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

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Executive Summary

CAFE standards have been in place since 1978. After the increase in petroleum prices in 1998-99, CAFE standards again arose as a public policy issue. This paper attempts to model the impact of higher CAFE standards on producer and consumer welfare, gasoline consumption, externalities from increased driving, and the emissions of traditional pollutants, given that CAFE standards are successful in inducing manufacturers to engage in technology forcing. The study then examines CAFE standards from a cost-benefit and a cost-effectiveness viewpoint.

In particular, a long-run 3.0 MPG increase in the CAFE standard would impose social welfare losses of $5.556 billion per year and save 5.1 billion gallons of gasoline per year. This amounts to a hidden tax of $1.09 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 20 times more expensive than the gas tax increase. The marginal welfare costs of long-term increases in the CAFE standard amount to $1.26 per gallon and exceed by a factor of five recent estimates of the marginal societal benefits from avoided externalities. Increasing the CAFE standard is therefore neither cost-effective nor cost-beneficial.

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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 U.S. Senate of an amendment that would have required a fifty percent 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 paper evaluates the "long-term" economic implications of raising the standard by 3.0 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 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 acceleration per gallon of fuel consumed. Previous work on CAFE standards, such as Kleit (1990) and Thorpe (1996), focused on short-term responses to higher CAFE standards, where technology forcing was not an option for manufacturers.

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

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 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 study 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 non-binding. Section IV provides estimates of the impacts for a long-term 3.0 MPG gallon 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 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. 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 U.S. 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 percent 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, 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 the year 2001, however, such vehicles made up approximately one-half of the sales of personal vehicles. By 2001, light trucks were required to reach 20.7 miles per gallon. (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 fifty-five dollars per car-MPG for each manufacturer. For example, if a manufacturer producers one million cars with an average MPG of 26.5 MPG 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, which is 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. Since 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 above, higher CAFE standards were defeated in the U.S. Senate in early 2002. Proposals to raise the standards, however, continue to be evaluated in both the executive and legislative branch. 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. Since the current method of reducing carbon dioxide emissions from vehicles is to raise fuel economy, California’s law is simply another form of CAFE regulation.

B. 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 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 paper, I will assume this amount is both an average and a marginal benefit.)

The NRC divides the estimate into three components: $0.12 cents 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 of these estimates 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 the climate change externality is between 1 and 4 cents a gallon, implying 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. First, this estimate ignores the benefits from specialization according to comparative advantage. Second, the estimate assumes that CAFE changes can have a material influence on worldwide energy supply and demand. Because the United States only has about 26 percent of world oil consumption,[3] however, and there seems to be significant elasticity to the supply of oil, the U.S. does not appear to have any significant monopsony power in this market. Finally, it is unclear how reducing domestic consumption increases "oil

[2] See National Research Council, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, July 2001, http://books.nap.edu/html/cafe/.
[3] See Energy Information Administration, http://www.eia.doe.gov/emeu/ipsr/t24.txt

security." Oil is traded in a world market, implying that it is difficult to insulate the U.S. 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 cents 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, oxides of nitrogen, and carbon monoxide (NOx, VOC, and CO respectively) from automobiles at the street level. 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, via what is termed the "rebound effect," they can be expected to increase emissions of traditional pollutants. (See Espey, 1997.) Indeed, the results below indicate that higher CAFE standards serve to increase the emissions of traditional pollutants.

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.[4] The question here 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. Nivola and Crandall (1995, 27) counter that fuel costs are prominently displayed for the consumer to read. 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.

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[4] For the extent of such taxes, see http://www.energy.ca.gov/fuels/gasoline/gas_taxes_by_state.html.

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,[5] 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.

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 are broken into five categories; 1) Small; 2) Mid-size; 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.

Transaction prices are generated by taking the average price for each category in the GM 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 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

[5] See Kleit (1990). For a similar model, see Thorpe (1997).

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 (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 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 calculated elasticities are presented in table 12.

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.[6] 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 percent of the small car market. While 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

[6] Below I will attempt to account for the likelihood that CAFE standards were already binding by running the model "backwards" using short-run elasticities of supply, and then "forwards" using the long-run elasticity of supply.

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 backwards. 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 at 166-170.) 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 serve to 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 for this paper, however, the demand for large vehicles is generally less elastic than the demand for small vehicles.[7]

D. 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.

[7] There are some caveats to this, as a review of Table 12 will make apparent. The own demand for medium and large cars is relatively elastic, but this is due to the high cross-

E. 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, in order to meet CAFE standards.

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," where firms increase the fuel efficiency of particular vehicles in response to CAFE standards.[8]

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:

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

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,

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

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

In this model, the firm faces total cost:

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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 mini-vans.

[8] 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.

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

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, 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[9] marginal cost of fuel economy is 0, 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) $TC_i = C_i(Q_i) + Q_iD_i(MPG_i)$,

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

Minimizing total (net) costs with respect to MPG_i yields:

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

[9] 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.

