Short- and Long-Range Impacts of Increases in the Corporate Average Fuel Economy (CAFE) Standard

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Abstract

A short-run 1.0 mile per gallon (MPG) increase in the Corporate Average Fuel Economy (CAFE) Standard above existing, binding levels would impose welfare losses on society of $33.9 billion per year while reducing gasoline consumption by 5.8 billion gallons per year. This amounts to a hidden tax of $5.85 per gallon conserved. An increase of 23 cents per gallon in the gasoline tax would save the same amount of fuel and impose costs on society of $670 million per year. Therefore, a short-run CAFE increase is 50 times more expensive to society than an increase in the gasoline tax. The marginal welfare costs of further short-term increases in the CAFE standard equal $4.10 per gallon of fuel conserved and substantially exceeds plausible estimates of the marginal societal benefits from the avoided externalities associated with reduced gasoline consumption.

A long-run 3.0 MPG increase in the CAFE standard would impose social welfare losses of $3 billion per year and save 5.1 billion gallons of gasoline per year. This amounts to a hidden tax of $0.58 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 $275 million per year. The 3.0 MPG increase is thus 11 times more expensive than the gas tax increase. The marginal welfare costs of long-term increases in the CAFE standard amount to $1.06 per gallon and exceed by a factor of four plausible estimates of the marginal societal benefits from avoided externalities associated with the reduction in gasoline consumption. Increasing the CAFE standard in either the short-or long-term is neither cost-effective nor cost-beneficial.

Executive Summary

Short-Run CAFE Increase:

A short-run increase of 1.0 mile per gallon (MPG) in both car and truck CAFE standards above existing, binding levels would impose social welfare losses on society of $33.9 billion per year. The short-run is the one-to-three year period in which auto manufacturers are locked in to existing models and technologies and thus must meet any mandatory CAFE increases by adjustments in the mix of products sold.

Such a short-run 1.0 MPG increase in the CAFE standard would reduce gasoline consumption by 5.8 billion gallons per year, for an average welfare loss to society of $5.85 per gallon of fuel conserved. Further increases beyond the 1.0 mpg would impose additional losses of $4.10 per gallon.

A gasoline tax increase of roughly 23 cents per gallon imposed at the beginning of the five-year period would also reduce gasoline consumption by 5.8 billion gallons per year by the end of the period. Welfare losses to society would amount to $670 million per year. In the short-term, fuel conservation through CAFE increases is therefore 50 times more expensive than raising the tax on gasoline.

In the short-term, the $4.10 per gallon marginal welfare costs of a 1.0 MPG CAFE increase would exceed the marginal benefits associated with reduced gasoline consumption externalities of $0.26 per gallon as derived from a recent study by the National Research Council (NRC). This is a factor of roughly 16 to one. The NRC marginal benefit estimates include values for the avoided costs of global climate externalities and from assumed increases in oil import dependence.

Long Run CAFE Increase:

In the long run, a 3.0 MPG increase above existing, binding levels in both car and truck CAFE standards decreases social welfare by $2.965 billion per year. The 3.0 MPG increase reflects the focus of the May 2001 report of the Vice President's task force on national energy policy, as well as of several congressional proposals.

The long-run mandatory 3.0 MPG increase reduces gasoline consumption by 5.091 billion gallons per year, for an average cost of $0.58 per gallon. The marginal cost of further increases in the CAFE standards is $1.06 per gallon and increases rapidly beyond that point. Smaller adverse effects on new vehicle sales drive the smaller long-term effects on fuel consumption and costs.

A gasoline tax of 11 cents per gallon would also reduce annual gasoline consumption by 5.091 billion gallons per year, for a social welfare loss of just $275 million.

In the long run, a CAFE increase of 3.0 MPG above present levels would impose welfare losses 11 times higher than the 11 cent per gallon gasoline tax.

Cost-Benefit Analysis:

The incremental short-run costs of $4.10 per gallon and long-run costs of $1.05 per gallon substantially exceed the $0.26 per gallon of marginal benefits from reduced gasoline consumption inferred from the NRC study.

The 1.0 MPG short-run increase in the CAFE standard is more than 50 times more expensive to society than a 23 cents per gallon gasoline tax that would achieve the same fuel savings. The 3.0 MPG long-run increase in CAFE is 11 times more expensive than the 11 cents per gallon gasoline tax increase necessary to save the same quantity of fuel.

I conclude (1) that mandatory increases in the CAFE standards of 1.0 MPG in the short run and 3.0 MPG in the long run impose costs on society are well in excess of any benefits from reduced fuel consumption; and (2) that they are far more costly than alternative, market-based approaches such as a gasoline or carbon tax.

I. Introduction and Background

The General Motors Corporation (GM) has asked me to update and extend earlier studies I have performed over the years regarding the consumer and producer welfare impacts of raising the Corporate Average Fuel Economy (CAFE) standards for cars and light trucks. I have written extensively on this issue. My dissertation at Yale University focused on CAFE standards. As a staff economist at the Federal Trade Commission, I was the primary author of FTC staff comments to the National Highway Traffic and Safety Administration regarding the welfare effects of mandatory increases in the CAFE standard.[1] An article I wrote in the academic literature dealt with the short-run implications of increasing CAFE standards.[2] Another article dealt with the issue of whether or not CAFE standards in the long run represent sustainable policy.[3] The approach taken here is modeled closely on the FTC study, updated with more recent literature and market situations, and significantly expanded to address the long-term implications of increases in the CAFE standards.

This report evaluates two different scenarios. The first concerns the short-term economic implications of raising the CAFE standard by 1.0 mile per gallon (MPG). The "short-run" refers to a length of time such that auto manufacturers can do little to change the fuel economy of specific vehicles and therefore must resort to marketing and pricing incentives to induce vehicle buyers to adjust the mix of cars and light trucks that they are willing to buy. In auto industry parlance this approach is often called "mix shifting." Discussions with GM product planners and engineers, and with other industry experts suggest that three years generally are required before any significant changes in vehicle and powertrain design can be made in response to a CAFE mandate.

The report also evaluates the "long-term" economic implications of raising the standard by 3.0 MPG above current levels. I chose 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.[4] The long run 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

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[1] Comments of the Staff of the Bureau of Economics of the Federal Trade Commission, Intent to Prepare an Environmental Impact Statement for the Corporate Average Fuel Economy Program, National Highway Traffic Safety Administration, November 13, 1989.

