions, one must know the emissions per mile by model year and vintage. The difficulty here is that although regulators set the standards at one level, emissions over time are generally larger because on-board emission systems deteriorate and automobile users fail to maintain and repair them. Data on emission rates by model year and vintage were obtained from Air Improvement Resources.[15]

Unlike the rest of the model, I use 2004 pollution characteristics for the base year and years 1990–2003 for the stockage years. This is because these levels are set by government regulation, and we can have some confidence at this point in time that this will be the actual emissions from MY 2004 and later vehicles.

IV. RESULTS OF THE MODEL WHERE THE CURRENT CAFE STANDARD IS NONBINDING

Tables 4 and 5 present the results of raising the CAFE standard by 3.0 MPG for a one-year period far enough in the future so that it can be considered long run. U.S. manufacturers between them would lose about $463 million, and U.S. consumers would lose approximately $953 million. (Consumer welfare losses are calculated along the lines of Braeutigam and Noll 1984.) Total losses to producers and consumers therefore amount to $1.415 billion.

It is also necessary to calculate the increase in externalities caused by higher CAFE standards, along the lines of Table 6 CAFE standards lead to more miles driven, which leads to increased accidents and congestion. Edlin (1999, 4) estimates that accidents cost about 8 cents per additional mile driven. Lutter finds that the average congestion cost per mile of vehicle use is about 2.4 cents per mile. This is likely a conservative estimate of the congestion cost of extra driving, because the marginal cost of congestion is expected to be higher than the average cost.[16] On the other hand,

15. The emissions measured here are solely from tailpipes. As discussed, there are some questions about whether reduced gasoline consumption would imply reduced refinery pollution.

16. This is the average cost calculated as the cost of congestion-related delays and fuel costs, $78 billion, divided by aggregate vehicle miles traveled by light duty vehicles. See Lutter (2002).

TABLE 4
Price and Output Effects of CAFE Increase of 3.0 MPG for Both Cars and Trucks

	Totals by Class		Change from Initial		Output by Firms (millions of units)				Change of Output by Firms (millions of units)			
Class	Prices ($000)	Quantity (million)	Prices ($000)	Quantity (million)	GM	Ford	Chrys.	Forgn.	GM	Ford	Chrys.	Forgn.
1	14.290	2.079	−0.046	0.022	0.606	0.329	0.099	1.046	0.017	0.016	0.003	−0.014
2	18.555	2.898	0.047	−0.023	1.237	0.631	0.393	0.638	−0.018	−0.009	−0.003	0.006
3	21.766	1.829	0.056	−0.011	0.261	0.353	0.237	0.978	−0.006	−0.010	−0.006	0.010
4	21.680	0.503	0.073	−0.003	0.101	0.213	0.003	0.187	−0.003	−0.002	0.000	0.002
5	30.463	1.101	0.098	−0.001	0.233	0.113	0.000	0.755	−0.007	−0.003	0.000	0.010
6	17.330	1.705	−0.015	0.013	0.340	0.794	0.248	0.349	0.012	0.011	−0.009	−0.001
7	23.592	1.701	0.168	−0.017	0.840	0.429	0.310	0.000	−0.005	−0.006	−0.006	0.000
8	26.335	1.596	0.051	0.000	0.353	0.424	0.256	0.431	0.001	−0.005	0.002	0.003
9	31.478	1.452	0.182	−0.011	0.320	0.329	0.299	0.515	−0.011	−0.011	−0.001	0.012
10	25.105	1.082	−0.052	0.008	0.248	0.260	0.335	0.240	0.003	0.001	0.007	−0.002
11	20.755	0.953	0.144	−0.016	0.319	0.196	0.429	0.000	−0.001	−0.006	−0.008	0.000

TABLE 5
Producer and Consumer Welfare Impacts of CAFE Increase of 3.0 MPG for Cars and Trucks

	GM	Ford	Chrysler	Foreign	U.S. Total
Change in Producers Surplus ($ billion)	−0.163	−0.199	−0.101	0.220	−0.463
Change in Consumer Surplus ($ billion)	−0.953		Total U.S. Change in Surplus ($ billion)		−1.415

TABLE 6
The Impact of Standards on Externalities

		Pollution Impacts (million kgs)		
	Miles Driven (millions)	VOCs	NOx	CO
Original MY level	1,652,362	578,722	453,814	4,855,112
CAFE-induced change in MY level	26,304	9383	7684	81,621
Change in stockage levels	468	628	717	9748
Total change	26,772	10,011	8401	91,369
Percent change	1.62	1.73	1.85	1.88
External cost per unit	$0.104/mile	$1.43/kg	$1.43/kg	—
Total external cost	$2.214 billion	$0.014 billion	$0.012 billion	Total externality cost: $2.240 billion Total cost: $3.665 billion

NHTSA used a figure of 6.15 cents per mile. Here I will an average of the more conservative figures in the literature with an externality per mile of 10.4 cents (the Edlin estimate for accidents plus the Lutter estimate for congestion) with the NHTSA estimate (6.15 cents), yielding an externality cost of 8.27 cents per mile.[17]

17. The externality costs are a linear function of the costs per mile, so interested readers can choose their own externality cost level for analysis.

TABLE 7
Impact of Higher Standards on Gasoline Consumption

MY pre-CAFE gas. cons. (billion gall.)	75.045	Average cost of gasoline externality saved without and with externalities	\$0.264/\$0.700
Change in MY gas. cons. (billion gall.)	−5.425		
Change in stockage consumption (billion gall.)	0.033		
Net change in consumption (billion gall.)	−5.392	Marginal cost of gasoline externality saved (inferred) without and with externalities	\$0.582/\$0.934
Percentage change in consumption	−7.19		

TABLE 8
Welfare Effects–3.0 MPG Increase, Low- and High-Cost Scenarios
CAFE Nonbinding Binding Model

	Low-Cost Scenario	High-Cost Scenario
Changes in Producer and Consumer Surplus (\$ billion)		
Foreign firms	0.118	0.335
U.S. firms total	−0.253	−0.693
Change in consumer surplus (\$ billion)	−0.513	−1.454
Change in U.S. total surplus (\$ billion)	−0.766	−2.147
Change in gasoline consumption (billion gallons)	−5.345	−5.449
Externalities costs		
Change in miles driven	28.100	24.982
Total externality costs (\$ billion)	\$2.372	\$2.092
Total costs (\$ billion)	\$3.138	\$4.239
Average cost of reducing gasoline externality without and with externalities	\$0.143/\$0.587	\$0.394/\$0.778
Marginal cost of reducing gasoline externality (inferred) without and with externalities	\$0.329/\$0.761	\$0.854/\$1.119

In contrast, the economic value of the increases in pollution are relatively small. The federal Office of Management and Budget (OMB) values VOCs at approximately \$0.51 to \$2.36 per kg, and NOx at the same level. CO, at least according to the OMB, appears to have no marginal cost impact on the economy.[18] For purposes of this work, I choose an externality cost of \$1.43 per kg for both VOCs and NOx.

As Table 6 indicates, miles driven increase 26.3 billion, or 1.62% of MY 1999 fleet levels. Pollution impacts are also presented in Table 6. Emissions of all three traditional pollutants rise between 1.73% and 1.88%. This increase is due in large part to the rebound effect, which causes more driving and more pollution.

The net externality cost of higher CAFE standards, using the estimates presented in the preceding paragraphs, is \$2.24 billion. As Table 6 indicates, almost 99% of the increased externality costs come from accidents and congestion.

18. See www.whitehouse.gov/omb/inforeg/costbenefitreport1998.pdf.

In this model, gasoline consumption declines by 5.392 billion gallons, or 7.21% of total fleet consumption. As Table 7 indicates, the average cost of gasoline saved is \$0.264 when using only consumer and producer welfare effects and \$0.700 per gallon when externality effects are included.

The model does not explicitly generate a marginal cost per gallon saved. To generate such a figure, I ran the model 50 times, for MPG increases of 0.10 MPG at a time, for MPG increases ranging from 0.1 MPG to 5.0 MPG. I then ran a regression of total cost on gallons saved, gallons saved squared, and gallons saved cubed (costs in billion dollars, gallons saved in billions). Taking the relevant derivatives and solving for the amount of gasoline saved with a CAFE increase of 3.0 MPG yields a marginal cost per gallon saved of \$0.582 when only producer and consumer effects are considered. The total marginal cost, including externalities, is \$0.934.

Table 8 presents the simulations with both the low cost and the high cost of fuel improvement are used. Under the low-cost assumption, the marginal cost of a gallon of gasoline save is \$0.761, and with the high-cost scenario it is \$1.119. One of the factors these scenarios reveal is that the higher the welfare cost of imposing CAFE standards, the lower the externality effects. This is because as CAFE standards become more expensive for consumers, fewer cars are bought, and fewer automobile miles are driven.

All of the results of sections III and IV assume that the current CAFE standard is not binding at today's standard but would be binding for any increases. The NRC study, however, concludes that the existing standards are in fact binding, and this is consistent with my discussions with industry engineers and economists. I next turn to the case of binding current constraints.

V. THE EFFECT OF RAISING CAFE STANDARDS ASSUMING THE STANDARDS ARE ALREADY BINDING

It is conceptually possible to calculate the impact of increasing CAFE standards given that they are already binding. This is an important consideration. It is a well-known result of public finance economics that the losses due to taxation are a function of the taxes squared, rather than simply a linear function of the taxes. If CAFE standards were already binding in MY 1999, it implies that the approach used underestimates the true loss to the economy of raising CAFE standards. The first part of this section outlines the several-step process for estimating this loss. The second part applies the methodology of the first part to this market.

Modeling the Existing CAFE Shadow Tax

To make the estimation of the losses to increasing an already-binding CAFE standard, I take the following steps. First, I assume that U.S. firms in MY 1999 engaged in mix shifting but not technology forcing as a result of CAFE standards. Second, I obtained input ratios by car type for General Motors (GM) cars (with a Chevrolet Malibu having an input ratio of 1.0). I assume that the marginal costs of production for cars are a linear function of these input ratios. Third, I assume that marketing and other costs (including goodwill) constitute a constant fraction R of marginal costs. (Recall that because a competitive model is being used here, price equals [total] marginal cost.) In this context, assume that the shadow CAFE tax per MPG on vehicles is L. Also assume that the PT equals the pass-through rate, the rate at which changes in taxes are passed through to the final consumer. This implies the equation

$$(11)\quad (1+R)MC_i + PT * L(S[(S/MPG_i)-1]) = P_i,$$

where P_i equals price of car i, MC_i equals marginal cost of car i, S is the implicit CAFE standard (here it would be the fleet MPG that actually occurred in MY 1999), MPG_i is the miles per gallon achieved by car i, and $L(S[S/MPG_i] - 1)$ is the formula for per-car MPG, derived from CAFE harmonic averaging. Because I only have data on GM models (and only sufficient data on GM car models) I estimate the value of L using least squares across GM car models.

Fourth, the implicit tax L calculated here applies directly only to GM cars. I assumed that Ford and Chrysler have similar CAFE taxes on their cars. Because they currently have CAFE levels roughly equivalent to GM's, their implicit taxes may be similar to GM's. (In fact, Ford and Chrysler had slightly lower fleet MPGs than GM in MY 1999.) I also assume that the CAFE tax on trucks is equal to the tax on cars. Because there is substantial evidence that U.S. manufacturers have had more difficulty reaching their CAFE standards for trucks rather than cars, this assumption serves to underestimate the relevant loss to society.

Fifth, given an estimated CAFE shadow tax L, I ran the 1999 model (the one presented already) backward, setting the CAFE tax at $-L$, generating a new equilibrium in prices and quantities.

Sixth, the supply curves calculated for the initial model will have the relevant values subtracted from its intercept terms to recalibrate the model for the unconstrained scenario.

At this point I have a new initial no-CAFE or free market equilibrium with demand and supply curves. The model can then be run for firms to reach a particular CAFE standard. Changes in welfare from this equilibrium to the higher CAFE standard equilibrium can then be calculated.

