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Clearing the air: The costs and consequences of higher CAFE standards and increased gasoline taxes

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Abstract

Concerns about energy security and climate change have sparked legislators' interest in reducing gasoline consumption by increasing corporate average fuel-economy (CAFE) standards. Using an empirically rich simulation model and cost estimates for anticipated fuel-economy technologies, we estimate annual costs of reducing long-run gasoline consumption by 10% via a 3.8 miles per gallon increase in the standards, and the potential cost savings from allowing manufacturers to buy and sell fuel-economy credits. Maximum gasoline savings would be realized only after all existing vehicles were replaced, or 14 years in our model. A gasoline tax would produce greater immediate savings by encouraging people to drive less, and eventually to choose more-fuel-efficient vehicles. We demonstrate the advantage of a tax by comparing the cost of the higher CAFE standards over the first 14 years against the cost of a gasoline tax that would save the same amount of gasoline over that time.
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1. Introduction

Growing recognition that the Earth's climate has been gradually warming—and that atmospheric carbon is partly responsible for this—has led some public interest groups and

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members of Congress to propose increasing the corporate average fuel-economy (CAFE) standards for automobiles.[1] Fuel-economy standards would not only cut US emissions of carbon dioxide, but would also reduce US dependence on oil and the accompanying risk of economic disruption from oil price volatility.[2]

A central purpose of this paper is to estimate the private costs of raising the CAFE standards, and of increasing the federal tax on gasoline—an alternative policy for reducing gasoline consumption—using a consistent set of assumptions. We also estimate the cost savings that would result if automobile manufacturers could comply with higher CAFE standards by trading ‘‘fuel-economy credits’’, which would allow some firms to under-comply with the CAFE standards provided that other firms over-complied by an equivalent amount.[3]

Our paper builds on several previous analyses of costs resulting from raising the CAFE standards. Similar to Goldberg [10], we model the supply of automobiles using an aggregate oligopoly-and-product-differentiation model. While Goldberg focuses on 1-year adjustments that manufacturers could make to comply with CAFE standards (adjusting their product prices and changing the domestic content of their vehicles so they can be reclassified from ‘‘domestic’’ to ‘‘foreign’’), we focus on long-run adjustments that manufacturers might employ—specifically, adjustments to fuel economy and/or vehicle prices.[4]

Parry et al. [18] and Kleit [14] also focus on the long-run effects of higher CAFE standards. Our analysis differs from theirs in several ways. In particular, those studies both assume that the market for automobiles is competitive. We offer a more realistic model of the passenger vehicle market, with automakers possessing some market power and offering products differentiated by real, or perceived, quality differences. Consumer responses are dictated by elasticities derived from survey data and estimates of vehicle mark-ups (with higher mark-ups implying less elastic demands). We believe that this more accurate portrayal of the supply side of the market (few would argue that the vehicle market is perfectly competitive), coupled with a model of consumer

[1]In the US, 20% of anthropogenic carbon emissions come from the combustion of gasoline.

[2]Raising the CAFE standards may have little effect on local pollutants such as carbon monoxide, which are regulated by the Environmental Protection Agency (EPA) on a grams-per-mile basis and are, therefore, not directly related to a vehicle's mileage rating. In a study of cars produced in 1979–1990, Harrington [13] found that, compared with high-mpg cars, low-mpg cars had greater carbon monoxide and hydrocarbon emissions as they aged, and their pollution control equipment degraded. Harrington noted, however, that this finding does not necessarily mean that further increases in CAFE standards would produce still more emission reductions in the future because improved reliability of pollution control equipment might eliminate this effect. Further, as discussed below, driving-related externalities such as congestion, accidents, and noise could increase because better fuel economy would make vehicles cheaper to operate, encouraging additional driving.

[3]For a qualitative comparison of these three policies, see [3]. Alternative comparisons of the costs of more stringent CAFE standards versus higher gasoline taxes, based on the model used in this paper, may be found in [4].