[2] Kleit, "The Effect of Annual Changes in Automobile Fuel Economy Standards," Journal of Regulatory Economics, 2:2 (June 1990) 151-172. For a similar approach see Thorpe, "Fuel Economy Standards, New Vehicle Sales, and Average Fuel Efficiency," Journal of Regulatory Economics, 11 (1997) 311-26.

[3] Kleit, "Enforcing Time-Inconsistent Regulations," Economic Inquiry 30:4 (October 1992) 639-648.

[4] See "National Energy Policy," Report of the National Energy Policy Development Group (May 2001) http://www.whitehouse.gov/energy/, at page 4-10.

acceleration per gallon of fuel consumed.[5] In industry parlance, this approach is often referred to as "technology forcing."

Both the short-run and the long-run analysis are evaluated 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 then analyzes the costs and benefits of increasing the standards. Thus, four different situations are analyzed in this report.

As we shall see, and consistent with economic intuition, technology forcing is much less expensive than mix shifting, but much more expensive than market-based alternatives such as an increase in the fuel tax. Increased gasoline taxes encourage consumers to identify and utilize many additional options to reduce fuel consumption, such as reduced driving intensity for used as well as new vehicles, as well as to purchase more fuel efficient vehicles. In addition, increased gasoline taxes result in reductions in vehicle miles traveled for used as well as new vehicles, decreased retention rates for older, less fuel-efficient efficient vehicles, and in the longer term, adjustments in residential and workplace locations and increased commuting via the "information highway."

In contrast, CAFE standard increases affect only new vehicles and do nothing to reduce driving. In fact, they tend to encourage increased driving as costs per mile driven decline. They also encourage the retention of older, less "fuel-efficient" vehicles.

The ostensible goal of CAFE standards is to reduce whatever externality is associated with the consumption of gasoline. As noted in President Clinton's Executive Order 12866, which was adopted by the Bush Administration's Office of Information and Regulatory Affairs (OIRA), any regulatory policy must pass two basic tests: it must be cost-beneficial, and it must be cost effective. That is, the marginal benefits of such a policy must equal or exceed the marginal costs and there must be no alternative that can obtain those benefits at a lower cost. A third criterion is that the policy must take into account any adverse, unintended consequences for human safety or the environment.

Any increase in the CAFE standard, therefore, must be achievable at a lower cost than the least cost alternative, and it must have a marginal cost per gallon of gasoline saved equal to the marginal benefits in terms of reduced levels of any externality. The costs presented here, therefore, should be compared to the costs achieved by other alternatives, such as a gasoline or carbon tax. They must be compared to the benefits from avoiding any external costs of gasoline consumption, including any costs associated with greenhouse gas emissions and dependence on imported oil. The recent NRC report concluded that the sum total of the external costs amounts to $0.26 per gallon.[6] Finally, any unintended adverse consequences of increased CAFE standards must also be assessed.

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[5] The long-term is based on the Sierra Research Report for changes that would occur by Model Year 2010. See note 9 below.

[6] See National Research Council, http://books.nap.edu/html/cafe/.

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 additional external benefit of reducing gasoline consumption by one gallon just equals the additional welfare costs imposed on vehicle consumers and producers.

The plan of this study is as follows. Section II develops a model in which the current CAFE standard is assumed to be non-binding. Section III provides estimates of total, average, and marginal costs of the 1.0 MPG CAFE increase under that assumption. It compares average and marginal costs of the CAFE increases with those incurred under a gasoline tax saving the same amount of fuel. Finally, it computes the impact of the CAFE increase on three criteria pollutants associated with automotive tailpipe emissions.

Section IV provides estimates of the above impacts for the long-term 3.0 MPG gallon mandatory CAFE increase under the assumption that the current CAFE standard is not binding. Section V then revises the model to take into account the arguably more realistic assumption that the current CAFE standard is in fact binding. It then reports estimates for both the short-term 1.0 MPG increase and the long-term 3.0 MPG increase.

Section VI provides a brief cost-benefit analysis of short-and long-term CAFE increases and Section VII provides a summary and conclusion.

II. Assumptions of the Model

Many of the theoretical details of this model used are similar to what I used in my previous work, 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 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.

A. Base year and categories.

Given the availability of data, model year (MY) 1999 was chosen as the base year. (All dollar figures therefore are in 1999 dollars.) Light vehicles were broken down into eleven categories:

Cars:

1) Small
2) Mid-size
3) Large
4) Sports
5) Luxury.

Trucks:

6) Small pickups
7) Large pickups
8) Small SUVs
9) Large SUVs
10) Minivans
11) Vans.

For convenience, the data are broken down into four firms, General Motors, 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 One.

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

B. Demand Side

Elasticities and cross-elasticities between categories are calculated using the internal GM demand model supplied to me. The elasticities and cross elasticities are calculated by raising the price of all vehicles in a particular category by one percent, and determining the resulting percentage change in demand, not only in that category, but for all other categories as well. Because 10.0 percent of cars are placed in a category designated as "Other" in the GM model, all elasticities are multiplied by 0.90. The elasticities calculated are presented in Table Twenty-Four.

C. 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. 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.

D. Treatment of Foreign Firms

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.

E. The Technology Forcing Model

Unlike my previous work, here I present a model of "technology forcing," where firms increase the fuel efficiency of particular vehicles in response to CAFE standards. It is therefore necessary to present the theoretical underpinnings of this model before presenting the necessary empirical inputs.

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

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

where λ is the shadow cost of compliance[7] (set to a fine of \$55 in the statute), 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,

$$(2) \qquad MPG = \sum_{i=1}^{T} Q_i \Big/ \sum_{i=1}^{T} \left(Q_i / MPG_1\right)$$

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

In this model, the firm faces total cost

$$(3) \quad TC = \sum C_i\left(Q_i, MPG_i\right) + F .$$

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, we assume that a firm will invest in fuel efficiency without CAFE standards as long as they it finds it profitable to do so, that is, consumers are willing to pay for fuel economy increases. Under this assumption, the free market net[8] marginal cost of fuel economy is 0, as the marginal cost of fuel economy will equal the marginal returns of fuel economy to the consumer.

Let us define the cost function for any vehicle type i as

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

where D_i represents the cost of fuel economy. Inserting the impact of fuel economy standards, total cost becomes

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[7] While statute sets the CAFE fine at \$55 per vehicle-mpg, firms that view the statute as binding may have a higher cost of compliance.