An additional problem comes from the multiproduct nature of the market. This implies that taxes on one type of vehicle will impact prices of other types of vehicle. Given

TABLE 9
Pass-Through Rates by Car Type

Type	Description	MPG	dP/dt
1	small car	32.52	−0.839
2	midsize car	27.15	0.040
3	large car	26.05	0.228
4	sports car	24.84	0.783
5	luxury car	23.80	0.876
6	small truck	24.56	−1.168
7	large truck	19.34	0.246
8	small suv	21.36	−0.300
9	large suv	16.91	1.171
10	minivan	23.71	−1.253
11	van	19.78	0.007

TABLE 10
Estimating the 1999 CAFE Tax
(t-Statistics in Parentheses)

	Model 1	Model 2
Constant	0.725 (0.39)	—
Input ratio	15.271 (1.48)	15.835 (49.36)
CAFE tax	1.986 (1.12)	1.652 (2.32)
R^2	0.951	0.950
Number of observations	25	25

this, it takes some work through manipulation of supply and demand matrices to determine the pass-through rates for each type of vehicles. This work is available on request.

For this model, the results of the impact of a CAFE tax by vehicle type for GM cars are presented in Table 9. For every dollar of CAFE shadow tax, dP/dt represents the pass-through rate for GM. For example, every dollar of CAFE tax reduces the price of small cars by about $0.84, and increases the price of luxury cars by about $0.88.

Table 10 presents the estimation results for the level of the CAFE tax in MY 1999. The dependent variable is the price in thousand dollars of GM cars. The two independent variables are the input ratios and the coefficient on the CAFE tax, as implied by Table 9. The model is run with and without a constant term. However, the estimated constant term in model 1 has a very low t-statistic. Model 2, which is run without a constant, has large t-statistics and a high R^2 (0.950). The estimated shadow tax from this estimation is

TABLE 11
Welfare Effects–3.0 MPG Increase
CAFE Already-Binding Model

Changes in Producer Surplus ($ billion)	Change from MY 1999 Equilibrium	Change from No-CAFE Equilibrium
General Motors	−0.309	−0.337
Ford	−0.346	−0.385
Chrysler	−0.148	−0.154
Foreign firms	0.192	0.16
U.S. firms total	−0.8038	−0.876
Change in consumer surplus ($ billion)	−1.097	−1.07
Change in U.S. total surplus ($ billion)	−1.901	−1.946

$1,652/MPG, and this is the level used in the simulations to follow.[19]

Welfare Implications of Raising CAFE Standards Given that Standards Are Already Binding

Tables 11 and 12 present the welfare changes as a result of raising the long-run CAFE standard 3.0 MPG above the 1999 level, assuming a short-run tax of $1,652 was binding in MY 1999 and using the median cost of fuel technology scenario. As expected, the harm to the economy is greater than that in the previous long-term model.

Total producer and consumer welfare losses to society from the MY 1999 equilibrium of raising the long-run CAFE standard 3.0 MPG are $1.901 billion. Miles driven rise 26.151 billion from the MY 1999 equilibrium. Emissions of VOCs, NOx, and, CO rise between 1.74% to 1.91% from the MY 1999 equilibrium. Total externality costs are $4.089 billion. Consumption of gasoline is reduced 5.240 billion gallons. The average cost of reducing a gasoline externality is $0.363 from the MY 1999 equilibrium including only producer and consumer welfare terms. Including externalities, the average cost of reducing a gasoline externality is $0.780.

Total U.S. producer and consumer losses from the no-CAFE equilibrium of raising

19. The resulting changes in MPG because of this negative tax of $1,652 per MPG are −1.05, −1.42, and −0.55 MPG for GM, Ford, and Chrysler cars, and −0.59, −0.50, and −0.40 MPG for GM, Ford, and Chrysler trucks.

TABLE 12
Externality and Gasoline Consumption Effects–3.0 MPG Increase
CAFE Already-Binding Model

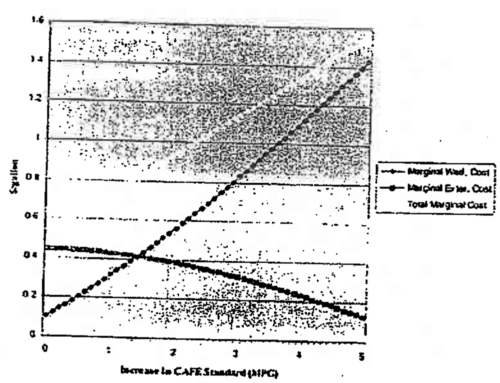
	Change from MY 1999 Equilibrium	Change from No-CAFE Equilibrium
% Change in VOC emissions	1.74	2.12
% Change in NOx emissions	1.87	2.23
% Change in CO emissions	1.91	2.26
Change in gasoline consumption (billion gallons)	5.240	6.600
Change in miles driven (billions)	26.151	32.792
Total externality costs ($ billion)	2.188	2.743
Total costs ($ billion)	4.089	4.689
Average cost of reducing gasoline externality without and with externalities	$0.363/$0.780	$0.295/$0.710
Marginal cost of reducing gasoline externality (inferred) without and with externalities	$0.695/$1.050	

the long-run CAFE standard 3.0 MPG are $1.946 billion. Miles driven rise 32.792 billion miles from the no-CAFE equilibrium. Emissions of VOCs, NOx, and, CO rise from 2.12% to 2.26% from the no-CAFE equilibrium. The total cost of CAFE related externalities is $2.743 billion. Gasoline consumption falls 6.6 billion gallons from the no-CAFE equilibrium. The average cost of reducing a gasoline externality from the no-CAFE equilibrium is $0.295, including only producer and consumer welfare losses, and $0.710 when including all losses.

Similar to before, I use the results of Table 11 to estimate the marginal cost of saving a gallon of gasoline. I generate 50 data points, increasing the required fuel economy 0.1 MPG each time. I then regress gallons saved, linear, quadratic, and cubic terms on total cost. I then can estimate the derivative of total cost with respect to gallon saved. Given this, the marginal cost of reducing a gasoline consumption externality is $0.695 in producer and consumer welfare terms, and $1.050 when including externalities.

Figure 1 graphs out the marginal cost per gallon saved as a function of the increase in MPG. When the CAFE increase is 0.0 MPG (form current levels), the marginal welfare cost per gallon saved is estimated to be $0.10, with the externality cost estimated to be $0.440, for a total welfare cost per gallon saved of $0.54. As the CAFE standard increase, total marginal cost increases. However, the marginal external cost decreases. As discussed, this results because as the cost to consumers of CAFE standards increases, fewer automobiles are purchased, and therefore fewer miles are driven.

FIGURE 1
The Marginal Cost of a Gallon Saved
Base-Case Scenario (Standards Already Binding)



Results for low and high cost scenarios are laid out in Table 13. In the low-cost scenario the marginal cost of fuel economy is estimated to be $0.827 per gallon, whereas that marginal cost is estimated to be $1.283 in the high-cost scenario.

VI. COST-EFFECTIVENESS AND COST-BENEFIT ANALYSIS

This section asks two questions. First, do the benefits of CAFE standards exceed the costs? For benefits, I use the NRC figure of

TABLE 13
Low- and High-Cost Scenarios, CAFE Binding Model, Changes from No-CAFE Equilibrium

Changes in Producer and Consumer Surplus ($ billion)	Low-Cost Scenario	High-Cost Scenario
Foreign firms	0.084	0.2478
U.S. firms total	−0.480	−1.3096
Change in consumer surplus ($ billion)	−0.574	−1.6360
Change in U.S. total surplus ($ billion)	−1.053	−2.946
Change in gasoline consumption (billion gallons)	6.568	6.638
Externalities costs		
Change in miles driven	34.098	31.290
Total externality costs ($ billion)	2.820	2.618
Total costs ($ billion)	3.873	5.564
Average cost of reducing gasoline externality without and with externalities	$0.160/$0.429	$0.444/$0.838
Marginal cost of reducing gasoline externality (inferred) without and with externalities	$0.388/$0.827	$1.018/$1.283

$0.26 per gallon of externality, although one could use NHTSA's far lower figure of 8.3 cents.[20] Second, are CAFE standards cost-effective? In this context, this means comparing the cost of CAFE standards to the cost of a gasoline tax that would generate equivalent gasoline savings.

The discussion so far indicates the impact of a CAFE increase of 3.0 MPG. For cost-effectiveness measures, I need to know the level of the tax that would generate equivalent gasoline savings. Pindyck (1979) indicates that the elasticity of demand for gasoline over a five-year period is approximately 0.49, a number that is roughly halfway between short-run and long-run estimates by Dahl and Sterner (1991). I will also assume a base gasoline consumption in the United States of 120 billion gallons at an initial price of $1.25 per gallon and that the demand curve for gasoline is linear in shape. Using these assumptions, it is straightforward to determine the gasoline tax needed to reach the desired level of gasoline savings.

Economic theory indicates under these assumptions that the total loss to society from such a tax equals one-half the tax times the reduction in the number of gallons of gasoline consumption, and the marginal loss equals the level of the relevant tax.[21] Thus the comparison here is between the gasoline savings of a one-year CAFE standard increase of 3.0 MPG (announced credibly several years in advance so that new technologies could be introduced) and an increase in the gasoline tax years in advance that has long-run impacts in the same year as the hypothetical CAFE standard increase.

Assuming that CAFE standards were not binding in 1999, the median cost scenario implies that an increase in the CAFE standard of 3.0 MPG decreased gasoline consumption by 5.392 billion gallons, for an average cost per gallon in the base scenario of $0.70. This is about 2.7 times the $0.26 per gallon benefit estimated by the NRC.

Using estimates for the long-run elasticity of gasoline demand, a tax of $0.115 per gallon would be required to induce savings of 5.392 billion gallons of gasoline. Thus a tax would impose an average cost on society of half of that amount, or $0.05775 per gallon. In other words, the 3.0 MPG increase in the CAFE mandate would cost society 12 times more than a gasoline tax increase saving the same amount of fuel. At the margin, saving a gallon of gasoline costs the economy $0.93 in this scenario, far higher than the $0.26 benefit estimated by the NRC.

20. Note that in performing a cost-benefit analysis of CAFE standards, the price of gasoline will equal the marginal benefit of consumption. Thus the value of the externality associated with the consumption of gasoline will constitute the net benefit to society from reductions in gasoline consumption.

21. I do not subtract from the cost of a gasoline tax the economic impact on accidents and congestion resulting from the decrease in miles driven.

TABLE 14
Initial Conditions—Demand Elasticities

Class	Parameters Used in CAFE Simulation Demand Elasticity Table										
	1	2	3	4	5	6	7	8	9	10	11
1 small car	−2.808	0.423	0.063	0.018	0.000	0.036	0.027	0.009	0.009	0.009	0.000
2 medium car	0.684	−3.528	1.107	0.027	0.018	0.018	0.018	0.036	0.045	0.054	0.009
3 large cars	0.270	1.926	−4.500	0.027	0.216	0.009	0.054	0.018	0.063	0.054	0.009
4 sport car	0.549	0.423	0.324	−2.250	0.009	0.090	0.198	0.045	0.108	0.018	0.000
5 luxury car	0.045	0.405	1.062	0.009	−1.737	0.000	0.027	0.045	0.189	0.072	0.009
6 small truck	0.162	0.099	0.000	0.009	0.000	−2.988	0.702	0.045	0.054	0.009	0.009
7 large truck	0.063	0.072	0.018	0.009	0.000	0.234	−1.548	0.027	0.090	0.018	0.036
8 small SUV	0.216	0.279	0.099	0.027	0.009	0.090	0.351	−3.645	0.747	0.108	0.072
9 large SUV	0.117	0.243	0.171	0.018	0.018	0.054	0.387	0.414	−2.043	0.234	0.108
10 minivan	0.081	0.171	0.063	0.000	0.009	0.009	0.045	0.027	0.135	−2.286	0.180
11 van	0.027	0.036	0.009	0.009	0.000	0.009	0.054	0.036	0.072	0.387	−2.385

Perhaps the more appropriate scenario is the one that compares a mandated CAFE increase to a binding CAFE constraint in 1999. In that scenario, gasoline consumption falls by 5.240 billion gallons per year, for an average cost in the base scenario of $0.78 per gallon. This is three times the NRC estimated benefits.

This same reduction in gasoline consumption could be achieved by a gasoline tax increase of $0.111 cents per gallon, implying social costs of 0.05505 per gallon. Thus, the $0.78 cost per gallon of CAFE standards would be approximately 14 times more costly to society than the tax that would save the same amount of gasoline. At the margin, a gallon of gasoline saved by CAFE standards costs $1.05, four times the NRC estimated benefits.

VII. CONCLUSION

Increases in CAFE standards above current levels are neither cost-effective nor cost-beneficial. Assuming that current CAFE standards are already binding, in the long-run median cost scenario, increasing the CAFE standard by more than 3.0 MPG would impose additional costs of over $4 billion per year and reduce gasoline consumption by about 5.2 billion gallons per year. This amounts to about 12 times the cost of a gas tax increase that would save the same amount of fuel. The long-term marginal costs of the 3.0 MPG mandate would exceed the additional benefits of avoided gasoline consumption externalities by a factor of four to one.