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

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

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

In equilibrium, $S \;=\; MPG$, which implies:

(9) $$dTC/dQ_i \;=\; dC/dQ_i \;+\; D_i(MPG_i) + \;\lambda S\big((S/MPG_i) - 1\big) .$$

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

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[10] 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

[10] 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 original equipment manufacturers 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

certain level. Thus, it estimates the required numbers for this model – the cost to consumers net of the benefits. The NRC study provides no such numbers. Initially, for both cars and trucks, I estimated a 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 above, in this model, D=0 at the MY 1999 equilibrium level (ΔMPG=0), making the assumption that at this point CAFE standards were "just non-binding." Without binding CAFE standards, 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 $(\Delta MPG)^2$ for cars and 32.8 $(\Delta MPG)^2$ 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. 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.)

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

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2010 would cost consumers more than the discounted value of future fuel savings and would, therefore, increase the cost of transportation to consumers.

drive more, a phenomenon that is referred to as the "rebound effect." A recent study (Greene *et al*, 1999), whose results I employ, finds that for every 10 percent that fuel economy is increased, driving increases 2 percent.

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. (Since 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 percent is used.

G. Pollution Impacts

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 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 MY 2004 and later vehicles.

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

Table 2 begins the presentation of 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." Shadow 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. 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.

Welfare effects are presented in table 3. U.S. manufacturers between them would lose about $633 million, while U.S. consumers would lose approximately $1.596 billion.

(Consumer welfare losses are calculated along the lines of Braeutigam and Noll, 1984.) Total losses to producers and consumers therefore amount to $2.2 billion.

It is also necessary to calculate the increase in externalities caused by higher CAFE standards. CAFE standards lead to more miles driven, which leads to increased accidents and congestion. Edlin (1999 at 4) estimates that accidents cost about 8 cents per additional mile driven. Winston and Shirley (1998 at 64) present a higher estimate—about 20 cents per mile.[11] 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, as the marginal cost of congestion is expected to be higher than the average cost.[12] Here I will use the more conservative figures, with an externality per mile of 10.4 cents (the Edlin estimate for accidents plus the Lutter estimate for congestion.)

In contrast, the economic value of the increases in pollution are relatively small. The federal Office of Management and Budget values VOCs at approximately $0.51 to $2.36 per kilogram, and Nitrogen Oxides at the same level. Carbon monoxide, at least according to OMB, appears to have no marginal cost impact on the economy.[13] For purposes of this paper, I choose an externality cost of $1.43 per kilogram for both VOC and NOx.

As table 4 indicates, miles driven increase 25.650 billion, or 1.48 percent of MY 1999 fleet levels. Pollution impacts are also presented in table 4. 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 net externality cost of higher CAFE standards, using the estimates presented in the two paragraphs above, is $2.641 billion. As table 4 indicates, almost 99 percent of the increased externality costs come from accidents and congestion.

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[11] I note that both the Edlin and the Winston and Shirly estimates are taken from the fact that drivers do not pay insurance on a per mile basis. If, on the other hand, one modeled the decision to drive as including the probability of an accident and the resulting higher insurance costs, these figures might be lower.

[12] This is the average cost calculated as the cost of congestion-related delays and fuel costs, $78 billion, divided by aggregate VMT by light duty vehicles. See Lutter, Randall, "CAFE: The Numbers Behind the Story" March 2002 http://www.aei.brookings.org/policy/page.php?id=84

[13] See http://www.whitehouse.gov/omb/inforeg/costbenefitreport1998.pdf

In this model, gasoline consumption declines by 5.242 billion gallons or 7.21 percent of total fleet consumption. 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. 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 6. 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 when only producer and consumer effects are considered. The total marginal cost, including externalities, is $1.26.

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 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 above underestimates the true loss to the economy of raising CAFE standards. Part A of this section outlines the several step process for estimating this loss. Part B applies the methodology of Part A to this market.

A. 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 assumed 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:

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

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.

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 through manipulation of supply and demand matrices to determine the pass-through rates for each type of vehicles. This work is available upon request from the author.

For the model of this report, the results of the impact of a CAFE tax by vehicle type for GM cars are presented in table 7. 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 8 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 7. 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.[14]

[14] 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.

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

Tables 9 and 10 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. 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 $2.965 billion. Miles driven rise 1.88 percent from the MY 1999 equilibrium. Emissions of VOCs, NOx, and, carbon monoxide rise between 1.64 to 1.86 percent from the MY 1999 equilibrium. Total externality costs are $2.591 billion. 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 including only producer and consumer welfare terms. Including externalities, the average cost of reducing a gasoline externality is $1.16.

Total U.S. producer and consumer losses from the no-CAFE equilibrium of raising the long-run CAFE standard 3.0 MPG are $3.026 billion. Miles driven rise 1.93 percent from the MY 1999 equilibrium. Emissions of VOCs, NOx, and, carbon monoxide rise from 2.07 to 2.25 percent from the no-CAFE equilibrium. The total cost of CAFE related externalities is $6.428 billion. 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 including only producer and consumer welfare losses, and $1.00 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 30 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, and the coefficients in table 11, the marginal cost of reducing a gasoline consumption externality is $1.06 in producer and consumer welfare terms, and $1.43 when including externalities.