[8] 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. Thus, these represent economic rather than engineering costs. I ask the careful reader not to confuse these two concepts.

$$(5)\quad TC = \sum_{i=1}^{T}\left(C(Q_i) + Q_i D_i(MPG_i)\right)$$

$$+ \lambda\left(\sum_{i=1}^{T} Q_i\right)\left(S - \left(\sum_{i=1}^{T} Q_1 \Big/ \sum (Q_i/MPG_i)\right)\right)$$

Minimizing total costs with respect to MPG_i yields

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

If the constraint is binding, MPG=S, and

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

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

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

$$= dC/dQ_i + D_i(MPG_i) + \lambda\left[S - 2MPG + (MPG^2/MPG_i)\right]$$

In equilibrium, $S = MPG$, which implies

$$(9)\qquad dTC/dQ_i = dC/dQ_i + D_i(MPG_i) + \lambda S\left((S/MPG_i) - 1\right).$$

It is necessary to employ empirical estimates for the D_i function, which represents the cost of fuel economy to vehicle producers. The 1999 Sierra Research report[9] is used for this purpose. The Sierra report estimates the cost of additional fuel economy improvements in the year 2010. The report has a series of estimates of how much money – in excess of returns to the consumer – would be required to increase fuel economy to a certain level. Initially, for both cars and trucks, I estimated a function

$$(10)\qquad dD/dMPG = a\_MPG + b(\_MPG)^2,$$

[9] See http://www.tc.gc.ca/envaffairs/subgroups1/vehicle%5Ftechnology%5Fold /study2/Final_report/Final_Report.htm. The Sierra Research report relies on estimates of the costs and fuel economy benefits of different technologies based on confidential data supplied by different OEMs and suppliers, from technical papers, and the engineering expertise of Sierra Research employees. At current U.S. gasoline prices, Sierra estimated that nearly all technologies that would be available by 2010 would cost consumers more than the discounted value of future fuel savings and would, therefore, increase the cost of transportation to consumers. I have used the Sierra data to estimate the costs of the 3.0 MPG long-term mandatory CAFE increases.

where _MPG equals the change in MPG above the unconstrained market level. I expected both coefficients a and b to be positive. Consistent with the discussion above, in this model, D=0 at the pre-CAFE equilibrium level (_MPG=0), as firms should invest in fuel economy up to the point where consumers are willing to pay for it. In both car and truck estimates, however, the coefficient b was slightly negative and insignificant. I therefore re-estimated the equations, setting the relevant b's to 0. I obtained an a=24.0 for cars and 65.6 for trucks. This implies (by integration) the total cost of increasing fuel economy (net of the benefits to consumers) is $12(\_MPG)^2$ for cars and $32.8\ (\_MPG)^2$ for trucks.

It should be noted that the long-term model implicitly assumes that the vehicle manufacturers have perfect foresight with respect to the demand for fuel economy several years into the future. Given this perfect foresight, they 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.

F. 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 phenomena that is referred to as the "rebound effect." A recent study, whose results I employ, finds that for every 10 percent that fuel economy is increased, driving increases 2 percent.[10]

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 previous studies. As in my previous work, a (real) discount rate of 4 percent is used.

G. Pollution Impacts

CAFE standards have important consequences for emissions of traditional pollutants, volatile organic compounds, oxides of nitrogen, and carbon monoxide (NOx, VOC, and CO respectively) from automobiles. These traditional pollutants are regulated by the EPA on a per mile basis. Thus, CAFE does nothing to change the grams/mile emissions. However, if CAFE standards increase miles driven, say via the rebound effect for mileage, they can be expected to increase emissions of traditional pollutants.

To model pollution emissions, one must know the emissions per mile by model year and vintage. The difficulty here is that while regulators set the standards at one level, emissions over

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[10] See Greene *et. al.*, "Fuel Economy Rebound Effect for U.S. Household Vehicles," Energy Journal 20 (1999) 1-31.

time are generally larger as 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, Inc.

Unlike the rest of the model, I use year 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 2004 vehicles.

III. Results of the Short-Run Model Assuming the Current CAFE Standard is Not Binding

The model was run to induce a 1.0 MPG increase in the fuel economy average for both cars and trucks, above the actual 1999 level, from GM, Ford, and Chrysler. The results, in terms of price and output effects, are contained in Table Two.

Shadow taxes needed to induce a 1.0 MPG change in U.S. firms' average fuel efficiency range from a low of $1173 per MPG for Ford cars to a high of $2959 for Chrysler trucks. (See Table Three.) Raising the three firms' MPG by 1.0 MPG results in a "market substitution" effect from the other, non-constrained, firms. For example, because CAFE standards reduce luxury car sales from the three constrained firms, they increase profit opportunities in that sector for unconstrained firms. The net result, across the entire market, is that industry car MPG increases only 0.460 miles per gallon, not 1.0 mpg, while industry truck MPG increases 0.854. (See Table Four.)

Table Five presents the welfare effects. GM profits fall $409 million, Ford profits fall $1.094 billion, and Chrysler (domestic) profits fall $0.843 billion. Non-constrained firms' profits rise $3.638 billion. Changes in consumer welfare, which occur in a multi-product market, are calculated along the lines of Braeutigam and Noll.[11] The net change in consumer welfare estimate is a decline of $13.505 billion. The net domestic loss to society is $15.851 billion. The largest welfare effects in this model occur in the truck sector.

The impact of a higher short-run CAFE standard on pollution is presented in Table Six. Short-run increases in CAFE can be expected to reduce pollution because they reduce the number of new vehicles on the road. However, this impact may be offset by reductions in the turnover of existing vehicles, which are generally more polluting.[12] Emissions of VOCs decline approximately 1.0 percent in total, with over half of the decrease in the current fleet (model year, or MY) VOC pollution offset by increases in VOC emissions from the stock of vehicles on the road. Emissions of oxides of nitrogen decrease about 0.4 percent, with almost 84 percent of the new vehicle fleet reductions being offset by increases in pollution from the existing fleet. For carbon monoxide, emissions actually increase by 0.11 percent, as the impact of reduced turnover is greater in magnitude than the effect on the current fleet.

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[11] Braeutigam and Noll, "The Regulation of Surface Freight Transportation: The Welfare Effects Revisited," <u>The Review of Economics and Statistics</u>, 66(1):80-87 (1984).
[12] See, e.g., Howard Gruenspecht, "Differentiated Regulation: The Case of Auto Emissions Standards," <u>American Economic Review</u> 72:2 (1982) 328-31.