[4]Current CAFE standards distinguish between domestic and imported cars. An automobile generally qualifies as domestically produced if at least 75% of its manufacturer costs are attributable to value added in the US and Canada. Automakers could potentially maintain their CAFE compliance by shifting low-mpg vehicles from their domestic fleet to their imported fleet via reductions in the ‘‘domestic content’’ of those vehicles. This tactic could be useful to firms whose imported fleet average fuel economy was above the CAFE standard and whose domestic fleet average was below the standard. We model a single standard for cars, which allows firms a little additional flexibility and thus may slightly understate some firms' CAFE compliance costs.

reactions that is based on observed responses and markups, yields a more accurate representation of the potential producer and consumer losses that might result from tighter CAFE standards.[5]

Like Kleit, we compare the costs from higher CAFE standards with those resulting from a higher tax on gasoline. However, we do this using a consistent set of assumptions about consumer preferences and technology costs, and based on saving the same quantity of gasoline with both policies. By contrast, Kleit uses a gasoline tax elasticity derived from historical estimates based on past costs of improving fuel-economy, rather than on projected future costs from his CAFE model. Further, Kleit compares costs per gallon saved by these policies in an inconsistent way.[6]

Parry et al. do not compare costs from alternative policies, but do consider the potential for CAFE standards to improve welfare when there are failures in the market for fuel economy. We do not address this issue, arguing that the information about fuel economy that is provided to new-vehicle buyers makes the fuel-economy market reasonably efficient.

The paper is organized as follows. We describe our new passenger vehicle simulation model in Section 2 and the data used for it in Section 3. In Section 4 we describe the supply and demand elasticities used in calculating the costs of an increase in the gasoline tax. We present our results in Section 5 and in Section 6 we discuss whether either policy would be likely to improve social welfare.

2. A model of the market for new passenger vehicles

We model the effects of CAFE standards on the market for new passenger vehicles using a static model that represents long-run equilibrium adjustments. Multiple producers compete on price and fuel economy, with consumers treating the present discounted value of a vehicle's lifetime fuel savings (relative to its pre-policy baseline) as a reduction in the vehicle's purchase price. Firms produce many types of vehicles, from subcompacts to large SUVs, and maximize profits given consumer demand and subject to minimum-fuel-economy standards. Consumer preferences are represented by a matrix of demand elasticities across firms and vehicles. We hold attributes other than price and fuel economy constant, so shifts in unit sales will result only from changes in relative and absolute new-vehicle prices. (Consumers may respond by changing their choice of vehicle or by forgoing purchasing a new vehicle.) For each level of CAFE stringency (or retail gasoline price, when we model the effect of a gasoline tax), the simulation model finds the unique, static Nash equilibrium solution: that combination of vehicle prices and fuel-economy ratings that maximizes each firm's profits given the actions of the other firms and the preferences of consumers, subject to satisfying the CAFE constraints. Our results can be interpreted as

[5]Parry provides a more detailed theoretical model of the consumer side of the market, but the consumer choices in his empirical results are driven by an elasticity matrix that is similar to ours but less detailed. Specifically, his matrix accounts for cross-elasticities between vehicle categories (such as a subcompact and a compact) but not between manufacturers for a given category.

[6]Kleit's estimate of the gasoline saved by the tax is derived from a long-run elasticity, so it reflects the savings that would occur once the whole vehicle fleet had been retired and replaced with vehicles made after the tax was imposed. By contrast, his CAFE estimate is the present discounted value of lifetime gasoline savings achieved by a single model year of vehicles. This comparison significantly overstates the cost per gallon saved of CAFE standards relative to the tax because it does not allow for the full replacement of the existing fleet under CAFE, as it does for the tax.

describing the effects that an increase in the CAFE standards would have had on current producer and consumer welfare if the policy had been announced long enough in advance to allow for anticipated fuel-economy technologies to be developed and for firms to redesign their vehicles.

2.1. Supply: vehicle pricing and fuel-economy decisions

We model the passenger vehicle market as served by a multi-firm, differentiated-product industry in which firms engage in Bertrand competition across multiple vehicle categories and seek individually to maximize their profits across all of their products. In accordance with the current CAFE policy, firms face fuel-economy constraints requiring a given average fuel economy for their light trucks and, separately, their cars, based on units sold. Firms satisfy the constraints by adjusting their prices to attract their customers toward higher-mpg vehicles—a practice called *mix-shifting*—or by applying technologies to improve the fuel economy of their vehicles. All firms have access to the same technologies, the costs of which vary by type of vehicle.