CAFE standards suffer from a wealth of difficulties. They discriminate against American production, they encourage people to drive more, and retain their used vehicles longer, increase automobile accidents and congestion, the emissions of several pollutants, and they have the potential for serious consumer injury. If policy makers desire to reduce energy consumption, it would seem they should focus their attention on raising energy taxes.

REFERENCES

Bohi, D. R., and M. A. Toman. *The Economics of Energy Security*. Boston: Kluwer, 1996.

Bordley, R. F. "Estimating Automotive Elasticities from Segment Elasticities and First Choice/Second Choice Data." *Review of Economics and Statistics*, 75, 1993, 455–62.

Braeutigam, R. R., and R. G. Noll. "The Regulation of Surface Freight Transportation: The Welfare Effects Revisited." *Review of Economics and Statistics*, 66, 1984, 80–87.

Dahl, C. A., and T. Sterner. "Analyzing Gasoline Demand Elasticities: A Survey." *Energy Economics*, 13, 1991, 203–10.

Dixit, A. K., and R. S. Pindyck. *Investment under Uncertainty*. Princeton, NJ: Princeton University Press, 1994.

Edlin, A. S. "Per Mile Premiums for Auto Insurance." National Bureau of Economic Research Working Paper No. W6934, 1999. Cambridge, MA.

Espey, M. "Pollution Control and Energy Conservation: Complements or Antagonists? A Study of Gasoline Taxes and Automobile Fuel Economy Standards." *Energy Journal*, 18, 1997, 23–38.

Greene, D. L. "Why CAFE Worked." *Energy Policy*, 1997, available online at www.cta.ornl.gov/Research/teep/CAFEabs.html.

Greene, D., and J. Hopson. "An Analysis of Alternative Forms of Automotive Fuel Economy Standards for the United States." Transportation Research Board Annual Meeting CD, 2003.

Greene, D. L., J. R. Kahn, and R. C. Gibson. "Fuel Economy Rebound Effect for U.S. Household Vehicles." *Energy Journal*, 20, 1999, 1–31.

Kleit, A. N. "The Effect of Annual Changes in Automobile Fuel Economy Standards." *Journal of Regulatory Economics*, 2, 1990, 151–72.

———. "Enforcing Time-Inconsistent Regulations." *Economic Inquiry*, 30, 1992, 639–48.

Lutter, R. *CAFE: The Numbers behind the Story.* AEI-Brookings Joint Center for Regulatory Studies, 2002, available online at www.aei-brookings.org/policy/page.php?id=84.

National Highway Traffic Safety Administration. "Light Truck Average Fuel Economy Standards." 2003. Available online at www.nhtsa.gov/cars/rules/ruleings/CAFE05-07/index.html.

Nivola, P. S., and R. W. Crandall. *The Extra Mile.* Washington, DC: Brookings, 1995.

Orazio, A., P. Goldberg, and E. Kyriazidou. "Credit Constraints in the Market for Consumer Durables: Evidence from Micro Data on Car Loans." NBER Working Paper W7694, 2000. Cambridge, MA.

Pindyck, R. S. *The Structure of World Energy Demand.* Cambridge, MA: MIT Press, 1979.

Roe, B., K. J. Boyle, and M. F. Teisl. "Using Conjoint Analysis to Derive Estimates of Compensating Variation." *Journal of Environmental Economics and Management*, 31, 1996, 145–59.

Sutherland, R. J. "'No Cost' Efforts to Reduce Carbon Emissions in the U.S.: An Economic Perspective." *Energy Journal*, 21, 2000, 89–112.

Thorpe, S. G. "Fuel Economy Standards, New Vehicle Sales, and Average Fuel Efficiency." *Journal of Regulatory Economics*, 11, 1997, 311–26.

Toman, M. A., and J. Shogren. "How Much Climate Change Is Too Much: An Economic Perspective." *Climate Change Issues Brief* 25, Resources for the Future, 2000.

Train, K. "Discount Rates in Consumers' Energy Related Decisions: A Review of Literature." *Energy*, 10, 1985, 124–125.

JOINT CENTER
AEI-BROOKINGS JOINT CENTER FOR REGULATORY STUDIES

Do Regulations Requiring Light Trucks To Be More Fuel Efficient Make Economic Sense?

An Evaluation of NHTSA's Proposed Standards

Randall Lutter and Troy Kravitz

Regulatory Analysis 03-2

February 2003

Randall Lutter is a fellow with the AEI-Brookings Joint Center and a resident scholar at the American Enterprise Institute. Troy Kravitz is a researcher at the Joint Center. They thank Bob Hahn, Andrew Kleit and David Schrank for helpful comments. The authors are solely responsible for the views in this paper. Dr. Lutter can be reached at rlutter@aei.org.

JOINT CENTER

AEI-BROOKINGS JOINT CENTER FOR REGULATORY STUDIES

In response to growing concerns about understanding the impact of regulation on consumers, business, and government, the American Enterprise Institute and the Brookings Institution have established the AEI-Brookings Joint Center for Regulatory Studies. The primary purpose of the center is to hold lawmakers and regulators more accountable by providing thoughtful, objective analysis of existing regulatory programs and new regulatory proposals. The Joint Center builds on AEI's and Brookings's impressive body of work over the past three decades that has evaluated the economic impact of regulation and offered constructive suggestions for implementing reforms to enhance productivity and consumer welfare. The views in Joint Center publications are those of the authors and do not necessarily reflect the views of the staff, council of academic advisers, or fellows.

All AEI-Brookings Joint Center publications can be found at www.aei.brookings.org

Executive Summary

The National Highway Transportation Safety Administration (NHTSA) recently proposed increasing the fuel economy of new light trucks by 1.5 miles per gallon for vehicles produced in model year 2007. NHTSA's analysis of its proposal implausibly concludes that the benefits to consumers are more than twice the costs to manufacturers, ignoring effects on the environment or dependence on foreign oil.

NHTSA's proposal has several serious flaws. It wrongly presumes that manufacturers cannot produce items that consumers are willing to buy, even though they could make money by doing so. Its analysis uses overly optimistic measures of net benefits. In addition, NHTSA neglects the adverse effects from the increased driving induced by the proposal. By lowering the cost of driving, NHTSA's proposal increases vehicle miles traveled, thereby boosting traffic accidents and congestion. The increase in the costs of accidents and congestion fully offsets and probably outweighs the social benefits resulting from greater fuel economy.

If NHTSA is interested in a cost-effective way of reducing gasoline use, it should consider giving consumers better information about fuel economy of new vehicles, or suggest a modest gasoline tax. A penny per gallon levy would conserve more fuel in 2007 than NHTSA's proposal, while lowering, rather than increasing, traffic congestion and accidents.

Do Regulations Requiring Light Trucks To Be More Fuel Efficient Make Economic Sense?
An Evaluation of NHTSA's Proposed Standards

Randall Lutter and Troy Kravitz

Introduction

The National Highway Transportation Safety Administration (NHTSA) recently proposed more stringent fuel efficiency standards for light trucks—the minivans, sports utility vehicles, and pickup trucks that now make up about half of the new vehicle market. In its proposal to increase the fuel economy of new light trucks by 1.5 miles per gallon by 2007, NHTSA tentatively concludes such a standard is "within the technological feasibility and economic practicability of the primary contributors to the light truck market, is capable of being met without substantial product restrictions, vehicle weight reductions or adverse effects on air quality, and will enhance the ability of the nation to conserve fuel consumption and reduce its dependence on foreign oil."[1] To justify its proposal, NHTSA presents estimates that the proposed rule would cost manufacturers $370 million for vehicles produced in model year 2007 while saving consumers $790 million in fuel costs.[2] In fact, NHTSA's proposed rule is likely to impose significant costs on vehicle manufacturers and buyers *without* bringing net benefits to society at large.

NHTSA's justification for its proposal has three key deficiencies. First, NHTSA implausibly concludes that the benefits to consumers from more fuel-efficient vehicles are twice the costs to producers, even before estimating any effects on the environment or energy dependence. This conclusion is a red flag event for economists: It implies that

[1] See U.S. Department of Transportation (2002c, p. 77019).
[2] See Department of Transportation (2002a, Executive Summary).

manufacturers cannot produce items that consumers are willing and able to buy, even though they could make money by doing so! If true, it means that NHTSA should prefer better labeling and information disclosure instead of mandatory new fuel economy standards.

Second, NHTSA's analysis inappropriately overstates net benefits. It ignores the value to consumers of reduced performance associated with better fuel economy. It assumes consumers can finance new vehicle purchases at interest rates lower than those available in the market. In addition, it entirely neglects the increased risk of highway fatalities that would ensue from reductions in vehicle weight.

Third, and most importantly, NHTSA ignores the adverse effects of the increased driving that will result from mandating more fuel-efficient vehicles. The greater fuel efficiency will increase driving by reducing its cost, and additional driving will contribute to additional risk of traffic accidents and greater traffic congestion. These two adverse effects fully offset and probably outweigh the social value of reduced gasoline consumption.[3]

NHTSA has authority – and an obligation – to consider the full economic implications of alternative standards. Congress has directed the Secretary of Transportation to set fuel economy standards that are "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in [a] model year."[4] But NHTSA, in view of the legislative history, has interpreted its mandate to mean it must consider manufacturers' "asserted capabilities, product plans and economic conditions against their projected capabilities, the need for the nation to conserve energy

[3] Emission of nitrogen oxides, which the Environmental Protection Agency regulates on a per-mile basis, would also rise as a result of increased vehicle use, but this effect is too small to matter for our analysis.

and the effect of other regulations (including motor vehicle safety and emissions regulations) and other public policy objectives."[5] Thus, NHTSA sets corporate average fuel economy (CAFE) standards at the "maximum feasible level" based upon "technical feasibility, economic practicability, the effect of government motor vehicle standards on fuel economy and the need of the U.S. to conserve energy."[6]

To the extent that NHTSA has discretion under this legal standard, it has to adopt the least burdensome regulation consistent with meeting its regulatory objectives and must design regulations in the most cost-effective manner, according to President Clinton's Executive Order 12866 on Regulatory Planning and Review – which is still in force.[7] Yet our economic analysis indicates that NHTSA's proposed new fuel economy standard is unnecessarily burdensome and far from cost-effective.

To reduce gasoline consumption in the U.S. cost-effectively, NHTSA should pursue the plain implication of its own analysis and consider improved fuel economy labels on light trucks for sale. If it seeks greater cuts in gas consumption, NHTSA should ask Congress to raise taxes on gasoline.[8] Taxes would be more cost-effective than more stringent CAFE standards because they would decrease traffic accidents and congestion, while more stringent CAFE would raise them.

After describing the existing program regulating fuel efficiency standards, we describe three problems with NHTSA's economic analysis. We show that mandatory standards will not benefit consumers, we then demonstrate that NHTSA's analysis overstates net benefits, and finally we show that the unintended adverse effects of

[4] See 49 *United States Code* 32902.
[5] See U.S. Department of Transportation (2002c, p. 77019).
[6] See Department of Transportation (2002b, Abstract).
[7] See Clinton (1993).

additional driving will fully outweigh and probably exceed the social benefit of reduced fuel consumption. We conclude with some policy recommendations.

Background

After the Arab oil embargo of 1973 caused a sharp increase in the price of oil, the federal government – in 1975 – began mandating minimum levels of fuel efficiency for new motor vehicles.[9] It set CAFE standards for light trucks (pickups, vans and sport utility vehicles with gross vehicle weight ratings of 8,500 pounds or less) of 17.2 miles per gallon (mpg) for model year (MY) 1979. Over time the standards have slowly increased, with the current level for light trucks of 20.7 mpg in place since MY 1996.[10]

Different CAFE standards for light trucks and passenger cars have been responsible for important changes in the vehicle fleet over the years. Minivans and sport-utility vehicles (SUVs) have become more popular partly because they are subject to the light truck standard, which is significantly less stringent than the one applied to passenger cars: 20.7 instead of 27.5 mpg.[11] In 1999 light trucks constituted approximately 48 percent of new vehicle sales,[12] and in 2000 light trucks were estimated to be 45 percent of the vehicle fleet.[13] Manufacturers have virtually discontinued making traditional big station wagons in part because they are classified as passenger cars subject to the higher standard.