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 will use the NRC figure of $0.26 per gallon of externality.[15] 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 above 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 half way between short-run and long-run estimates by Dahl and Sterner (1991). 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 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, while the marginal loss equals the level of the relevant tax.[16] 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, an increase in the CAFE standard of 3.0 MPG decreased gasoline consumption by 5.242 billion gallons, for an average cost per gallon of $0.93. This is more than three times the $0.26 per gallon benefit estimated by the NRC.

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[15] 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.

Using estimates for the long-run elasticity of gasoline demand, a tax of $0.111 per gallon would be required to induce savings of 5.242 billion gallons of gasoline. Thus, a tax would impose an average cost on society of half of that amount, or $0.0555 per gallon. In other words, the 3.0 MPG increase in the CAFE mandate would cost society 16.8 times more than a gasoline tax increase saving the same amount of fuel. At the margin, saving a gallon of gasoline costs the economy $1.26 in this scenario, far higher than the $0.26 benefit estimated by the NRC.

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 5.091 billion gallons per year, for an average cost of $1.16 per gallon. This is more than four times the NRC estimated benefits.

This same reduction in gasoline consumption could be achieved by a gasoline tax increase of $0.108 cents per gallon. The gasoline tax would impose social costs of $275 million, compared to $5.556 billion from higher CAFE standards. Thus, the 3.0 MPG increase in the CAFE mandate would cost society 20 times more than a gasoline tax increase saving the same amount of fuel.

In this scenario, where CAFE standards are already considered to be binding, the marginal cost of mandating the long-run 3.0 MPG CAFE increase is $1.43 per gallon. This is over five times the NRC estimate of the marginal benefits of saving gasoline.

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, increasing the CAFE standard by more than 3.0 MPG would impose additional costs of $5.556 billion per year and reduce gasoline consumption by 5.091 billion gallons per year. This amounts almost 20 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

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[16] I note that 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.

exceed the additional benefits of avoided gasoline consumption externalities by a factor of over five 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.

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Table 1
Initial Conditions – Prices and Quantities
Model Year 1999

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 2
Price and Output Effects of 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

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 3
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)	-0.219	-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 4
The Impact of Standards on Pollution Emissions

	Miles Driven	Pollution Impacts (all in million kilograms)		
		VOC	NOX	CO
Original MY Level	1,733,070 million	638.962	487.739	5,288.892
CAFE – induced change in MY Level	24,773 million	9.307	7.387	79.297
Change in Stockage Levels	877 million	1.167	1.33	17.931
Total Change	25,650 million	10.474	8.720	97.228
Percent Change	1.48%	1.64%	1.79%	1.84%
Externality Cost Per Unit	$0.104 per mile	$1.43/kilogram	$1.43/kilogram	–
Total Externality Cost	$2.641 billion	$0.015 billion	$0.012 million	Total Externality Cost: $2.668 billion Total Cost: $4.898 billion

Table 5
Impact of Higher Standards on Gasoline Consumption

MY Pre-CAFE Gas. Cons. (billion gallons)	72.695	**Average Cost of Gasoline Externality Saved W/o and with externalities**	$0.43/$0.93
Change in MY Gas Cons. (billion gallons)	-5.299		
Change in Stockage Consumption (billion gallons)	0.057		
Net change in Consumption (billion gallons)	5.242	**Marginal Cost of Gasoline Externality Saved (inferred) W/o and with externalities**	$0.92/$1.26
Percentage Change in Consumption	7.21%		

Table 6
Regression Results to Estimate Marginal Cost of Gasoline Savings

	Producer and Consumer Effects	**All Effects**
Variable	**Coefficient** (T-statistic)	**Coefficient** (T-statistic)
Gallons Saved	-6.90 (31.68)	0.653 (77.94)
(Gallons Saved)^2	7.02 (758.07)	0.0470 (13.18)
(Gallons Saved)^3	0.23 (246.71)	0.00137 (3.78)
	Number of Obs: 30 R-square:0.963	Number of Obs: 30 R-square:0.990.9

Table 7
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 8
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 9
Welfare Effects - 3.0 MPG Increase
CAFE Already Binding Model

	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 10
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	1.64%	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%)
% Change in Miles Driven	1.88%	1.93%
Total Externality Costs ($ billion)	$2.591	$3.402
Total Costs ($ billion)	$5.556	$6.428
Average cost of reducing Gasoline Externality W/o and with externalities	$0.58/$1.16	$0.47/$1.00
Marginal cost of reducing Gasoline Externality (inferred) W/o and with externalities	$1.09/$1.43	

Table 11
Regression Results to Estimate Marginal Cost of Gasoline Savings
CAFE Already Binding Model

	Producer and Consumer Effects	**All Effects**
Variable	**Coefficient** (T-statistic)	**Coefficient** (T-statistic)
Gallons Saved	0.047 (-149.54)	0.618 (48.45)
(Gallons Saved)^2	0.065 (599.63)	0.056 (12.69)
(Gallons Saved)^3	0.0025 (270.06)	0.00073 (1.98)
	Number of Obs: 30 R-square: 0.997	Number of Obs: 30 R-square: 0.999

Table 12
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