The firms' objective functions are given by

$$\max_{p_{ij},F_{ij}} \pi_i = \sum_j^J (p_{ij} - c_{ij}(q_{ij}) - v_j(F_{ij}))q_{ij} \tag{1}$$

subject to a pair of fuel-economy constraints (for cars and for light trucks) of the form

$$g_i(q_{i1},\ldots,q_{iJ'}) = CAFE_{\text{car}|\text{trk}} - \frac{\sum_{j'} q_{ij'}}{\sum_{j'}(q_{ij'}/(FE_{ij'}+F_{ij'}))} \leqslant 0. \tag{2}$$

Firms are indicated by i and vehicle types (e.g., subcompact, minivan, etc.) by j. In the constraints, J' and j' indicate that vehicle type is restricted to either cars or light trucks, as appropriate to the particular CAFE standard. Vehicle prices and quantities are given by p and q. We assume unit production costs are constant, $c_{ij}(q_{ij}) = c_{ij}$, in the absence of new CAFE standards and rise only in response to higher fuel-economy requirements, according to technological costs estimated by the National Research Council (NRC), as discussed below.[7] We do not directly observe the unit costs c_{ij}, instead calculating them implicitly based on our assumption about the relationship between unobserved producer markups $(p_{ij}-c_{ij})/p_{ij}$ and retail markups, which we do observe. Those calculations are described in the next section, along with all of our parameter assumptions. Based on NRC estimates, we assume that fuel-economy technology costs $v(F)$ are convex and increasing in F, the change in vehicle fuel economy in miles per gallon. Demand q is declining in vehicle prices and increasing in fuel economy, as governed by parameter values discussed below.

In the function $g_i(q_{i1},\ldots q_{iJ'})$, baseline vehicle fuel economy FE is given in miles per gallon. Compliance with the car or truck fuel-economy constraints, $CAFE_{\text{car}|\text{trk}}$, is determined by a firm's calendar-year-sales-weighted harmonic mean rate of fuel consumption (in gallons of gasoline per mile). In the actual CAFE program, firms have 3 years in which to use credits earned for past (or

[7] We experimented with unit costs that were sensitive to quantity, with an elasticity of 0.1 as suggested by an industry economist. This increased the complexity of our model but had little effect on our results.

future) over-compliance to offset under-compliance in a particular year. This provides them with flexibility in the face of uncertainty about the final composition of their actual vehicle sales each year. In our model there is no such uncertainty and firms comply based on single-year sales.[8] With six firms and 10 vehicle types (as described in the data section), our optimization routine jointly maximizes each firm's profit function subject to the CAFE constraints, the cost of improving fuel economy, and to consumers' demand responses, by adjusting 120 variables—the prices and fuel-economy levels of 60 vehicle models (with each vehicle model representing a firm-vehicle type combination, e.g., Toyota mid-size car).[9]

2.2. Supply: producers' decisions with inter-firm credit trading

We also model a variant of the CAFE program in which firms can trade fuel-economy credits.[10] A firm could make up a shortfall in its average fuel economy by buying fuel-economy credits from an over-compliant firm. The system would produce aggregate cost savings relative to the no-trading scenario because automakers with better baseline average fuel-economy ratings would have lower marginal CAFE-compliance costs, and could thus generate credits more cheaply than some firms could meet the standards on their own.

We assume that all trades would be conducted at a single, market-clearing price coinciding with the industry's common marginal cost of compliance. With credit trading, firms' objective functions become

$$\max_{p_{ij},F_{ij}} \pi_i = \sum_j^J (p_{ij} - c_{ij} - v_j(F_{ij}))q_{ij} + p_{\text{carcredit}}K_{i,\text{car}} + p_{\text{trkcredit}}K_{i,\text{trk}} \tag{1$'$}$$

subject to fuel-economy constraints for cars and for light trucks of the form

$$g_i(q_{i1},\ldots,q_{iJ'}) = CAFE_{\text{car|trk}} - \frac{\sum_{j'} q_{ij'}}{\sum_{j'}(q_{ij'}/(FE_{ij'} + F_{ij'} - k_{ij'}))} \leqslant 0. \tag{2$'$}$$

Firm i's car and truck fuel-economy credits are indicated by $K_{i,\text{car}}$ and $K_{i,\text{trk}}$, respectively, and are denominated in gallons saved per 100 miles. Equilibrium credit prices are given by $p_{\text{carcredit}}$ and $p_{\text{trkcredit}}$. In constraint (2′), the lower-case $k_{ij'}$ indicate the mpg equivalents of the credits, which depend on the mileage rating of the vehicle to which they are "applied" or from which they are earned.[11] Note that $K<0$ and $k<0$ for a credit buyer and $K, k>0$ for a credit seller.