Table Seven presents the results of the gasoline model. New vehicle fleet gasoline consumption declines by 3.870 billion gallons. This is offset somewhat by an increase of 496 million gallons from the increased retention of older vehicles. The net reduction in gasoline consumption is 3.374 billion, implying an average cost per gasoline saved of $4.70.

The model does not explicitly generate a marginal cost per gallon saved. To generate such a figure, I ran the model 30 times, for MPG increases of 0.05 MPG at a time, up to an MPG increase of 1.5. 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). (No constant is used, as total costs are zero if gallons saved are zero.) The results of this regression are reported in Table Eight. Taking the relevant derivatives, and solving for the amount of gasoline saved with a CAFE increase of 1.0 MPG yields a marginal cost per gallon saved of $4.37

In the short-run a gasoline tax of 13.5 cents per gallon would also reduce gasoline consumption by 3.374 billion gallons per year, for a total welfare loss imposed on domestic and auto consumers and producers of just $228 million per year[13] vs. the $15.9 billion in total societal losses imposed by the 1.0 MPG increase in the CAFE standard. In other words, the 1.0 MPG short-run increase in the CAFE mandate imposes a hidden tax that is 70 times more expensive to society than the welfare losses imposed by a 13.5 cent per gallon increase in the gasoline tax.[14]

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[13] See, e.g., Dahl and Sterner, "Analyzing Gasoline Demand Elasticities: A Survey," Energy Economics 13:3 (1991), page 203-10. Using the Dahl and Sterner results, I will employ a short-run elasticity of demand for gasoline of –0.26, and a longer run (five year) elasticity of demand of –0.49. I will also assume a base gasoline consumption in the U.S. 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 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, while the marginal loss equals the level of the relevant tax.

[14] I note here that the comparison is between a one year increase of 1.0 MPG in CAFE standards occurring in the short run (say in one year) and a one year increase in the gas tax, also occurring in the same year.

IV. Results of the Long-Run Model Where the Current CAFE Standard is Non-Binding

Table Nine begins the presentation of the results of raising the CAFE standard by 3.0 MPG in the long-run. Here the relevant welfare changes are smaller than in the short-run model, as the availability of relatively less expensive technology reduces the cost to society of higher standards

Table Ten presents the shadow taxes required by firm. Since all three firms meet the standards in large part by technology forcing, and are assumed to have the same technology available to them, all three have similar shadow tax values. Taxes on cars range from $66 to $70 per MPG, while taxes on trucks, where technology increases are more expensive, range from $181 to $184 per MPG.

Welfare effects are presented in Table Eleven. U.S. manufacturers between them would lose about $633 million, while U.S. consumers would lose approximately $1.596 billion. Total losses to society therefore amount to $2.2 billion.

Pollution impacts are presented in Table Twelve. Emissions of all three traditional pollutants rise between 1.64 and 1.84 percent. This increase is due in large part to the rebound effect, which causes more driving and more pollution. (The stockage effect here is small, because changes in price in the new car market are fairly small compared to the short run model.)

Impacts on gasoline consumption are reported in Table Thirteen. In this model, gasoline consumption declines by 5.242 billion gallons or 7.21 percent. The average cost to society of gasoline savings is 43 cents per gallon. A gasoline tax increase of 11 cents per gallon would save the same amount of fuel at a cost to society of $292 million per year vs. the $2.2 billion in welfare losses imposed by the 3.0 MPG increase in the CAFE standard. In other words, the 3.0 MPG increase in the CAFE standard imposes a hidden tax amounting to 7.6 times the explicit tax increase necessary to save the same amount of fuel.[15]

Once again, the model does not explicitly generate a marginal cost per gallon saved. To generate such a figure, I ran the model 30 times, for MPG increases of 0.10 MPG at a time, for MPG increases ranging from 1.1 MPG to 4.0 MPG. As before, 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). The results of this regression are reported in Table Fourteen. 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 $0.92.

The $0.92 cents per gallon marginal cost of increasing CAFE standards by 3.0 MPG in the long-run compares with benefits of $0.26 per gallon, based on the NRC study. Thus, in the long-term the marginal cost of a 3.0 MPG CAFE increase is 3.5 times the marginal benefit.

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[15] Here the comparison 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.

All of the results of Sections III and IV assume the current CAFE standard is not binding at today's standard, but would be binding for any increases. The NRC study, cited above, however, concludes that the existing standards are, in fact, binding and this is consistent with my discussions with GM 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

A. Modeling Approach

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 above underestimates the true loss to the economy of raising CAFE standards.

To make this estimation, I took the following steps. First, I assumed 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 assumed that marketing and other costs (including goodwill) constitute a constant fraction R of marginal costs. (Recall that because we are using a competitive model, 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

$$(1+R)MC_i + PT{*}L\,(S((S/MPG_i)-1)) = P_i, \qquad (11)$$

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. Since 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 above) "backwards," 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.

B. Calculating the Pass-Through Rate and the Level of the GM Shadow Tax

An additional problem comes from the multi-product nature of the market. This implies that taxes on one type of vehicle will impact prices of other types of vehicle. Given this, it takes some work to determine the pass-through rates for each type of vehicles, as presented below.

Let demand be characterized by

(12) D: $P= A- BQ$, P,Q, A, are N x 1 vectors, B an N x N matrix.

This implies

(13) $Q = B^{-1} (A-P)$;

"Fringe" supply (here foreign firms) is such that

(14) $P = K + LQ_F$; where Q_F is fringe supply, K an N x vector, L an N x N matrix,

implying

(15) $Q_F = L^{-1}(P-K)$

Residual demand is

(16) $Q_R = Q - Q_F = B^{-1} (A-P) - L^{-1}(P-K)= P(-L^{-1}-B^{-1}) + H_1$, H_1 a vector of constants.

Facing a vector of taxes T, the U.S. three firms have supply relationship

(17) $MC = P = Z + T +YQ_s$, Z an N x 1 vector, Y an N x N matrix;

$$Q_s = Y^{-1}(P-Z-T) = Y^{-1}P - Y^{-1}T - H_2,$$

H_2 a vector of constants.

Putting supply and demand together yields,

(18)
$$Y^{-1}P - Y^{-1}T - H_2 = P(-L^{-1}-B^{-1}) + H_1,$$
$$P(Y^{-1}+L^{-1}+B^{-1}) = Y^{-1}T + H_2 + H_1;$$
$$P = (Y^{-1}+L^{-1}+B^{-1})^{-1}Y^{-1}T + H_3,$$
H_3 a vector of constants.