During the 1990s, Congress prevented NHTSA from issuing more stringent CAFE standards. Through a rider to the Department of Transportation's annual

[8] See Appendix A for a comparison of taxes and CAFE standards. An increase in gasoline taxes need not increase the size of government if coupled with decreases in other taxes.
[9] Firms that did not comply paid a fine. In years 1983-1998 these fines amounted to roughly $475 million. See Congressional Research Service (CRS) (2002a, pp. CRS-2).
[10] See Department of Transportation (2002a, Section I).
[11] See CRS (2002a, Summary).
[12] See CRS (2002b, pp. CRS-2).

appropriations bill for fiscal year 1996, Congress stipulated that funds could not be spent for preparing, proposing, or promulgating any increased CAFE standards.[14] In legislation for fiscal year 2001, Congress requested that the National Academy of Sciences and the Department of Transportation examine the effectiveness of CAFE standards.[15]

NHTSA has developed a proposed new CAFE standard for light trucks increasing gradually to 22.2 mpg for MY 2007 using data from the NRC and vehicle manufacturers.[16] While an increase of 1.5 mpg from the current standard does not seem large, the CAFE standard has risen so much so fast only once—for MY 1983, when a long period of high gasoline prices sustained consumers' interest in more fuel efficient vehicles.[17]

Despite fairly broad academic criticism of CAFE standards,[18] lawmakers have supported CAFE as a politically attractive means to limit U.S. dependence on foreign oil, to conserve fuel, and increasingly, to reduce emissions of carbon dioxide, a greenhouse gas. Senators Feinstein (D-CA) and Snowe (R-ME) recently proposed requiring light-duty trucks to meet the same fuel economy standards as passenger cars by 2011: 27.5 mpg.[19] This latest proposal is similar to legislation introduced by Sens. Kerry (D-MA),

---

[13] See CRS (2002a, pp. CRS-7).
[14] See Department of Transportation (1995, Section 330).
[15] See National Academy of Sciences (2002, p. 1). The National Research Council (NRC) examined the effectiveness and impact of CAFE standards for the National Academy of Sciences (NAS). See NAS (2002, Executive Summary).
[16] The estimated laboratory fleet averages under the two alternatives exceed the baselines since some manufacturers' plans for future models already exceed both 20.7 and 22.2 mpg. The estimated laboratory baseline with a 20.7 mpg minimum is 21.83 mpg for MY 2007; the estimated laboratory level after the proposed minimum of 22.2 mpg is 22.35 mpg for MY 2007. See Department of Transportation (2002a, Executive Summary). On-road fuel economy is assumed to be 85 percent of the laboratory test level. See Department of Transportation (2002b, Appendix A).
[17] The current high prices in the U.S. are expected to fall to long-term average levels when tension in the Persian Gulf and Venezuela subside.
[18] See, for example, Crandall and Graham (1989), Coate and VanDerHoff (2001), Dunham (1997), Kleit (2002), and Winston and Shirley (1998).
[19] See *Washington Post* (2003).

Hollings (D-SC) and McCain (R-AZ) less than a year ago. The Kerry-Hollings-McCain bill sought to increase the CAFE standard to 36 mpg by 2015 for most passenger vehicles, including light-duty trucks.[20] While the NHTSA proposed rule is less stringent, requiring 22.2 mpg by 2007, it is silent about what CAFE standard will be required in subsequent years.

Economic Analysis

We describe in turn three problems with NHTSA's proposal.

1. Mandatory fuel economy standards cannot benefit informed consumers.

A threshold question is whether more stringent regulations can offer net benefits to consumers, ignoring any environmental or energy security concerns. According to the Preliminary Economic Assessment of NHTSA, "The benefits [of improved fuel economy] are determined mainly from fuel savings over the lifetime of the vehicle."[21] In particular, NHTSA estimated that the benefits are $794 million for model year 2007 while the costs to vehicle manufacturers are only $373 million.[22] By themselves, these estimates imply there is a fundamental shortcoming—a failure—in the motor vehicle market, because these net benefits occur even in the absence of any environmental effects or dependence on foreign oil.

The only plausible cause of the market failure implied by NHTSA's analysis is inadequate consumer information about vehicle quality, and, in particular, the value of

[20] See Holly (2002).
[21] See Department of Transportation (2002a, Executive Summary).
[22] Using the data contained in the Preliminary Economic Assessment, we were unable to exactly reproduce NHTSA's calculations. We assumed that NHTSA employed a rebound effect of -.15 and on-road fuel economy 15 percent below fuel economy measured in laboratory tests. Under these assumptions, we were able to replicate NHTSA's analysis to within 2 percent. See Department of Transportation (2002a, Section VII).

fuel economy.[23] Although NHTSA cites "the difficulty and time involved in calculating the total savings associated with purchasing a more fuel-efficient vehicle"[24] as a possible reason why consumers have not demanded greater fuel efficiency, such difficulties are insufficient to cause a market failure from inadequate information. Consumers are already well informed about the costs of fueling new vehicles. All new vehicles must display federally mandated stickers with government estimates of city and highway miles per gallon on their windows.[25] Furthermore, these stickers, as illustrated in Appendix B, already provide estimates of the annual fuel costs, so that differences in fuel costs among different vehicles can be easily compared with differences in loan payments. The stickers even recommend comparing the fuel economy and fuel cost of different vehicles in the "FREE FUEL ECONOMY GUIDE available at the dealer."[26]

Moreover, there is little reason to believe that consumers systematically underestimate the price of gasoline. Consumers are likely to know the price of gas better than the price of, say, eggs, milk or other commodities. Among consumer products bought on a weekly basis, only gasoline is advertised on big street signs. This practice has arisen because drivers can fill up at one gas station pretty much as easily as at another and because drivers choose gas stations largely on the basis of price. Gasoline of a given octane is a homogeneous commodity sold by specialized retail outlets that do not bundle it with other goods. As a result, the returns to advertising are relatively large and service stations post prices prominently.

---

[23] See, for example, OMB (2003) and OMB (1996, Section I.A) for explanations of market failure. The other types of market failure (monopoly and externalities) are inapplicable.

[24] See Department of Transportation (2002c, p. 77023).

[25] See 40 CFR § 600.306-86.

[26] See Appendix B.

In addition, spending on gasoline is large enough to get the full attention of consumers when they buy new vehicles. The average household spent $1,055 on gasoline and motor oil in 1999, when gasoline prices were relatively low.[27] This figure represents nearly 3 percent of total out-of-pocket expenditures ($37,027), an amount roughly comparable to total spending on meat, fish, poultry, eggs and dairy products combined, which was $1,071.[28] Yet gasoline is different than these items. If the price of beef or turkey or salmon rises, consumers can switch to pork, chicken, catfish, or even beans to avoid bearing the full burden of the higher prices. On the other hand, to avoid higher gasoline prices, consumers must curtail car trips, use public transit, or join carpools, all of which are inconvenient or time-consuming options. Thus, consumers can shift to less expensive alternatives to gasoline only with considerable difficulty. As a result, they have additional incentives to buy fuel-efficient cars if they are at all concerned about minimizing unnecessary spending.

NHTSA effectively concludes that a market failure exists without direct evidence or other information of such a failure. Although economists have long recognized the possibility that markets fail because of inadequate information about the attributes of products,[29] NHTSA cites no surveys indicating that consumers fail to understand the implications of greater fuel economy for lifetime operating costs. Moreover, NHTSA ignores the considerable indirect evidence summarized above that no such failure exists.

If, contrary to the preceding empirical evidence, consumers were in fact ignorant about the fuel economy of vehicles they are considering purchasing, then the appropriate policy response would not be to mandate greater fuel economy, but, rather, to supply

[27] See U.S. Census Bureau (2001, No. 659).
[28] See U.S. Census Bureau (2001, No. 659).

consumers with the information they lack. New guidance on economic analysis recently proposed by the Office of Management and Budget (OMB) makes this point. It states, "If intervention is contemplated to address a market failure that arises from inadequate or asymmetric information, informational remedies will often be the preferred approach."[30] The guidance document goes on to explain, "A regulatory measure to improve the availability of information (particularly about the concealed characteristics of products) provides consumers a greater choice than a mandatory product standard or ban."[31] In essence, mandatory standards deny consumers access to vehicles they would prefer to buy. The superiority of providing information, instead of mandating standards has been broadly accepted for years. For example, in 1996 OMB advised, "If intervention is necessary to address a market failure arising from inadequate or asymmetric information, informational remedies will often be the preferred approaches."[32] It then elaborated, "As an alternative to a mandatory product standard or ban, a regulatory measure to improve the availability of information (particularly about the concealed characteristics of products) gives consumers a greater choice."[33] Thus, a plain reading of NHTSA's own evidence about the costs and benefits of more stringent CAFE standards – if it were adequately supported by facts – would point to a regulatory approach very different from its proposed mandatory standards. NHTSA should follow the implications of its own economic analysis and consider measures to improve consumer information, instead of mandating new fuel economy standards.

---

[29] See Akerlof (1971).
[30] See OMB (2003, p. 5516).
[31] See OMB (2003, p. 5516).
[32] See OMB (1996, Section II.6).
[33] See OMB (1996, Section II.6).

Of course another possible interpretation of NHTSA's economic analysis is that it contains errors.

2. NHTSA's measures of net benefits are too optimistic.

NHTSA uses measures of social cost that are optimistic in three respects. First, it uses engineering-based estimates that exclude the foregone value to the consumer of the declines in performance associated with better fuel economy. NHTSA acknowledges "There is often a trade-off between performance and fuel economy"[34] and that "All [such] tradeoffs necessarily involve costs to the extent that reduced engine size or performance reduces the value of the vehicle to the consumer."[35] But NHTSA "has not attempted to value these performance reductions,"[36] although it does "plan to do so in the event (and to the extent) that such tradeoffs will result from the final rule."[37] NHTSA's neglect of the value of performance reductions is one key reason that it has underestimated the costs and overestimated the net benefits of its proposal. NHTSA should analyze the cost of forgone performance.

Second, NHTSA may have underestimated how much consumers discount future fuel savings. While NHTSA estimated that the improved fuel economy will raise vehicle costs by only $47 per vehicle,[38] some buyers may be unable to borrow this much at the 7 percent interest rate (net of inflation) assumed by NHTSA.[39] The Consumer Expenditure Survey indicates that annual interest rates from 1984-1995 were 10 percent on used cars

---

[34] See Department of Transportation (2002a, Section IV).
[35] See Department of Transportation (2002a, Section IV).
[36] See Department of Transportation (2002a, Section IV).
[37] See Department of Transportation (2002a, Section IV).
[38] See Department of Transportation (2002a, Table VI-3).
[39] Although recent data indicate vehicle loan interest rates are currently less than 7 percent, we feel that current economic conditions do not represent expected future interest rates.

and 7.6 percent on new cars.[40] Using an interest rate of 10 percent to discount future fuel savings would reduce NHTSA's calculated fuel savings by $15 per vehicle.

There is some evidence that consumers use much higher discount rates in evaluating future energy savings. Train (1985) cites evidence from national surveys suggesting consumers require rates of return as high as 26 and 32 percent before investing in improvements in thermal integrity of their homes. The key rationale for such high discount rates is that investments in energy efficiency are irreversible and uncertain.[41] While we have no direct evidence about the appropriateness of these rates to vehicle fuel economy, we do note that the irreversibility and uncertainty associated with such investments suggests that consumers may impose rates of return significantly above more typical discount rates such as 7 or even 10 percent. NHTSA should discount future fuel savings at the rate appropriate for vehicle buyers.

Third, NHTSA's analysis fails to address the possibility that manufacturers will use lighter, less crashworthy vehicles, saying simply "We believe that manufacturers will meet the proposed CAFE levels without any meaningful deviation from the planned performance and weight of their vehicles."[42] Yet a recent National Research Council committee concluded: "The downweighting and downsizing that occurred in the later 1970s and early 1980s, some of which was due to CAFE standards, probably resulted in an additional 1,300 to 2,600 traffic fatalities in 1993."[43] Although the NRC did not ascribe a particular portion of these deaths to CAFE, Crandall and Graham's earlier analysis suggested that CAFE standards led to "several thousand additional fatalities over

[40] These interest rates are net of inflation. See Attanasio, Goldberg, and Kyriazidou (2000). Attanasio and co-authors find that credit constraints are binding for some groups in the population, particularly young and low-income households, but the implications of this finding for our purposes are complicated and unclear.
[41] See Dixit and Pindyck (1994) for a discussion.

the life of each model-year's cars."[44] Similarly, Coate and VanderHoff found that the greater weight of light trucks were a significant cause of lower fatality rates in single-vehicle accidents associated with light truck use.[45] In multiple vehicle accidents they found that the protective effects of light trucks to their occupants outweighed any increase in fatalities to occupants of other vehicles.[46] Their results indicate that increased use of light trucks prevented approximately 2,000 highway fatalities between 1994 and 1997.[47]

Use of lighter materials is the only important fuel economy measure that NHTSA does not carefully analyze in its proposal. NHTSA's neglect of these costs (and vehicle buyers' aversion to lighter vehicles) may help explain how it is able to conclude (wrongly) that the benefits to consumers of more stringent CAFE exceed the costs to producers. NHTSA should include the possible use of lighter materials in its analysis of costs.