[8] We could alternatively model the CAFE standards as a tax, because in the real world the penalty for non-compliance is a fine ($55 per vehicle sold, for every mile per gallon a firm is out of compliance). In practice, domestic automakers treat the standards as a binding constraint, apparently wishing to avoid potential exposure to legal liability and reputation effects.

[9] Only 106 variables are actually adjusted, due to product categories with no sales (see Table 1). To solve the constrained optimization problem we use Matlab's "fmincon" routine, which finds a minimum of a constrained nonlinear multivariable function.

[10] By trading fuel-economy credits, manufacturers would be indirectly trading credits for carbon dioxide emissions, which are not directly observed. For a discussion of trading programs having such characteristics, see [15].

[11] Note that the CAFE constraint (2′) limits the number of credits a firm can sell, closing the model. Credit trading equalizes marginal compliance costs and effectively associates credits K with particular vehicles. The number of credits

2.3. Demand: price elasticities and calibration

Consumers' passenger-vehicle choices deviate from what is observed in the baseline when new policies induce changes in effective vehicle prices (retail price minus the present discounted value of the vehicle's lifetime fuel savings due to fuel-economy improvements). Any changes this then causes in consumers' vehicle choices are determined by an $IJ \times IJ$ matrix of price elasticities, where I is the number of firms and J the number of vehicle types. The own elasticities along the diagonal are all negative, while the cross elasticities within and across firms are all positive. We base our $IJ \times IJ$ price elasticities on baseline wholesale automobile markups and on a $J \times J$ industry-level, cross-vehicle-type elasticity matrix that Kleit [14] estimated from survey data on new-vehicle buyers.[12] We do not observe the wholesale markups, assuming instead that they are twice as large as reported retail markups. The latter, defined as (*MSRP-dealer wholesale cost)/MSRP*, where MSRP is the manufacturer's suggested retail price, are available at the level of the individual vehicle.[13]

The relationship between the baseline wholesale markups $(\mathbf{p}_{i\cdot} - \mathbf{c}_{i\cdot})/\mathbf{p}_{i\cdot}$ and firm-level elasticities $(\partial \mathbf{q}_{i\cdot}/\partial \mathbf{p}_{ij})(\mathbf{p}_{ij}/\mathbf{q}_{i\cdot})$ can be seen from firm i's baseline (unconstrained) first-order conditions on the prices it sets for the J vehicle types it produces:[14]

$$\mathbf{0} = \mathbf{q}_{i\cdot} + \mathbf{A}_i \cdot (\mathbf{p}_{i\cdot} - \mathbf{c}_{i\cdot}), \text{ where } \mathbf{A}_i \equiv \begin{bmatrix} \frac{\partial q_{i,1}}{\partial p_{i,1}} & \cdots & \frac{\partial q_{i,J}}{\partial p_{i,1}} \\ \vdots & \ddots & \vdots \\ \frac{\partial q_{i,1}}{\partial p_{i,J}} & \cdots & \frac{\partial q_{i,J}}{\partial p_{i,J}} \end{bmatrix}. \tag{3}$$

In practice, we develop the firm-level elasticities by first replicating the $J \times J$ industry-level elasticities into an $IJ \times IJ$ matrix and then adjusting that matrix so that Eq. (3) is satisfied for each firm given observed prices and quantities and the unit costs implied by our wholesale markups.[15]

(*footnote continued*)
associated with a k-mpg increase in a vehicle's mileage rating is $100(1/M - 1/(M+k))$, where M is the vehicle's initial mpg rating. This is a decreasing function of M: for an over-compliant firm, setting $k = 1$ mpg will generate 0.108 credits if $M = 30$ mpg and 0.238 credits if $M = 20$ mpg. The formula also describes the reduction in under-compliant firms' demand for credits as M increases.

[12] CAMIP survey of new car buyers (General Motors, 1993).

[13] Bresnahan and Reiss [2] estimate the ratio of retail to manufacturer markups to be 0.7, though Goldberg [9] notes that they cannot statistically reject a value of 0.5, the ratio we assume here. While this ratio implies larger manufacturer markups for a given level of retail markups, it still yields markups much smaller than those Goldberg [9] estimates econometrically. As she notes, however, overcapacity in the automobile industry during her sample period could have caused her unit-cost estimates to be unusually low and thus her markups to be high.