Let T = tF, where t is a scalar (here the shadow CAFE tax), and F is a vector of CAFE functional forms based on type MPG. As before,

(19)
$$F_i = S*((S/MPG_i)-1)),$$

where MPG_i is the fuel efficiency of type i. This implies

(20)
$$dP/dt = (Y^{-1}+L^{-1}+B^{-1})^{-1}Y^{-1}F.$$

This function dP/dt is the vector of explanatory variables by type to be used to estimate the level of t faced by GM in 1999. In equation (11) above, it is equal to $PT*(S((S/MPG_i)-1))$.

For the model of this report, the results of the impact of a CAFE tax by vehicle type are presented in Table Fifteen. For every dollar of CAFE shadow tax, dP/dt represents the pass-through rate. 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 Sixteen 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 deduced in Table Sixteen. The model is run with and without a constant term. However, the estimated constant term in Model One has a very low t-statistic. Model Two, which is run without a constant, has large t-statistics and a high R-square (0.950). The estimated shadow tax from this estimation is $1652/MPG, and this is the level used in the simulations of Part C below.[16]

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[16] The resulting changes in MPG because of this negative tax of $1652 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.

C. Welfare Implications of Raising CAFE Standards Given that Standards are Already Binding

1. Short Run

Tables Seventeen and Eighteen summarize the welfare changes as a result of increasing the short-run CAFE standard 1.0 MPG above the 1999 level, assuming that a short-run tax of $1652 was binding in MY 1999. As expected, the economic harms are much greater than the previous models, which assumed the standards were just non-binding in MY 1999. The changes in this section are calculated from two baselines, the first from the actual MY 1999 equilibrium, and the second from the equilibrium that would have occurred in MY 1999 had their been no CAFE standard (the "no-CAFE equilibrium").

The total losses of a 1.0 MPG short-run increase in the CAFE standard from the MY 1999 actual market equilibrium are $33.9 billion. Consumer losses relative to actual CAFE constrained equilibrium are $23.2 billion. With respect to the MY 1999 equilibrium VOC emissions fall 2.83 percent, NOx emissions fall 1.2 percent, while CO emissions remain essentially unchanged. These impacts are largely the result of fewer new cars on the road. Gasoline consumption falls 5.8 billion gallons, amounting to 8 percent of consumption. The average cost of reducing a gasoline externality is $5.85.

With respect to the no-CAFE equilibrium, the total loss in economic welfare from an increase in CAFE 1.0 MPG above 1999 levels is approximately $39.5 billion. Losses to consumers relative to the free market equilibrium are $24.1 billion With respect to the no-CAFE equilibrium, VOC emissions decline 1.6 percent above the level in the free market equilibrium, while NOx emissions fall 0.4 percent. Carbon monoxide emissions rise 0.57 percent due to the impact on the used car market. Gasoline consumption falls 5.6 billion gallons, amounting to 7.8 percent of consumption. The average cost of reducing a gallon of gasoline externality is $7.01. The inferred marginal cost (in both scenarios) of reducing a gasoline externality is estimated to be $4.10 per gasoline externality at an MPG increase of 1.0.)

2. Long Run

Tables Twenty and Twenty-One present the welfare changes as a result of raising the long-run CAFE standard 3.0 MPG above the 1999 level, again assuming a short-run tax of $1652 was binding in MY 1999. Once again, harm to the economy is greater than that in the previous long-term model.

Total losses to society from the MY 1999 equilibrium of raising the long-run CAFE standard 3.0 MPG are $2.965 billion. Emissions of VOCs, NOx, and, carbon monoxide rise between 1.64 to 1.86 percent from the MY 1999 equilibrium. Consumption of gasoline is reduced 5.1 billion gallons or 7.14 percent from the MY 1999 equilibrium. The average cost of reducing a gasoline externality is $0.58 from the MY 1999 equilibrium.

Total losses to society from the no-CAFE equilibrium of raising the long-run CAFE standard 3.0 MPG are $3.026 billion. Emissions of VOCs, NOx, and, carbon monoxide rise from 2.07 to 2.25 percent from the no-CAFE equilibrium. Gasoline consumption falls 6.4 billion gallons, or 9.82 percent from the no-CAFE equilibrium. The average cost of reducing a gasoline externality from the no-CAFE equilibrium is $0.47. The marginal cost of reducing a gasoline consumption externality (in both scenarios) is $1.06.

A gasoline tax increase of 11 cents per gallon would achieve the 5.091 billion gallon reduction relative to a binding 1999 CAFE standard, while an increase of 14 cents per gallon would be required to achieve a reduction of 6.403 billion gallons relative to the no-CAFE equilibrium. In the first instance, the $2.965 billion in CAFE costs compares to costs of $275 million from the 11 cent per gallon increase in the gasoline tax. This is a ratio of 11 to 1. In the second instance (the no-CAFE equilibrium), the $3.026 billion in CAFE costs compare to $436 million in costs associated with a 14 cent per gallon increase in the gasoline tax. This is a ratio of seven to one.

VI. Cost-Benefit Analysis

The results of all four models are summarized in Table Twenty-Three. Because there is widespread agreement that the current CAFE standard is binding for both cars and trucks, the most relevant scenarios for public policy analyses seem to be those which compares the 1.0 MPG short-run and 3.0 MPG long-run mandatory CAFE increases to the constrained model year 1999 equilibrium. There are two fundamental issues: whether the mandatory CAFE increases are cost-effective and whether the incremental or marginal benefits associated with those mandates exceed the marginal welfare costs imposed on the nation’s consumers and producers.

In the short-run, a period of one to three years in which auto manufacturers are locked in to existing technologies and thus must meet any mandatory CAFE increases largely by adjustments in the mix of products sold, a 1.0 MPG increase in both car and truck CAFE standards above existing levels would impose consumer welfare losses amounting to $23 billion per year and domestic producer welfare losses of $11 billion per year, for a total loss to society of $34 billion. Gasoline consumption would decline by 5.8 billion gallons per year, for an average social welfare loss or cost of $5.85 per gallon of fuel conserved.

For CAFE standards to constitute cost-effective policy, the welfare costs of imposing higher CAFE standards should be compared to the welfare costs of an increase in the gasoline tax that would save the same amount of gasoline. Under consensus estimates of gasoline demand price elasticities, a gasoline tax of 23 cents per gallon would achieve the same reduction of 5.8 billion gallons per year over the relevant time frame. Social welfare losses associated with the gasoline tax increase amount to $670 million per year vs. the $34 billion costs of the 1.0 MPG increase in CAFE. In other words, the CAFE increase imposes a hidden tax 50 times higher than the explicit tax required to save the same amount of gasoline.