Given the lack of credible estimates about the adverse effects of more stringent CAFE on manufacturers and consumers, it is useful to pursue an alternative analytical approach that sidesteps this issue entirely. In the following section we ignore costs to producers associated with making vehicles more fuel-efficient and the benefits to consumers of greater fuel economy. Instead we focus only on the externalities of the proposed regulation. This approach works provided we stick only to external benefits and costs and exclude those already internal to the decision-making of vehicle purchasers or manufacturers. In particular we address whether the social costs of additional driving

---

[42] See Department of Transportation (2002a, Section IV).
[43] See NAS (2002, p. 111). Two committee members dissented.
[44] See Crandall and Graham (1989, p. 98).
[45] See Coate and VanderHoff (2001, p. 24).

resulting from the improved fuel economy are large relative to the social value of the fuel savings that the proposed standard might provide.

3. Net social effects of NHTSA's proposal are nil or even detrimental.

NHTSA acknowledges that more stringent CAFE standards will reduce the cost of driving and thereby increase the annual miles driven per vehicle.[48] Further, its economic analysis concedes that the increased driving is likely to worsen congestion and traffic accidents. Without any empirical justification, however, NHTSA simply asserts that the increases in the social costs associated with congestion and traffic accidents will be "slight."[49] In fact, this effect appears sufficiently large to outweigh the social value of reduced gasoline consumption.

Econometric studies suggest that a 10 percent reduction in the price of fuel increases miles driven by 1 percent to 3 percent.[50] The NRC and NHTSA used these estimates to infer that a 10 percent reduction in fuel cost attributable to mandatory fuel economy standards would increase miles driven in the range of 1 percent to 2 percent.[51] The Congressional Budget Office recently stated that potential gasoline savings from a rise in fuel economy would probably be offset by increases in driving of about 2 percent.[52]

Estimates of the social costs of additional vehicle miles traveled – especially increased traffic accidents and congestion – permit calculations of the social costs of the

---

[46] See Coate and VanderHoff (2001, p. 24).
[47] See Coate and VanderHoff (2001, p. 24).
[48] See Department of Transportation (2002a, Section VII).
[49] See Department of Transportation (2002a, Section VII, endnote 4).
[50] See CBO (2002, Chapter 2, footnote 11), Greene (1992), Greene, et al, (1999), and Goldberg (1998).
[51] See Department of Transportation (2002a, Section VII, endnote 5), and NAS (2002, p. 96).
[52] See CBO (2002, p. 19). The different estimates between NHTSA and CBO appear to be more a result of differing emphasis and/or interpretation of surveyed studies and less a product of surveying different studies.

additional driving induced by the higher CAFE standard. First note that the relative change in VMT, (that is, $\Delta VMT / VMT^0$), can be calculated as the product of the percentage change in fuel costs per mile and the rebound effect:

$$(1) \quad \Delta VMT / VMT^0 = r \; ((GPM^1 - GPM^0) / GPM^0)$$

where GPM^0 is the gallons per mile in the baseline, GMP^1 is the gallons per mile after the change in policy, and r is the elasticity of vehicle miles driven with respect to the cost of gasoline per mile.[53]

The proposed change in the CAFE standard from 20.7 to 22.2 mpg for MY 2007 would increase the estimated fuel economy level for a representative MY 2007 light truck from 21.83 to 22.35 mpg as measured in laboratory tests.[54] Since NHTSA and NRC assume on-road fuel economy to be 85 percent of laboratory fuel economy, on-road miles per gallon will rise from 18.56 to 19.0 mpg, an increase in fuel economy of 2.3 percent.[55] Assuming a rebound effect of -0.15, equation (1) implies an increase in VMT of 0.35 percent. For trucks that would have been driven 10,000 miles per year in the absence of a new CAFE standard, the increase in mileage, ΔVMT, would be about 35 miles per year.[56] This increased mileage results from a CAFE standard that saves 10.6 gallons of gasoline.[57] If the rebound effect were -.2, annual mileage would increase by 46 miles and fuel savings would be 10.0 gallons.

---

[53] This equation is consistent with NHTSA's approach. See Department of Transportation (2002a, Section VII).

[54] Estimated laboratory fuel economy levels exceed the standards since some manufacturers' plans for future models already exceed the proposed baseline.

[55] [100 x (((1 / 19.00) – (1 / 18.56)) / (1 / 18.56)) =2.38]. EPA's assumption of a 15 percent fuel economy "gap" may be understated given recent research. The Department of Energy, for example, assumes a fuel economy gap of 24.5 percent for light trucks and large SUVs. See Department of Energy (2000).

[56] As shown in Appendix C, the annual mileage that light trucks are driven is irrelevant for our conclusions; our assumption that mileage is 10,000 is solely for convenience.

[57] The gallons saved are $VMT^1 \times GPM^1 - VMT^0 \times GPM^0 = 10035 \times (1/19.00) - 10000 \times (1/18.56) = 10.63$.

To assess the external social costs of this increase in driving we focus on the cost of accidents and the cost of congestion.[58]

Extra driving boosts traffic accidents. A key question is how much of these costs drivers take into account in their decisions about how and how much to drive. Aaron Edlin of the University of California at Berkeley estimates the marginal cost of accidents to be about 8 cents per additional mile driven,[59] and the insured cost of accidents to be approximately 4 cents per mile driven. Edlin shows insurance premiums are (virtually) invariant with respect to miles driven, although the accident costs vary nearly proportionately with mileage.[60] Thus, in deciding how much to drive, drivers have no incentive to take into account the additional accident costs covered by insurance companies.

Cliff Winston and Chad Shirley present a higher estimate of marginal accident costs – about 20 cents per mile in 2000 dollars – but suggest that the only cost that travelers do not bear are the delays they cause other travelers.[61] They do not distinguish, however, between drivers and other travelers (for example, those that may not be responsible for an accident). They also do not address the lack of a direct relationship between miles driven and insurance premiums. These estimates and others in the literature are summarized in Table 1.

---

[58] NHTSA also considers the increased emissions of local air pollutants but finds these to be so small as to be negligible. See Department of Transportation (2002a, Section VII). Some analysts have suggested that we need also to consider the benefits of the increased driving induced by more fuel-efficient vehicles, but these are much too small to matter, as we show in Appendix E.
[59] See Edlin (1999, p. 4). Costs are calculated in fiscal year 2000 dollars.
[60] Researchers have found that fatalities are positively related to vehicle miles traveled. See Coate and VanderHoff (2001, p. 24).
[61] See Winston and Shirley (1998, p. 64.)

Table 1

Accident Cost Estimates

Author	Cost per mile (2000$)		Comment
	Marginal Cost	Average Cost	
Edlin (1999, p.4)	7.8¢		National cost. (The insured cost of 4¢ per mile is external to decision to drive.)
Levinson et al (1996)	6.3¢	5.6¢	Costs estimated by combining an accident rate model with costs per accident.
MacKenzie et al (1992)		3.6¢	Social cost not borne by drivers for the United States.
Parry and Small (2002, p.19)	3¢		External accident cost for the U.S.
Winston and Shirley (1998, p.64)	20¢		Analysis of the largest 116 urbanized areas (with pop. >200,000).

Extra driving also exacerbates delays on crowded roads. According to a commonly cited source, traffic delays cost Americans nearly $70 billion per year in lost time and extra fuel.[62] Researchers have estimated incremental congestion costs between a penny and a quarter per vehicle per mile in key U.S. cities and significantly more on important arteries.[63] To calculate congestion costs in urban areas, we use data from the Texas Transportation Institute (TTI). Its *2002 Urban Mobility Report* implies that the congestion cost among the 75 urban areas studied is about 15 cents per vehicle mile

[62] Congestion costs for 2001—$78 billion—are in Table A-9, *2001 Urban Mobility Report*, Texas Transportation Institute. For 2002, an updated version of the same report gave only $67.5 billion due to a slightly different sample size, an improved speed estimating procedure, and the California recession, which lessened increased congestion. The studies conclude that congestion is increasing.

[63] See, for example, Winston and Shirley (1998, p. 58). California Environmental Protection Agency (1996, p. 6-14) reports values as high as $0.99 per mile on some peak corridors and as low as 12 to 30 cents per mile throughout the Bay Area morning peak (2000$).

traveled during workdays.[64] The average congestion cost per mile of vehicle use is a low-ball estimate of the marginal congestion cost of extra driving.

Congestion costs may be lower because some research suggests that the disutility of congestion, that is, the hassle of traffic jams, is less than assumed by the *2002 Urban Mobility Report*, which figures the cost of travelers' time to be $12.85 per hour.[65] Congestion costs may be lower than these estimates because people choose the location of home and work according to their willingness to put up with traffic jams. In particular, Calfee and Winston estimate that the average willingness to pay to avoid an hour of congestion ranges from 14 to 26 percent of the gross hourly wage, with an average of 19 percent.[66] In 1998, the average gross wage in 64 metropolitan areas was $33,381 per year, or about $16.70 per hour, assuming 2000 hours of work each year.[67] Using this estimate of the hourly wage, Calfee and Winston's estimate of the willingness to pay to avoid congestion suggests that the per hour costs of congestion delays in the TTI sample should be about a fifth of $16.70, or $3.30. This lower estimate of the value of time suggests the average congestion costs in the *2002 Urban Mobility Report* would fall to about 5 cents per mile.[68]

To estimate the marginal costs of congestion, we use data from the *Urban Mobility Report*, which reports, in addition to congestion costs (delays and fuel), data on

---

[64] To derive this, note that the total annual cost of congestion-related delays averaged across the 75 cities is 900 million. See Schrank and Lomax (2002, p. A-61). The total daily vehicle miles traveled on freeways, expressways and principal arteries is 24.6 million. See Schrank and Lomax (2002, p. A-71). Since the report assumes 250 working days per year, the average cost of congestion-related delays among these 75 cities is $0.146 per mile: 900 / (24.6 x 250) = $.146 per mile.
[65] See Schrank and Lomax (2002, p.B-1).
[66] See Calfee and Winston (1988, p.91).
[67] See U.S. Census Bureau (2001, p.436).
[68] It is important to note that in the *Urban Mobility Report* congestion cost is composed of lost time and lost fuel. Adjustments to the wage rate only affect the former. Total congestion costs averaged $900 million in the 75 urban areas: $780 million delay cost and $120 million fuel cost. [(780 x .25 + 120) / (24.6 x 250) = $.05 per mile]. See earlier footnote.

vehicle miles traveled (VMT) and lane miles available on freeways and principal arterial roads for select urban areas with populations over 100,000. In particular, we consider data for the years 1994 though 2000 that TTI staff believes are most reliable.[69] After adjusting these data to be consistent with Calfee and Winston and also Winston and Shirley, we estimate marginal costs of congestion of about 23 cents in 2000. We describe the derivation of these estimates in Appendix D.

This estimate is high but close to the range of the published literature contained in Table 2, given the disparate geographic regions, peak periods being considered and methods. Our estimate of 23 cents per mile is different from other results because it represents the increase in congestion costs during the peak period from an additional mile driven during the day. Thus it may significantly understate the incremental congestion costs resulting from additional vehicle miles during the peak period. Other studies have focused on this measure of incremental congestion costs.