[14] Recall that we assume current CAFE standards are (just) short of binding on any firm, so there is no CAFE constraint in the baseline first-order conditions. Eq. (3) also reflects our assumption that unconstrained expenditures on fuel economy are zero ($v_j(F_{ij}) = 0$) and that the costs of alternate uses of those technologies are included in baseline unit costs c_i.

[15] Solving the equations is simplified by the fact that observed markups cluster into just two groups for each vehicle type (markups for large luxury sedans and large SUVs actually cluster into a single group, meaning they are marked up about the same amount by all firms). Because of the clustering, Eq. (3) can be solved by finding the one or two multipliers per vehicle type that, when applied to the corresponding industry-level elasticities, produce a firm-level

Some of the new fuel-saving technologies in our model could more than pay for themselves over the life of the vehicle, if used to improve fuel economy. However, they all have dual uses in the sense that they can also be used to hold a vehicle's rate of fuel consumption constant while its performance, weight, or energy-consuming amenities are increased. Thus, even when firms adopt the new technologies, average fuel economy will not necessarily increase. Indeed, the EPA has noted that between 1981 and 2003, average vehicle fuel economy changed very little (increasing from 20.5 to 20.8 mpg), while average horsepower nearly doubled (from 102 to 197), weight increased by almost 25% (from 3201 to 3974 lb), and 0-to-60 acceleration times fell by nearly 30%.[16] These gains could not have been achieved in the absence of innovation and they indicate that automakers have used new technologies to boost performance rather than fuel economy, except when the CAFE standards were raised.

Recall that we hold vehicle performance attributes (other than fuel economy) constant in our model. We capture firms' reluctance to voluntarily use the new technologies to boost fuel economy by performing an unconstrained, calibrating run of the model and then removing technologies that the firms freely adopt to boost fuel economy in that run. We are implicitly assuming that these technologies would have been used to boost vehicle performance instead.[17] Calibrating the model in this way raises the marginal cost of fuel economy because it eliminates the least expensive technologies.

Some analysts argue that higher (that is, tighter) CAFE standards could make new-car buyers better off because consumers are not sufficiently informed about the value of fuel economy to maximize private welfare on their own. If this were true, then tighter standards could improve consumer welfare by compensating for information failures in the market for fuel economy, and our calibration method would overestimate the cost of raising the CAFE standards. We argue, though, that there is no such market failure—that the information on new-vehicle window stickers, reporting the EPA's city and highway mileage rating and the vehicle's estimated annual fuel cost, is sufficient to allow consumers to make informed decisions about fuel economy.

While we feel that our assumption that firms would not voluntarily use new technologies to boost fuel economy is consistent with observed behavior, it is an important determinant of our cost estimate. As such, we provide sensitivity analysis for this assumption in the Appendix.

(*footnote continued*)
matrix **A** that is consistent with observed markups. The multipliers reflect the intensity of competition within each vehicle category.

[16]See EPA [7]. In the report, the EPA asserts that, "based on accepted engineering relationships, …had the new 2003 light vehicle fleet had the same average performance and same distribution of weight as in 1981, it could have achieved about 33% higher fuel economy."

[17]The technologies used in our model are ones identified in a CAFE study by the National Research Council [16]. Some of those technologies, such as the continuously variable transmission, can already be found in some new vehicles. None of the new technologies described by the NRC is expected to reduce the marginal cost of fuel economy below what is currently available (rather, they would extend the feasible range of fuel-economy gains). Thus, none would make it more profitable for firms to boost fuel economy instead of performance.

3. Data

Our data provide a detailed but stylized description of the US passenger-vehicle market. We include prices, unit sales, and fuel-economy ratings for vehicles sold in the US in 2001 (our baseline year) by the five largest firms in this market (General Motors, Ford, DaimlerChrysler, Toyota, and Honda, including divisions and wholly owned subsidiaries).[18] We also include a sixth firm that is a composite of most of the remainder of the industry.[19] The data comprise about 95% of the 16.6 million passenger vehicles sold in the US in 2001. Unit sales were 4–5% lower that year than in model years 2000 and 2002, so our cost estimates are slightly lower than they would be with data from those years.