Alternatively, from a cost-benefit perspective, the marginal costs of increasing CAFE by more than the 1.0 MPG amount to $4.10 per gallon. This compares with marginal benefits from reduced externalities of $0.26 per gallon, if one accepts the NRC study. This is a cost-benefit ratio of roughly 16 to one. In the short run, CAFE is neither cost-effective nor cost-beneficial.

In the long run, a period over which auto manufacturers are able to fully utilize new technologies in order to comply with increased CAFE mandates, a 3.0 MPG increase above existing levels in both car and truck CAFE standards decreases social welfare by $3.026 billion per year.

Once again, the most relevant scenario is the one that compare a mandated CAFE increase to a binding CAFE constraint in 1999. In that scenario, gasoline consumption falls by 5.091 billion gallons per year, for an average cost of $0.58 per gallon. Using estimates for the long-run gasoline demand price elasticity, this same reduction in gasoline consumption could be achieved by a gasoline tax increase of 11 cents per gallon. The gasoline tax would impose social costs of $275 million, compared to $2.9645 billion from higher CAFE standards. In other words, the 3.0 MPG increase in the CAFE mandate would cost society 11 times more than a 11 cent per gallon gasoline tax increase saving the same amount of fuel.

The marginal cost of mandating the long-run 3.0 MPG CAFE increase is $1.06 per gallon and increases rapidly beyond that point. This compares with a marginal external cost for gasoline consumption of $0.26, according to the NRC study. Thus, it is clear that in the long run, a 3.0 MPG CAFE increase is neither cost-effective, nor cost-beneficial.

It should also be noted that in the long-run model, the marginal cost of moving from the unconstrained or no-CAFE equilibrium to the MY 1999 CAFE-constrained equilibrium amounts to $0.13 cents per gallon, below the $0.26 per gallon estimate of the marginal benefits of reducing the gasoline consumption externality inferred from the NRC study. I must state, however, that I am skeptical of the NRC externality cost estimate of $0.26 per gallon.[17] The

[17] The NRC divides the estimate into three components: $0.02 cents per gallon for increased automotive emissions of criteria pollutants, $0.12 cents per gallon for adverse global climate effects, and $0.12 per gallon for oil import effects. My results suggest that mandatory CAFE increases will increase, not reduce automotive emissions. The $0.12 per gallon estimate for global warming is two to ten times the upper and lower bound found in other economic estimates. See, for example, Toman and Shogren, “How Much Climate Change is Too Much:

NRC estimate also excludes the offsetting externality costs of the CAFE mandate – including the increased vehicle emissions documented in this study.

VII. Conclusion

Mandatory increases in CAFE standards above current levels are neither cost-effective nor cost-beneficial. In the short run, a one mile per gallon increase in the CAFE mandate would impose social costs of $34 billion per year and reduce gasoline consumption by 5.8 billion gallons per year. This amounts to 50 times the cost of a gas tax increase that would save the save amount of fuel. The short-term marginal costs of the 1.0 mpg CAFE increase would exceed the marginal benefits associated with reduced gasoline consumption externalities by a factor of 16 to one and those costs rise rapidly with further short-term increases in the CAFE standard.

In the long run, increasing the CAFE standard by more than 3.0 MPG would impose additional costs of $3 billion per year and reduce gasoline consumption by 5.1 billion gallons per year. This amounts to 11 times the cost of a gas tax increase that would save the save 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 over 4 to one.

An Economic Perspective," *Climate Change Issues Brief* No. 25, Resources for the Future (September 2000), page 12. The $0.12 per gallon estimate for oil import effects ignores the benefits from specialization according to comparative advantage and falsely assumes that CAFE changes can have a material influence on worldwide energy supply and demand. See, e.g., Douglas R. Bohi and Michael A. Toman, *The Economics of Energy Security* (1996). Bohi and Toman conclude that there is no discernible oil import or energy security premium. In addition, I note that the gains to society from reducing the consumption of gasoline may be reduced or eliminated because gasoline is already a highly taxed good. For the extent of those taxes, see http://www.energy.ca.gov/fuels/gasoline/gas_taxes_by_state.html.

Table One
Initial Conditions – Prices and Quantities

Class	Initial Totals by Class			Initial Quantities by Firms (millions of units)			
	Prices ($000)	Quantity (million)	MPG	GM	Ford	Chrys.	Forgn.
1	14.336	2.057	33.53	0.589	0.313	0.096	1.059
2	18.508	2.921	27.26	1.255	0.640	0.395	0.631
3	21.710	1.840	26.86	0.267	0.363	0.243	0.968
4	21.607	0.506	26.03	0.104	0.214	0.004	0.184
5	30.365	1.102	24.44	0.240	0.117	0.000	0.746
6	17.345	0.970	22.68	0.223	0.400	0.134	0.213
7	23.424	1.455	18.83	0.576	0.513	0.356	0.000
8	26.284	1.169	20.24	0.323	0.320	0.154	0.372
9	31.296	1.459	18.30	0.390	0.304	0.486	0.279
10	25.157	0.964	23.49	0.184	0.255	0.387	0.207
11	20.611	0.336	18.90	0.191	0.092	0.053	0.000

Class	Initial MPG by Firms (miles per gallon)			
	GM	Ford	Chrys.	Forgn.
1	32.52	33.61	31.92	34.26
2	27.15	26.15	27.29	28.71
3	26.05	24.65	25.46	28.46
4	24.84	26.10	22.62	26.75
5	23.80	22.78	-	24.94
6	24.56	22.61	19.25	23.59
7	19.34	18.43	17.60	-
8	21.36	19.78	20.85	23.17
9	16.91	16.36	18.53	20.20
10	23.72	22.44	23.70	24.46
11	19.78	17.77	18.04	-

Table Two
Price and Output Effects of Short-Run CAFE Increase of 1.0 MPG
For Both Cars and Trucks

Class	Totals by Class		Change from Initial	
	Prices ($000)	Quantity (million)	Prices ($000)	Quantity (million)
1	13.269	2.531	-1.067	0.474
2	19.133	2.595	0.624	-0.326
3	22.662	1.619	0.952	-0.221
4	22.836	0.459	1.229	-0.047
5	32.473	1.069	2.108	-0.034
6	16.281	1.267	-1.066	0.297
7	27.444	1.066	4.020	-0.379
8	27.175	1.267	0.891	0.064
9	36.527	1.066	5.231	-0.383
10	22.825	1.234	-2.332	0.278
11	23.280	0.227	2.669	-0.108