Our estimate is closest to Winston and Shirley's finding of 26 cents per mile. Our treatment of the value of reduced travel time is consistent with theirs. Their estimates of the value of travel time range from 8 to 49 percent of average hourly earnings depending on the length of the commute and whether it occurred during peak or off-peak periods, and they state that their findings appear to be consistent with those of Calfee and Winston.[70] Winston and Shirley examined the largest 116 urbanized areas—those with populations over 200,000, and found optimal tolls of 26 cents per mile for the most congested cities during peak periods, although some cities and times reach almost 60

---

[69] We are grateful to David Schrank, who sent us a file for these data and advised us to choose these years.
[70] See Winston and Shirley (1998, p.38).

cents per mile.[71] Estimates from the TTI database should be lower because it includes smaller cities—75 urban areas with populations over 100,000—such as Boulder, Colorado and Brownsville, Texas. They should be higher, however, because they represent the increase in peak congestion costs associated with an increase in driving at any time of the day. In addition, they include the costs of commercial vehicle delays, which amount to about a fifth of the total congestion costs.[72] Finally, about 5 cents of this estimate reflects fuel costs, an item excluded from the other marginal cost estimates.

To derive an estimate of nationally representative congestion costs, we make several adjustments. The *2002 Urban Mobility Report* studied areas with 50 percent of the U.S. population, but only 18 percent of national VMT occurred in the areas and days assessed by the Report.[73] Assuming conservatively that marginal congestion costs elsewhere and on non-business days are a fifth of those that we estimate using data from the *Report*, a marginal estimate of national congestion cost would be 8.0¢ per mile.

These estimates and others from the published literature appear in Table 2.

---

[71] In 2000 dollars. See Winston and Shirley (1998, pp. 59-61).
[72] Private communication from David Schrank.
[73] The average population in year 2000 for the 75 urban areas studied in the 2002 Urban Mobility Report was 1,770,000, implying a total sample population of 132,750,000. See Schrank and Lomax (2002, p. 55). According to the Census Bureau, United States civilian population was 273,936,000 in 2000. See Census Bureau (2001, No. 1). Total vehicle miles traveled in year 2000 for the 75 urban areas during the days and times used in the study were over 461 billion miles. See Schrank and Lomax (2002, p. 71). This figure is about 18 percent of total U.S. VMT in 2000, which was 2,523 billion miles. See Department of Transportation (2001, Table VM-1).

Table 2

Congestion Cost Estimates

Author	Cost per mile (2000$)	Comment
California Environmental Protection Agency, p.6-14	Bay Area morning peak = 12¢ As high as 99¢ on some main corridors in Calif.	Examined congestion costs in California metropolitan areas.
Calfee and Winston (1998, pp.93-94)	12¢	Surveyed the 10 most populous urban areas in the mid-1990s; estimate assumes cost of traffic delays is 20 percent of gross wage.
Parry and Small (2002, p.17)	3.5¢	Marginal congestion cost averaged across the United States.
Schrank and Lomax (TTI) (2001, p.44)	Avg. cost = 19¢[74]	Estimated congestion costs for 68 urban areas. Assumes cost of travelers' time is $12.43 per hour.
Schrank and Lomax (TTI) (2002, p.61)	Avg. cost= 15¢	Estimated congestion costs for 75 urban areas. Assumes cost of travelers' time is $12.85 per hour.
Winston and Shirley (1998, p.59)	26¢, although individual cities and times range from 1¢ to 59¢	For the most congested cities during peak travel times. Analysis was performed for the largest 116 urbanized areas (those with pop. >200,000).

*Note: costs per mile are optimal tolls, except for the Schrank and Lomax estimates.

To estimate the additional societal cost (ΔS) from the additional driving we use

(2) $\Delta S = \Delta VMT \times$ (accident costs + congestion costs)

Given the range of uncertainty in congestion and accident costs, we assume first that the marginal costs of accidents and congestion are 3¢ and 8¢ per mile, respectively.

---

[74] The *2001 Urban Mobility Report* found total congestion costs to be $77,790 million and total annual VMT of 433,160 million miles (assuming 250 working days) for the 68 urban areas. This works out to an average congestion cost of 17.96¢ in 1999 (18.56¢ in 2000 dollars). See Schrank and Lomax (2001, pp. 44-52).

In this case ΔS would be $3.85 for a vehicle driven 10,000 miles.[75] Since the improvement in fuel economy would save about 10.6 gallons for the year, the social cost of the extra driving is 36¢ per gallon of gasoline saved.[76] With lower estimates, say 2¢ and 6¢ respectively, the social cost of the extra driving is about 26¢ per gallon of gas saved. In a recent study Parry and Small report marginal congestion cost averaged across the United States to be 3.5¢ per mile, and external accident costs to be 3¢ per mile.[77] Given their rebound effect of -.22,[78] the social cost per gallon saved is 34¢. Thus, we estimate that the external social costs from the additional driving induced by NHTSA's proposal to range from 26¢ to 36¢ per mile.

To judge whether these are high or low requires an assessment of the social value of saving fuel. Both NHTSA and NRC have provided estimates, which appear in Table 3.

[75] $5.25 = 35 miles (5¢ + 10¢).
[76] $.50 per gallon = 5.25 / 10.6.
[77] See Parry and Small (2002, pp. 17-19).
[78] See Parry and Small (2002, p. 20).

Table 3

Estimates of the Social Benefits of Reducing Gasoline Consumption
(cents per gallon)

	NHTSA	NRC	Comments
Lower world oil prices	4.8¢	12¢	NHTSA and NRC both believe U.S. influence over oil price is small or limited.[79]
Reduced risk of oil supply disruptions and security component	3.5¢		NRC estimate represents combined effects of the monopsony, supply and security components.
Reduced environmental damages from refinery and distribution emissions	Emission of "some pollutants may decline ... while others may increase."[80]	2¢	
Reduced greenhouse gas emissions	NHTSA presented no quantitative estimate of the reductions in greenhouse gas emissions resulting from its proposal.[81]	12¢	According to NRC, "This figure is significantly higher than typical estimates."[82]
Total	8.3¢	26¢	

According to NHTSA, the value of externalities per gallon of gasoline is 8.3¢, of which 4.8¢ represents savings because reduced U.S. demand lowers world oil prices. Another 3.5¢ is for the decreased exposure to oil supply disruptions. Our estimates of external social costs from more driving, 26¢ to 36¢ per mile, are much greater than NHTSA's estimate of the value of fuel saving.

Considering a different set of effects than those quantified by NHTSA, the NRC arrives at a societal benefit of 26¢ per gallon saved. The social costs of the additional

[79] See Department of Transportation (2002a, Section VII) and NAS (2002, p. 86).
[80] See Department of Transportation (2002a, Section VII).
[81] See Department of Transportation (2002a, Section VII, Environmental Costs of Oil Refining and Consumption).

driving are as large or larger than this estimate, which includes an estimate of the benefits of controlling greenhouse gas emissions that the NRC describes as "high."

The social cost of the additional driving induced by more fuel-efficient vehicles thus fully offsets and probably outweighs the societal benefit of saving fuel. Importantly, this result holds for any level of driving, as shown in Appendix C. Thus, taking into account the external benefits and the most significant external costs of NHTSA's proposal – including global warming, disruptions to U.S. oil supply, traffic accidents, and congestion – the proposed CAFE revision provides no net benefits and is in fact likely to have detrimental effects.

Policy Choice

NHTSA's proposed rule is inconsistent with Executive Order 12866 on Regulatory Planning and Review. The 1993 E.O. stipulates that

> Each agency shall tailor its regulations to impose the least burden on society, including individuals, businesses of differing sizes, and other entities (including small communities and governmental entities), consistent with obtaining the regulatory objectives, taking into account, among other things and to the extent practicable, the cumulative costs of regulations.[83]

Since NHTSA is justifying its proposal by an alleged inefficiency in vehicle markets, rather than concerns about the environment, or dependence on foreign oil, it needs to consider the plain implications of its view. A regulation mandating greater information disclosure would surely be less burdensome than one requiring more fuel-efficient vehicles. Printing more detailed fuel economy labels and allowing consumers to choose what vehicles to drive would be less expensive than mandating a fuel economy standard. Even a gasoline tax, by reducing instead of increasing driving and the

---

[82] See NAS (2002, p. 85).
[83] See Clinton (1993, Section 1(b)(11)).

associated traffic accidents and congestion, is likely to reduce gasoline use at lower social cost than CAFE. To comply with E.O. 12866, NHTSA should consider proposing better fuel economy labels, and, if it seeks greater reductions in gasoline use, a modest gas tax.

Conclusion

To conserve gasoline, the National Highway Transportation Safety Administration recently proposed to increase the stringency of corporate average fuel economy standards for light trucks by 1.5 miles per gallon for model year 2007. While the proposal does not seem very stringent, in fact it is the biggest increase since the early 1980s. More importantly, it is a very inefficient way of achieving the stated regulatory goal of reducing fuel use.

To defend its proposal, NHTSA points to the fuel savings that consumers would experience as a result of more stringent CAFE, claiming this benefit alone outweighs costs to producers. This argument presumes that vehicle manufacturers interested in making money are unable to build vehicles that consumers are willing and able to pay for, even though they could profit by doing so. This presumption – which is unsupported by any direct evidence – is the cornerstone of NHTSA's proposal.

NHTSA reached its conclusions that consumer benefits outweigh costs to vehicle manufacturers by using an analytic approach that overstates benefits to consumers and understates costs to manufacturers. If NHTSA's analysis were correct it would mean– according to OMB's own guidelines – that NHTSA should prefer regulations that give consumers better information about fuel economy, an approach that NHTSA has not even considered.

While NHTSA's proposal will reduce gasoline consumption, it will also increase driving. The social costs of the increased driving – accidents and traffic jams – will fully offset the social benefits of reduced fuel consumption and will probably outweigh them.

If NHTSA is interested in a cost-effective way of reducing gasoline use, it should consider improving the fuel economy stickers on new vehicles to give consumers more information. It could also suggest a modest gasoline tax, which would provide incentives to all drivers to conserve fuel—the purported goal of NHTSA's proposal. Indeed, a tax of a penny per gallon effective in 2007 would reduce gasoline use by about as much as NHTSA's proposed standard[84]—while reducing instead of increasing driving and the associated risks.

[84] See Appendix A.

References

Akerlof, George. 1970. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *The Quarterly Journal of Economics* 84, No. 3, pp.488-500.

Attanasio, Orazio, Pinolopi Goldberg, Ekaterini Kyriazidou. 2000. "Credit Constraints in the Market for Consumer Durables: Evidence From Micro Data on Car Loans." Working Paper 7694 for National Bureau of Economic Research.

Calfee, Jack, and Clifford Winston. 1998. "The Value of Auto Travel Time: Implications for Congestion Policy." *Journal of Public Economics* 69, pp.83-102.

California Environmental Protection Agency. 1996. "Transportation Pricing Strategies for California: An assessment of Congestion, Emissions, Energy, and Equity Impacts." 92-316. Sacramento, CA: California Air Resources Board.

Clinton, William J. 1993. "Executive Order 12866: Regulatory Planning and Review." *Presidential Documents*. Washington, DC: General Printing Office. http://www.epa.gov/fedrgstr/eo/eo12866.htm

Coate, Douglas, and James VanderHoff. 2001. "The Truth About Light Trucks." *Regulation* 24, No. 1, pp.22-27.

Congressional Budget Office. 2002. *Reducing Gasoline Consumption: Three Policy Options*. Washington DC: General Printing Office. ftp://ftp.cbo.gov/39xx/doc3991/11-21-GasolineStudy.pdf (downloaded: 1/14/03)

Congressional Research Service. 2002a. Issue Brief for Congress IB90122: *Automobile and Light Truck Fuel Economy: The CAFE Standards*. Washington, DC: General Printing Office. http://www.ncseonline.org/NLE/CRSreports/03Jan/IB90122.pdf (downloaded: 1/14/03)

Congressional Research Service. 2002b. Report for Congress RS20298: *Sport Utility Vehicles, Mini-Vans and Light Trucks: An Overview of Fuel Economy and Emissions Standards*. Washington, DC: General Printing Office. http://www.cnie.org/nle/crsreports/RS20298.pdf (downloaded: 1/14/03)

Crandall, Robert W., and John D. Graham. 1989. "The Effect of Fuel Economy Standards on Automobile Safety." *Journal of Law and Economics* 32, No. 1, pp.97-118.

Delucchi, Mark A. 2000. "Environmental Externalities of Motor-Vehicle Use in the US." *Journal of Transport Economics and Policy* 34, No. 2, pp.135-168.

Dixit, Avinash, and Robert S. Pindyck. 1994. *Investments Under Uncertainty*. Princeton, NJ: Princeton University Press.

Dunham, Wayne R. 1997. "Are Automobile Safety Regulations Worth the Price: Evidence from Used Car Markets." *Economic Inquiry* 35, No. 3, pp.579-589.