We combine data by vehicle type and firm. For instance, the Ford Taurus and Mercury Sable, Ford's two non-luxury, midsize-car models for 2001, are represented in our model by the "Ford midsize car", with unit sales equal to total US sales of the Taurus and Sable, and price and fuel-economy rating equal to the median values for the various configurations of these cars.[20] The price and fuel economy of an actual vehicle vary with engine size, transmission type, and other attributes that we do not include in our analysis.

We assign each vehicle to one of 10 vehicle types, based largely on the EPA's classifications.[21] Our model includes six types of car:

- subcompact (including sports cars),
- compact (including sedans and wagons),
- midsize (including sedans and wagons),
- large (including sedans and wagons),
- luxury small (subcompact and compact with price >\$31,000),
- luxury large (midsize and large with price >\$35,000)

and four types of light truck:

- minivan,
- small SUV (6 or fewer cylinders),

[18]Calendar-year unit sales: www.autonews.com, 'Sales, US Car—2001' and 'Sales, US Light Truck—2001'. Wholesale and manufacturers' suggested retail prices (MSRP) for many configurations of each vehicle model: www.edmunds.com, 'New Car Pricing' for 2001 model year. Model-year combined estimated fuel economy for actual driving conditions (i.e., as indicated in the new vehicle window sticker), for multiple configurations of engine size, transmission type, drive wheels: EPA, Office of Transportation and Air Quality, www.epa.gov/otaq/fedata.htm, 2001 model year. The model year begins in October; thus the overlap of model-year prices and fuel economy with calendar-year sales data is 9 months.

[19]The composite firm includes BMW, Volkswagen, Isuzu, Mazda, Mitsubishi, Nissan, Subaru, Hyundai, Daewoo, and Kia. Foreign subsidiaries included in the "domestic" firms' data include Saab (owned by GM), Jaguar and Volvo (owned by Ford), and Mercedes-Benz (owned by DaimlerChrysler).

[20]We use median rather than mean values because, while prices and fuel-economy ratings are available for all observed vehicle configurations, vehicle sales are available only at the "nameplate" level.

[21]We further classify luxury cars and SUVs into large and small types, corresponding to natural divisions in the data. The price thresholds for luxury cars capture traditional luxury brands (e.g., Jaguar, Mercedes-Benz, BMW, Lincoln, Cadillac).

- large SUV (8 cylinders),
- pickup (including small and standard sizes)

The estimated costs of reducing gasoline consumption are specific to each vehicle type and come from a recent study on CAFE by the NRC [16]. The NRC considered fuel-saving technologies that are anticipated within 10–15 years, as well as some that are ready for adoption but are not yet in widespread use.[22] The NRC holds vehicle attributes other than mpg constant, so their cost estimates are consistent with our modeling assumptions.[23]

Consumers value the expected discounted lifetime fuel savings from improved gasoline mileage when they purchase a new vehicle. We assume that fuel economy is also valued in the used-car market, so consumers do not value fuel savings any less if they expect to trade in their new vehicle before its useful life expires.[24] For the sake of comparability with the NRC study, we adopt their assumptions about the price of gasoline ($1.50 per gal), average vehicle life (14 years), vehicle miles traveled per year (15,600 in the first year), rate of decline in miles (4.5% per year), and discount rate (12%).[25]

A 12% discount rate is slightly higher than the interest rate consumers reported facing for used-car purchases in the most recent Consumer Expenditure Survey (consumers can be expected to discount the value of future fuel savings at a rate at least equal to their cost of borrowing funds). The discount rate matters less here than it otherwise would because of the way we calibrate our model. If we assumed a lower discount rate, the value of fuel savings would rise and producers would adopt more fuel-saving technologies in our calibrating run. Since we eliminate all freely adopted technologies from that run, however, the lower discount rate would also raise the cost of improved fuel economy, offsetting the increase in the value of fuel savings.

Below, Table 1 reports the baseline data for our model. Although we use actual firm names, and the numbers are based on observed data for these firms, our aggregation of the data makes this a highly stylized representation of the US automobile market.

[22]Their cost estimates are expressed as retail price equivalents, with a 40% markup assumed to be shared among parts suppliers, automaker, and dealer. Since our model marks up all manufacturer costs, we avoid double markups on these technologies by assuming that automakers acquire them at a 10% markup over supplier costs. (Our simulation model applies the remaining 30%, on average.)