Class	Output by Firms (millions of units)				Change of Output by Firms (millions of units)			
	GM	Ford	Chrys.	Forgn.	GM	Ford	Chrys.	Forgn.
1	0.920	0.518	0.184	0.909	0.331	0.205	0.088	-0.151
2	1.025	0.556	0.336	0.677	-0.229	-0.084	-0.059	0.046
3	0.187	0.263	0.112	1.057	-0.080	-0.099	-0.130	0.085
4	0.053	0.201	0.000	0.206	-0.051	-0.014	-0.004	0.022
5	0.136	0.080	0.000	0.852	-0.103	-0.037	0.000	0.106
6	0.415	0.617	0.046	0.188	0.192	0.217	-0.087	-0.025
7	0.529	0.397	0.140	0.079	-0.048	-0.116	-0.216	0.000
8	0.371	0.291	0.173	0.398	0.048	-0.029	0.019	0.027
9	0.169	0.111	0.422	0.373	-0.221	-0.193	-0.064	0.094
10	0.249	0.316	0.579	0.170	0.065	0.061	0.189	-0.037
11	0.174	0.034	0.019	0.000	-0.016	-0.058	-0.034	0.000

Table Three
Shadow Taxes By Firm
Short-Run Model

	Shadow Taxes by Firm ($/MPG)		
	GM	**Ford**	**Chrysler**
Cars	1488	1173	2301
Trucks	2786	2959	3159

Table Four
Change in Firm MPGs
Short-Run Model

	Change in MPG by Firm				
	GM	**Ford**	**Chrysler**	**Foreign**	**Total**
Cars	1.000	1.000	1.000	-0.344	0.460
Trucks	1.000	1.000	1.000	-0.287	0.854

Table Five
Welfare Effects
Short-Run Model

	GM	**Ford**	**Chrysler**	**Foreign**	**U.S total**
Change in Producers Surplus ($ billion)	-0.409	-1.094	-0.843	3.638	-2.347
Change in Consumer Surplus ($ billion)	-13.505		**Total U.S. Change in. Surplus ($ billion)**	-15.851	

Table Six
The Impact of Standards on Pollution Emissions
Short-Run Model

	Pollution Impacts (all in million kilograms)		
	VOC	**NOX**	**CO**
Original MY Emissions	638.962	487.739	5,288.892
Induced change from reduced vehicle sales	-15.156	-12.146	-130.061
Change in Stockage Emissions	8.882	10.152	135.932
Total Change	-6.273	-1.994	5.871
Percent Change	-0.982%	-0.409%	0.111%

Table Seven
Impact of Higher Standards on Gasoline Consumption
Short-Run Model

<table>
<tr><td colspan="4"></td></tr>
<tr><td>MY Pre-CAFE Gas. Cons. (billion gall.)</td><td>72.695</td><td rowspan="2">Domestic Average Cost of Gasoline Externality Saved</td><td rowspan="2">$4.70</td></tr>
<tr><td>Change in MY Gas Cons. (billion gall.)</td><td>-3.870</td></tr>
<tr><td>Change in Stockage Consumption (billion gall.)</td><td>0.496</td><td colspan="2"></td></tr>
<tr><td>Net change in Consumption (billion gall.)</td><td>-3.374</td><td rowspan="2">Domestic Marginal Cost of Gasoline Externality Saved (inferred)</td><td rowspan="2">$4.37</td></tr>
<tr><td>Percentage Change in Consumption</td><td>-4.578%</td></tr>
</table>

Table Eight
Regression Results to Estimate Marginal Cost of Gasoline Savings
Short-Run Model

Variable	Coefficient	T-statistic
Gallons Saved	5.288	68.32
(Gallons Saved)^2	-0.227	-6.61
(Gallons Saved)^3	0.0181	5.03
	Number of Obs: 30	R-square: 0.99

Table Nine
Price and Output Effects of Long-Run CAFE Increase of
3.0 MPG For Both Cars and Trucks

Class	Totals by Class		Change from Initial	
	Prices ($000)	Quantity (million)	Prices ($000)	Quantity (million)
1	14.279	2.584	-0.057	0.027
2	18.568	2.893	-0.060	-0.028
3	21.783	1.827	0.073	-0.013
4	21.706	0.503	0.099	-0.003
5	30.496	1.102	0.131	0.000
6	17.292	0.990	-0.053	0.020
7	23.798	1.421	0.374	-0.034
8	26.389	1.172	0.105	0.003
9	31.746	1.429	0.450	-0.030
10	25.024	0.982	-0.133	0.018
11	20.896	0.347	0.285	0.011

Table Nine (continued)

Class	Output by Firms (millions of units)				Change of Output by Firms (millions of units)			
	GM	Ford	Chrys.	Forgn.	GM	Ford	Chrys.	Forgn.
1	0.610	0.333	0.099	1.042	0.021	0.020	0.003	-0.017
2	1.233	0.629	0.392	0.640	-0.022	-0.011	-0.003	0.008
3	0.260	0.351	0.235	0.981	-0.008	-0.012	-0.007	0.013
4	0.100	0.212	0.003	0.187	-0.004	-0.002	0.000	0.003
5	0.231	0.113	0.000	0.759	-0.009	-0.004	0.000	0.013
6	0.242	0.417	0.121	0.210	0.019	0.016	-0.013	-0.003
7	0.572	0.503	0.337	0.000	-0.004	0.010	-0.020	0.000
8	0.326	0.314	0.155	0.378	-0.003	-0.006	0.001	0.006
9	0.366	0.285	0.483	0.295	-0.024	-0.019	-0.003	0.016
10	0.190	0.258	0.402	0.203	0.005	0.003	0.015	-0.004
11	0.189	0.086	0.050	0.000	-0.002	-0.006	-0.003	0.000

Table Ten
Shadow Taxes By Firm
Long-Run Model

	Shadow Taxes by Firm ($000/MPG)		
	GM	**Ford**	**Chrysler**
Cars	0.068	0.066	0.070
Trucks	0.181	0.183	0.184

Table Eleven
Welfare Impacts of Long-Run CAFE Increase of 3.0 MPG
for Both Cars and Trucks

	GM	**Ford**	**Chrysler**	**Foreign**	**U.S total**
Change in Producers Surplus ($ billion)	-0.219	-0.265	-0.149	0.296	-0.633
Change in Consumer Surplus ($ billion)	-1.596		**Total U.S. Change in. Surplus ($ billion)**	-2.230	