Edlin, Aaron S. 1999. "Per Mile Premiums for Auto Insurance." Working Paper W6934 for National Bureau of Economic Research.

Federal Reserve Board. 2002. *Statistical Release: Finance Companies*. Table G-20. http://www.federalreserve.gov/releases/g20/Current/g20.pdf

Goldberg, Pinelopi Koujianou. 1998. "The Effects of the Corporate Average Fuel Efficiency Standards in the US." *Journal of Industrial Economics* 46, No. 1, pp.1-33.

Greene, David L. 1997. "Why CAFE Worked." Tennessee: Oak Ridge National Laboratory.

Greene, David L. 1992. "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" *The Energy Journal* 13, No. 1, pp.117-143.

Greene, Dávid L., James R. Kahn, Robert C. Gibson. 1999. "Fuel Economy Rebound Effect for U.S. Household Vehicles." *Energy Journal* 20, No. 3, pp.1-31. http://www.iaee.org/documents/vol20(3).pdf

Greenspan, Alan, and Darrel Cohen. 1996. *Motor Vehicle Stocks, Scrappage, and Sales*. Washington, DC: Federal Reserve Board.

Hayashi, Yoshitsugu, Kenneth Button, Peter Nijkamp, eds. 1999. *Environmental Analysis and Economic Policy* 4, pp.285-303.

Holly, Chris. 2002. "McCain Brokers Senate Deal to Boost Fuel Economy Standards." *Energy Daily*. March 11, 2002.

Inside Energy. 2002. "Bush Administration Proposes Boost in Fuel Economy." December 16, 2002.

Kayser, Hilke A. 2000. "Gasoline Demand and Car Choice: Estimating Gasoline Demand Using Household Information." *Energy Economics* 22, No. 3, pp.331-348.

Kleit, Andrew N. 2002. "CAFE Changes, By the Numbers." *Regulation* 25, No. 3, pp.32-35. http://www.cato.org/pubs/regulation/regv25n3/v25n3-8.pdf

Leiby, Paul N., Donald Jones, T. Randall Curlee, Russell Lee. 1997. "Oil Imports: An Assessment of Benefits and Costs." Tennessee: Oak Ridge National Laboratory. http://pzl1.ed.ornl.gov/ORNL6851.pdf

Levinson, D., D. Gillen, A. Kanafani, J.M. Mathieu. 1996. *The Full Cost of Intercity Transportation—A Comparison of High Speed Rail, Air and Highway Transportation in California.* UCB-ITS-RR-96-3. Berkeley, CA: University of California at Berkeley, Institute of Transportation Studies.

Lutter, Randall. 2002. *CAFE: The Numbers Behind the Story.* Policy Matters 02-13. Washington, DC: AEI-Brookings Joint Center for Regulatory Studies. http://www.aei-brookings.org/policy/page.php?id=84 (downloaded: 1/14/03)

MacKenzie, J.J., R.C. Dower, D.D.T. Chen. 1992. *The Going Rate: What It Really Costs to Drive*. Washington, DC: World Resources Institute.

McFarland, W.F., and M. Chui. 1987. *The Value of Travel Time: New Elements Developed Using a Speed Choice Model.* Transportation Research Record 1116, TRB. Washington, DC: National Research Council.

Miller, Ted. 1993. "Cost and Functional Consequences of U.S. Roadway Crashes." *Accident Analysis and Review* 25, pp. 593-607.

Murphy, James J., and Mark A. Delucchi. 1998. "A Review of the Literature on the Social Cost of Motor Vehicle Use in the United States." *Journal of Transportation and Statistics* 1, No. 1, pp.15-42.

National Academy of Sciences, National Research Council. 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.* Washington, DC: National Academy Press. http://search.nap.edu/books/0309076013/html/ (downloaded: 1/14/03)

Niskanen, William A., and Peter Van Doren. March 1, 2002. "Government Should Steer Clear of the Fuel Economy Issue." *Los Angeles Times.*

Parry, Ian W.H., and Kenneth Small. 2002. *Does Britain or the United States Have the Right Gasoline Tax?* Discussion Paper 02-12. Washington, DC: Resources for the Future.

Porter, Richard C. 1999. *Economics at the Wheel: The Costs of Cars and Drivers.* San Diego, CA: Academic Press.

Schrank, David, and Tim Lomax. 2001. "2001 Urban Mobility Report." Texas Transportation Institute. http://mobility.tamu.edu/ums/2001/study/final_report.pdf

Schrank, David, and Tim Lomax. 2002. "2002 Urban Mobility Report." Texas Transportation Institute. http://mobility.tamu.edu/ums/study/final_report.pdf

Small, Kenneth A., and Camilla Kazimi. 1995. "On the Costs of Air Pollution From Motor Vehicles." *Journal of Transportation Economics and Policy* 29, January 1995, pp.7-32,

The White House Bulletin. 2003. "Snowe and Feinstein Introduce Bill to Make SUVs, Light Trucks Meet Fuel Mileage Standards for Cars by 2011." January 30, 2003.

Train, Kenneth. 1985. "Discount Rates in Consumers' Energy Related Decisions: A Review of the Literature." *Energy* 10, No. 12, pp. 1243-1253.

U.S. Census Bureau. 1997 through 2002. *Statistical Abstract of the United States.* http://www.census.gov/prod/www/statistical-abstract-us.html

U.S. Department of Energy, Energy Information Administration. 2003. *Annual Energy Outlook 2003 with Projections to 2025.* DOE/EIA-0383(2003).

U.S. Department of Energy, Office of Transportation Technologies. 2000. "Fact of the Week, Fact #122: April 3, 2000." http://www.ott.doe.gov/facts/archives/fotw122.shtml (downloaded: 2/06/03)

U.S. Department of Transportation. 1995. *Fiscal Year Appropriations for 1996.* http://www.fhwa.dot.gov/content.html

U.S. Department of Transportation, Federal Highway Administration. 1997. *1997 Federal Highway Cost Allocation Study.* http://www.fhwa.dot.gov/policy/hcas/final/index.htm

U.S. Department of Transportation, Federal Highway Administration. 2001. *Highway Statistics 2001.* http://www.fhwa.dot.gov/ohim/hs01/index.htm

U.S. Department of Transportation, National Highway Traffic Safety Administration. 2002a. "Corporate Average Fuel Economy Standards for MY 2005-2007 Light Trucks: Preliminary Economic Assessment." *Federal Register* 67: 77015. http://www.nhtsa.dot.gov/cars/rules/rulings/CAFE/EnvAssess-d/EconomyStandards/index.html (downloaded: 1/14/03)

U.S. Department of Transportation, National Highway Traffic Safety Administration. 2002b. "Corporate Average Fuel Economy Standards for MY 2005-2007 Light Trucks: Notice of Proposed Rulemaking." *Federal Register* 67: 77015. http://www.nhtsa.dot.gov/cars/rules/rulings/CAFE/EnvAssess-d/CAFELightTruck.html#VI (downloaded: 1/14/03)

U.S. Department of Transportation. 2002c. "Light Truck Fuel Economy Standards Model Years 2005-07: Notice of Proposed Rulemaking." *Federal Register* 67: 77015.

U.S. Department of Transportation, Bureau of Transportation Statistics. 2002d. *Transportation Indicators Report.*

U.S. Office of Management and Budget. 1996. *Economic Analysis of Federal Regulations Under Executive Order 12866.* Washington, DC: General Printing Office.

U.S. Office of Management and Budget. 2003. "Draft 2003 Report to Congress on the Costs and Benefits of Federal Regulations: Notice and Request for Comments." *Federal Register* 68: 5492.

Washington Post. 2003. "Washington in Brief: New Fuel Standards for SUVs Sought." February 1, 2003, p. A-5.

Winston, Clifford, and Chad Shirley. 1998. *Alternate Route: Toward Efficient Urban Transportation.* Washington DC: The Brookings Institution Press.

Yun, John M. 2002. "Offsetting Behavior Effects of the Corporate Average Fuel Economy Standards." *Economic Inquiry* 40, No. 2, pp.260-270.

Appendix A

The Effect of a Modest Gasoline Tax on Fuel Consumption

A very modest gasoline tax is as effective in reducing gasoline consumption as NHTSA's proposed CAFE standard. A tax of 1 cent–per-gallon of gasoline would save as much fuel as the NHTSA proposal in 2007; a mere 3 cents would save almost 150 million additional gallons in 2010. The effectiveness of a gasoline tax results from its applicability to all vehicles, not just new light trucks. The gallons saved from the change in price are:

(1) $\Delta G = G^0 r ((P^1 - P^0) / P^0)$

where G^0 equals the total gallons of gasoline consumed by motor vehicles in a given year, r equals the rebound effect, P^0 is the initial price of a gallon of gasoline, and P^1 is the price per gallon with the added tax. Thus, P^1-P^0 represents the amount of the tax per gallon.

To show the effects of a modest gasoline tax in 2007, we use Department of Energy forecasts of the *Annual Energy Outlook 2003 with Projections to 2025* (AEO 2003).[85] The *AEO 2003* estimates motor vehicle energy consumption to be 18.59 quadrillion British Thermal Units (Btu) in 2007.[86] Given that one quadrillion Btu is equivalent to 7.75 billion gallons of motor gasoline,[87] fuel consumption by motor vehicles is 144 billion gallons. The *AEO 2003* forecasts gasoline to cost, $1.41 per gallon in 2007.[88] Assuming a long-run rebound effect of -.2 and a gasoline tax of just 1 penny

---

[85] See U.S. Department of Energy (2003).
[86] See U.S. Department of Energy (2003, Table 2).
[87] See U.S. Department of Transportation (2002d, Human and Natural Environment, p. 3).
[88] See U.S. Department of Energy (2003, Table 12). Although this estimate is slightly lower than the NHTSA forecast, we adopt it here to ensure internal consistency in our calculations.

per gallon, equation (1) yields decreased motor vehicle fuel consumption of 200 million gallons.[89]

The total gallons saved in a given year under the NHTSA proposal is the sum of the gallons saved by each affected model year during the year in question. The gallons saved for a model year, i, in a given year are:

$$(2) \qquad \Delta G_i = LTS_i\,(VMT_i^1 \times GPM^1 - VMT_i^0 \times GPM^0)$$

where LTS_i is the light truck sales projection, VMT_i^0 and GPM^0 are the vehicle miles traveled and the gallons per mile before the tightened standard, and VMT_i^1 and GPM^1 are the vehicle miles traveled and the gallons per mile after the CAFE increase.

NHTSA projects light truck sales to be 7.65 million vehicles in 2005, 7.80 million in 2006, and 7.92 million in 2007.[90] NHTSA further estimates vehicle miles traveled to be 12,885 miles in the first year of a vehicle's life, 12,444 miles in the second, and 12,007 in the third.[91] NHTSA's CAFE proposal would increase on-road fuel economy for MY 2005 light trucks from 18.03 to 18.15 mpg, from 18.27 to 18.55 mpg for MY 2006 light trucks, and from 18.56 to 19.00 mpg for MY 2007.[92] Tightened CAFE standards increase VMT according to:

$$(3) \qquad VMT_i^1 = VMT_i^0\,(1 + r\,(GPM^1 - GPM^0) / GPM^0)$$

Employing a rebound effect of -.15, in 2007 NHTSA's proposal would lead to VMT of 12,019 for MY 2005 (in their third year), 12,472 for MY 2006 (in their second year), and 12,930 for MY 2007 (in their first year). Given model year fuel savings derived in

---

[89] The change in fuel demand is 144,072,500,000 (-.2) (.01/1.41). We use -.2, because it is a better estimate of the long-run response to changes in fuel prices than -.15.

[90] See Department of Transportation (2002a, Section VII).

[91] See Department of Transportation (2002a, Section VII).

[92] Note that on-road fuel economy is estimated as 85 percent of laboratory fuel economy. See Department of Transportation (2002a, Section VII).

equation (2), the NHTSA proposal results in total fuel savings of approximately 200 million gallons in 2007, about equal to the 1 cent-per-gallon tax.