[23]We represent technology costs as continuous functions of gallons saved per hundred miles, by fitting quadratic curves to the data points in the NRC report. NRC's estimates assume a 5% vehicle-weight increase to accommodate future emissions and safety equipment requirements. NRC's vehicle types are similar to ours except theirs do not include luxury cars (we use the NRC technology cost estimates for "compact" and "large" cars, respectively). Technology costs for our large SUV are an average of NRC's estimates for midsize and large SUVs, and for our pickup are an average of NRC's small and large pickups.

[24]Some economists feel that fuel economy is undervalued in the used-car market because of information constraints—in particular the absence of a window sticker reporting the vehicle's fuel-economy rating—and that CAFE standards may be justified because this implies that new-vehicle fuel economy is also undervalued. To the extent this is so, our CAFE cost estimates understate the costs of this policy to new-car buyers and manufacturers, but then higher CAFE standards would make used-car buyers better off.

[25]We differ from the NRC in assuming a slightly more gradual, exponential rate of decay in miles traveled (they assume linear). The exponential function provides a slightly better fit to the vehicle usage data in the National Household Travel Survey (nhts.ornl.gov/2001/index.shtml); the functional form makes little difference in our analysis.

Table 1
Baseline data for stylized automobile market

2001 Model year	Sub-Comp	Compact	Midsize	Large	Lux Sml	Lux Lge	Minivan	SUV Sml	SUV Lge	Pickup
Price ($000)										
Ford	24.5	17.0	21.6	23.7	84.5	42.3	27.2	27.1	35.3	22.9
GM	19.0	16.1	21.2	25.0	46.8	44.3	28.0	25.5	34.7	23.6
Chrysler	—	17.4	19.1	24.6	44.7	61.6	27.5	18.9	31.1	21.9
Toyota	23.9	15.5	25.1	28.5	—	53.3	25.8	24.5	41.1	20.1
Honda	24.9	15.9	21.6	—	86.1	43.2	26.4	24.8	—	—
Other	19.5	16.3	23.2	—	36.6	55.5	23.6	26.2	—	20.1
Quantity (000)										
Ford	169	353	489	205	5	179	200	579	254	1155
GM	132	725	730	430	34	167	173	284	496	1106
Chrysler	—	254	109	185	92	71	423	280	392	491
Toyota	66	348	488	85	—	36	89	176	86	258
Honda	38	351	483	—	0.2	11	132	177	—	—
Other	219	1044	425	—	171	49	61	530	—	111
MPG										
Ford	24.7	35.0	26.6	24.7	23.5	25.7	23.3	22.3	19.2	20.1
GM	28.1	32.3	27.3	27.5	24.6	24.3	26.1	22.7	17.8	21.1
Chrysler	—	31.4	27.5	26.2	24.6	24.5	23.4	23.8	20.2	18.0
Toyota	29.4	39.8	25.3	28.1	—	24.5	24.6	25.4	17.3	21.5
Honda	34.9	39.7	29.4	—	22.8	23.4	23.4	25.3	—	—
Other	29.2	30.7	25.9	—	26.4	22.5	22.8	21.8	—	20.0

Table 2
Baseline corporate average fuel economy ratings (harmonic mean MPG)[a]

Standard	Ford	GM	Chrysler	Toyota	Honda	Other
Car (27.5 mpg)	27.5	28.5	27.6	29.4	32.9	28.6
Truck (20.7 mpg)	20.8	20.7	20.7	22.1	24.4	21.5

[a]These are not the firms' actual CAFE ratings; they are calculated from our stylized data.

All of the firms in the table are compliant with the initial CAFE standards of 27.5 mpg for cars and 20.7 mpg for light trucks, equal to the actual fuel-economy standards in effect that year.[26] Table 2 reports each firm's baseline corporate average fuel economy for each category of vehicle, using the formula for the sales-weighted harmonic mean (this formula is stipulated

[26]The MPG ratings reported in Table 1 reflect EPA dynamometer test results used in assessing CAFE compliance, and are a weighted average of highway and city tests. The MPG ratings printed on new-vehicle window stickers assume actual mileage will be about 16% lower than the test results, and we make this adjustment when we calculate lifetime fuel savings. Changes since the 2001 model year highlight the stylized nature of these data. For example Honda, BMW, Nissan, and Volkswagen now all manufacture large SUVs.

by the CAFE program, and is the reciprocal of a firm's weighted average fuel consumption rate in gallons per mile).