Table Twelve
The Impact of Standards on Pollution Emissions
Long-Run Model

	Pollution Impacts (all in million kilograms)		
	VOC	**NOX**	**CO**
Original MY Emissions	638.962	487.739	5,288.892
CAFE – induced change in MY Emission	9.307	7.387	79.297
Change in Stockage Emissions	1.167	1.33	17.931
Total Change	10.474	8.720	97.228
Percent Change	1.64%	1.79%	1.84%

Table Thirteen
Impact of Higher Standards on Gasoline Consumption
Long-Run Model

MY Pre-CAFE Gas. Cons. (billion gall.)	72.695	**Domestic Average Cost of Gasoline Externality Saved**	$0.43
Change in MY Gas Cons. (billion gall.)	-5.299		
Change in Stockage Consumption (billion gall.)	0.057		
Net change in Consumption (billion gall.)	5.242	**Domestic Marginal Cost of Gasoline Externality Saved (inferred)**	$0.92
Percentage Change in Consumption	7.21%		

Table Fourteen
Regression Results to Estimate Marginal Cost of Gasoline Savings
Long-Run Model

Variable	Coefficient	T-statistic
Gallons Saved	-6.90	31.68
(Gallons Saved)^2	7.02	758.07
(Gallons Saved)^3	0.23	246.71
	Number of Obs: 30	R-square:0.963

Table Fifteen
Pass-Through Rates by Car Type

Type – Description	MPG	F	dP/dt
1- small car	32.524	-4.158	-0.839
2 – midsize car	27.152	0.486	0.040
3 – large car	26.046	1.680	0.228
4 – sports car	24.837	3.107	0.783
5 – luxury car	23.796	4.451	0.876
6 – small truck	24.558	-3.727	-1.168
7 – large truck	19.339	0.658	0.246
8 – small suv	21.357	-1.292	-0.300
9 - large suv	16.912	3.619	1.171
10 – minivan	23.715	-3.150	-1.253
11 – van	19.777	0.201	0.007

Table Sixteen
Estimating the 1999 CAFE tax
(T-Statistics in Parentheses)

	Model One	Model Two
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-square	0.951	0.950
Number of Observations	25	25

Table Seventeen
Results of CAFE Previously Binding Model
Welfare Effects
Short-Run Model - 1.0 MPG Increase

	Change from MY 1999 Equilibrium	**Change from No-CAFE Equilibrium**
Changes in Producer Surplus ($ billion)		
General Motors	-4.165	-6.297
Ford	-4.055	-6.245
Chrysler	-2.441	-2.893
Foreign Firms	6.647	5.984
U.S. Firms Total	-10.661	-15.435
Change in Consumer Surplus ($ billion)	-23.217	-24.055
Change in U.S. Total Surplus ($ billion)	-33.879	-39.490

Table Eighteen
Results of CAFE Previously Binding Model
Pollution and Gasoline Consumption Effects
Short-Run Model - 1.0 MPG Increase

	Change from MY 1999 Equilibrium	**Change from No-CAFE Equilibrium**
% Change in VOC Emissions	-2.829%	-1.621%
% Change in NOx Emissions	-1.208%	-0.427%
% Change in CO Emissions	0.021%	0.565%
Change in Gasoline Consumption (billion gallons)	-5.785 (-7.959%)	-5.633 (-7.777%)
Average cost of reducing Gasoline Externality	$5.85	$7.01
Marginal cost of reducing Gasoline Externality (inferred)	$4.10	

Table Nineteen
Regression Results to Estimate Marginal Cost of Gasoline Savings
Short-Run Model, CAFE Previously Binding Model

Variable	**Coefficient**	**T-statistic**
Gallons Saved	12.519	14.76
(Gallons Saved)^2	-1.408	-5.40
(Gallons Saved)^3	0.0782	4.11
	Number of Obs: 30	R-square: 0.975

Table Twenty
Results of CAFE Previously Binding Model
Welfare Effects
Long-Run Model - 3.0 MPG Increase

	Change from MY 1999 Equilibrium	**Change from No-CAFE Equilibrium**
Changes in Producer Surplus ($ billion)		
General Motors	-0.433	-0.470
Ford	-0.455	-0.501
Chrysler	-0.236	-0.244
Foreign Firms	0.260	0.213
U.S. Firms Total	-1.124	-1.215
Change in Consumer Surplus ($ billion)	-1.841	-1.811
Change in U.S. Total Surplus ($ billion)	-2.965	-3.026

Table Twenty-One
Results of CAFE Previously Binding Model
Pollution and Gasoline Consumption Effects
Long-Run Model - 3.0 MPG Increase

	Change from MY 1999 Equilibrium	**Change from No-CAFE Equilibrium**
% Change in VOC Emissions	1.64%	2.07%
% Change in NOx Emissions	1.80%	2.21%
% Change in CO Emissions	1.86%	2.25%
Change in Gasoline Consumption (billion gallons)	-5.091 (-7.15%)	-6.403 (-8.82%)
Average cost of reducing Gasoline Externality	\$0.58	\$0.47
Marginal cost of reducing Gasoline Externality (inferred)	\$1.06	

Table Twenty-Two
Regression Results to Estimate Marginal Cost of Gasoline Savings
Long-Run Model, CAFE Previously Binding Model

Variable	**Coefficient**	**T-statistic**
Gallons Saved	0.047	-149.54
(Gallons Saved)^2	0.065	599.63
(Gallons Saved)^3	0.0025	270.06
	Number of Obs: 30	R-square: 0.997

Table Twenty-Three
Summary of Results
Four Different Scenarios

	Short-Run 1.0 MPG Increase from Current Levels		**Long-Run 3.0 MPG Increase from Current Levels**	
	CAFE Not Binding	**CAFE Already Binding**	**CAFE Not Binding**	**CAFE Already Binding**
Gasoline Saved (gallons billion)	3.870	5.785	5.242	5.091
Cost to Society ($ billion)	$15.851	$33.879	$2.230	$2.965
Average Cost/Gallon	$4.70	$5.85	$0.43	$0.58
Marginal Cost of Gallon Saved	$4.37	$4.10	$0.92	$1.08
Tax need for equivalent savings	$0.135 per gallon	$0.231 per gallon	$0.111 per gallon	$0.108 per gallon
Cost to Society of Equivalent tax ($ billion)	$0.228	$0.670	$0.292	$0.275
Ratio of CAFE costs to costs of a tax increase	70	50	7.6	11