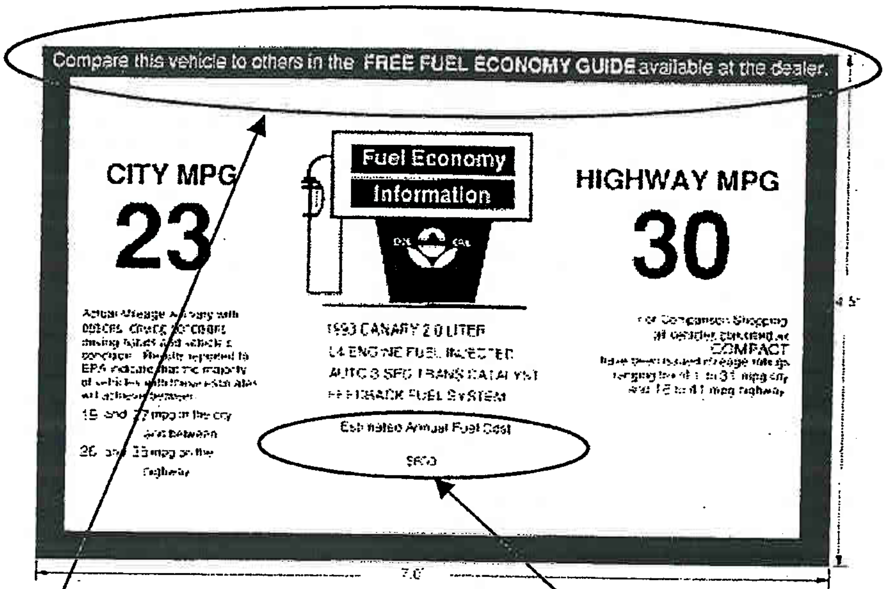
We repeated this analysis in 2010 to derive the effects of a 3 cents-per-gallon tax using predicted motor gasoline consumption of 156 billion gallons at a price of $1.43 per gallon.[93] A tax of 3 cents per gallon of gasoline would reduce consumption by 650 million gallons. The NHTSA proposal would save only 500 million gallons in 2010.[94]

One could calculate the tax burden associated with this idea, however, comparisons of it with the costs of CAFE are premature until NHTSA presents estimates of the full costs to producers and consumers of its proposal.

[93] See U.S. Department of Energy (2003, Tables 2 and 12).
[94] We used a linear regression of the logs of sales projections to estimate light truck sales for MY's 2008-2010. We assumed that on-road fuel economy would remain at 19.00 mpg in these years. See Department of Transportation (2002a, Section VII).

Appendix B

New Vehicle Fuel Economy Window Sticker[95]



a. Gasoline-fueled vehicle label

Note notice of FREE FUEL ECONOMY comparison guide.

Note "Estimated Annual Fuel Cost."

[95] See 40 CFR § 600.Appendix.

Appendix C

Irrelevance of Annual Mileage

While we have assumed for simplicity of presentation that all new light trucks would be driven 10,000 miles per year, our analysis and conclusions are completely independent of this assumption. In particular, the social cost per gallon saved is independent of initial miles driven, because both the social cost from additional driving and the gallons saved are proportional to the initial miles driven. To see this, first note that

$$(1) \qquad \Delta VMT / VMT^0 = r\,((GPM^1 - GPM^0) / GPM^0),$$

which implies

$$(2) \qquad \Delta VMT = VMT^0\,(r\,(GPM^1 - GPM^0) / GPM^0), \text{ and}$$

$$(3) \qquad VMT^1 = VMT^0\,(1 + r\,(GPM^1 - GPM^0) / GPM^0),$$

where $VMT^1 = VMT^0 + \Delta VMT$. Given a social cost, s, associated with an additional mile of driving, the total social cost from the extra driving is simply

$$(4) \qquad s\Delta VMT = s\,VMT^0\,(\,r\,(GPM^1 - GPM^0) / GPM^0).$$

The gallons saved from more fuel-efficient standards can be computed as

$$(5) \qquad \Delta G = (VMT^{\circ}GPM^{\circ}) - (VMT^1GPM^1),$$

or using (3)

$$(6) \qquad \Delta G = VMT^{\circ}\,[GPM^{\circ} - ((1 + \frac{r(GPM^1 - GPM^0)}{GPM^0})\,GPM^1)]$$

Thus, social cost per gallon saved ($s\Delta VMT / \Delta G$), is independent of initial miles driven since both (4) and (6) are proportional to VMT^0.

Appendix D

Incremental Congestion Costs In Urban Areas With Populations Greater Than 100,000

We received, courtesy of David Schrank of the Texas Transportation Institute, data on the congestion costs, vehicle miles traveled and lane miles of freeways, and principal and arterial roads for 75 U.S. cities for the years 1994 to 2000. TTI staff suggested that these 525 observations were the ones most likely to be fully comparable over time and space. Summary statistics for these data appear below.

Variable	Obs	Mean	Std. Dev	Min	Max
Year	525	1997	2.00197	1999	2000
Cost (2000$)	525	7.48×10^8	1.74×10^9	0	1.46×10^9
VMT	525	5.75×10^9	7.58×10^9	1.90×10^8	4.97×10^{10}
Lane Miles	525	2305.8	2633.9	140	16350

Cost is the sum of congestion costs, that is, both fuel and traveler time. VMT denotes vehicle miles traveled, in miles.

Inspection of the cost data revealed that it was fairly highly skewed, with 26 observations with no reported congestion costs. The 5th percentile cost was $5,000,000, the 10th was $\$2.0 \times 10^7$, and the 90th was $\$1.64 \times 10^9$.

Further examination of these data suggest that they are lumpy, in that city-years with congestion costs less than or equal to $10 million consist of the 26 observations of zero, 7 observations with congestion costs of $5 million, and 14 observations with congestion costs of $10 million.

To make these data consistent with the results of Calfee and Winston (1998) and Winston and Shirley (1998) we adjust these cost estimates. In particular, for each year, we adjust total cost to equal

(.12) total cost + (.88) total cost (x)

where x, the ratio of 19 percent of gross wages in selected major cities to the time cost of travel used in the TTI study, varies from .24 to .27 among the different years.[96]

The Cook-Weisberg test indicates substantial heteroskedasticity in the errors of a fixed effect regression of congestion costs on VMT, lane miles and dummy variables for years. The chi-squared statistic for this test is statistically significant at better than the 0.1 percent level.

A linear OLS fixed effects regression of total cost on vehicle miles traveled and total lane miles suggests marginal costs of 18 cents.

A nonlinear Box-Cox regression procedure yields[97]

Variable	Value	Std. Error	Z	P>|z|	[95% C.I.]
Lambda	.4338	.03164	13.71	0.00	.3719-.4959
Theta	.2377	.01366	17.40	0.00	.2109-.2645

Lambda and theta are the Box-Cox transformations for VMT and congestion cost, respectively. The confidence intervals suggest that the data reject both linear and logarithmic models. In this model the coefficient on the transformed VMT, which is statistically significant at better than the 99 percent confidence level, is .01706. These data imply that the marginal cost of an additional mile of driving is $.23.[98]

[96] The TTI data set use McFarland and Chui's (1987) value of travel time of $8.03 in 1985 adjusted to the appropriate year. See Schrank and Lomax (2002, Appendix B, p.1). The Statistical Abstract of the United States reports average annual pay by select metropolitan areas for the years in question in the Labor Force, Employment, and Earnings section. See U.S. Census Bureau (Average Annual Pay by Selected Metropolitan Area). These 71 metropolitan areas are not the same as the 75 cities in the TTI dataset. The TTI values range from 69 to 79 percent of the average annual pay, assuming 2000 working hours per year, and correspond to values of x between .27 and .24.

[97] The Box-Cox transformation requires strictly positive values, so we experiment with replacing the congestion costs reported to be zero with congestion values of $1 million and $2.5 million. We find that the marginal cost estimate is little affected by these assumptions. David Schrank confirms that the estimates of congestion costs close to zero involve significant rounding so these alternatives to zero congestion costs appear reasonable.

[98] The STATA 7.0 software that we used for this regression does not compute standard errors for non-linear functions of the relevant parameters, so we do not have a confidence interval for this estimate, although each of the relevant parameters is statistically significant at better than the 99 percent confidence level.

Although the model rejects a logarithmic transformation, we note that the log model implies a marginal cost of 16¢ to 17¢ (depending on whether the zeros are rounded to $2.5 million of $1 million before our adjustments) with a 95 percent confidence interval of 14¢ to 18¢ for the former case, and 14¢ to 18¢ for the latter.

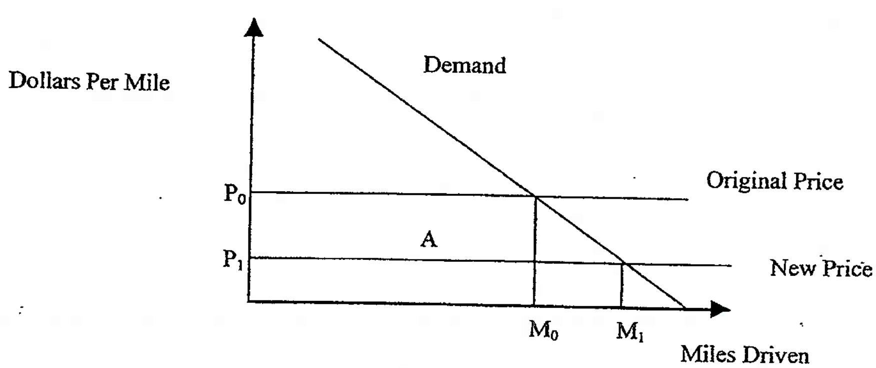
We also estimate this regression after subtracting the fuel costs of congestion. In this case we find that the marginal delay costs are 18¢ per mile, suggesting that the fuel costs of congestion rise by 5¢ with every additional vehicle mile traveled.

Appendix E

The Benefits of Additional Driving From Mandated Fuel Efficiency are Small[99]

While consumers find that additional driving induced by greater fuel economy has value, this benefit is too small to matter for our analysis. To show this, it is useful to distinguish between two different scenarios. First, more stringent CAFE standards may induce a consumer to buy a different vehicle. But, the consumer's utility of purchasing and operating one vehicle versus another is already subsumed in the demand curves for new vehicles. Thus, there is no reason in this scenario to account (in welfare terms) for the increase in miles driven.

Second, with more stringent CAFE standards a consumer may continue to buy the same vehicle he would have bought without the standards. In this scenario, there is an added consumer surplus to driving more miles, but it is so small as to be negligible. To see this consider a simple graphical model of demand for vehicle travel.



Given that the price of driving is initially P_0, the consumer will choose to drive M_0 miles. If more stringent CAFE standards lower the price of driving to P_1, driving

[99] Thanks go to Andrew Kleit for help with this appendix.

increases to M_1. The consumer gains are the rectangle A plus the familiar triangle, which we call B. The area A is what NHTSA refers to as the benefit of CAFE standards.

It is straightforward to show that the triangle B is small in relation to the area A. The area A is $M_0(P_0-P_1)$. The area of B is ½ $(M_1-M_0)(P_0-P_1)$. Thus, the ratio of B to A is simply ½ $(M_1-M_0)/M_0$.

To calculate this ratio, we have to solve for M_1-M_0 in term of M_0. Let $\Delta M=M_1-M_0$. We have already discussed the "rebound effect," r, which is the elasticity of miles driven with respect to fuel economy. Thus we estimate $(M_1-M_0)/M_0$ using

(1) $(M_1-M_0)/ M_0 = r \;\; ((GPM^1 - GPM^0) / GPM^0)$

where GPM^1 and GPM^0 are the gallons per mile under the current and the proposed CAFE standards.

The proposed change in the CAFE standard from 20.7 to 22.2 mpg for MY 2007 will increase the estimated on-road fuel economy level for a representative MY 2007 light truck from 18.56 to 19.00 mpg, an increase in fuel economy (measured in gallons per mile) of 2.3 percent.[100] Assuming a rebound effect of -0.15, the increase in VMT is 0.35 percent. The ratio of the area B to the rectangle A is about .17 percent.

The consumer surplus benefits of additional driving are also too small to matter for our conclusion that the social costs of additional driving are large relative to the value of the gallons saved. The consumer surplus per mile over the range from M_0-M_1 can be calculated as one half of the difference in the price of driving, P_0-P_1. Using NHTSA's assumed price of gasoline ($1.50/gallon), $P_0-P_1 = \$1.50 \;\; (GPM^1 - GPM^0)$, so the average

[100] These estimates are 85 percent of the MPG that NHTSA expects the new fleet to deliver in laboratory settings. See Department of Transportation (2002a, Section VII) for a discussion of its projections of MPG of the new fleet and see Department of Transportation (2002b, Appendix A) for the difference between laboratory and on-road performance.

consumer surplus per mile is about 0.08¢ = (½)($1.50) (.00107). This consumer surplus, which applies only to the households that did not change their choice of vehicle as a result of the more stringent fuel economy standards, is inconsequential.