4. Gasoline demand and supply elasticities

Our CAFE simulation model also plays an important role in our estimation of the effects of an increase in the gasoline tax. The price of gasoline affects consumers' choices about how much to drive and how fuel-efficient a vehicle to purchase. The price elasticity of the demand for gasoline is therefore a function of the elasticity of vehicle-miles-traveled (VMT) with respect to the per-mile fuel cost, and of vehicle fuel economy (FE) with respect to the price of gasoline. We estimate the latter elasticity by using our model to simulate the effect that a change in the price of gasoline has on average new-vehicle fuel economy. Doing so assures that the gasoline demand elasticity we use in our analysis of the gasoline tax is founded on the same consumer preferences and technology costs that we assume in our analysis of the CAFE standards. This method yields a fuel-economy elasticity estimate of $+0.22$.

For VMT elasticity, we note that the so-called "rebound effect"—the response of VMT to a change in p_g/FE, the per mile fuel cost of operating a vehicle, where p_g is the per gallon price of gasoline (below, we drop the subscript g when p is itself a subscript) and FE is fuel economy in miles per gallon—is usually estimated to lie between -0.1 and -0.3 (so a 10% increase in the price of gasoline is estimated to reduce VMT by between 1% and 3%). In this paper we assume a VMT elasticity of -0.2; we perform sensitivity analysis on this assumption.[27]

The overall price elasticity of gasoline consumption can be written as $\beta_{Q,p} = \beta_{VMT,h}(1-\beta_{FE,p}) - \beta_{FE,p}$, where Q is the demand for gasoline, $\beta_{Q,p}$ and $\beta_{FE,p}$ are the elasticities of Q and FE, respectively, with respect to the price of gasoline and $\beta_{VMT,h}$ is the elasticity of VMT with respect to per mile fuel cost $h \equiv (p_g/FE)$.[28] Thus, the total decrease in gasoline consumption from a permanent increase in the gasoline tax is due to driving less $(\beta_{VMT,h})$ and buying more fuel efficient vehicles $(-\beta_{FE,p})$, with an adjustment $(-\beta_{VMT,h}*\beta_{FE,p})$ for the increase in driving due to improved gas mileage and lower vehicle operating costs. (This adjustment term is the rebound effect). Given our assumption about VMT elasticity and our FE elasticity estimate, we calculate a long-run elasticity of demand for gasoline of -0.39.[29]

We assume a value of 2.0 for gasoline supply elasticity. That value comes from comparing the effects of changes in gasoline prices on quantities supplied in the Energy Information Administration's (EIA's) 2010 forecast.[30] Based on that supply elasticity and our estimate of

[27] We take this value from Greene's [12] assessment of the literature on VMT elasticity.

[28] This formula for the price elasticity of gasoline consumption can be found in Department of Energy [6]. It stems from defining aggregate gasoline consumption as $Q = VMT[w(p_g/FE)]/FE(p_g)$. We will be happy to provide a derivation of the elasticity upon request.

[29] This estimate is consistent with the Department of Energy's estimate of -0.38 for the long-run demand elasticity for gasoline, which was based on a review of the recent literature. See DOE [6]. Early studies tended to find higher elasticities. For example, in a 1991 survey of the literature, Dahl and Sterner [5] found an average long-run elasticity of -0.86.

[30] See Energy Information Administration, Annual Energy Outlook, (January, 2003) [Appendix B, Tables B11 and B12, available at: www.eia.doe.gov/oiaf/aeo/results.html]. We found little published information on the supply

the demand elasticity for gasoline, consumers' implied share of a gasoline tax is about 85%. We assume linear supply and demand curves for gasoline with the slopes determined by the relevant elasticities. We calculate the size of the cost triangle created by decreased gasoline consumption (often referred to as the excess burden or deadweight loss triangle, a designation that Small [20] points out may not be appropriate if the tax is justified by a negative externality).[31] We do not assume that tax revenues are used to reduce distortions created by pre-existing taxes, rather we implicitly assume that they are returned in a lump-sum fashion.

5. Results

Our comparisons of CAFE standards—with and without credit trading—focus on a policy that would reduce gasoline consumption by 10% after all existing vehicles were retired, which we assume would take 14 years. (We estimate that a 3.8-mpg increase in car and truck fuel-economy standards would achieve this target). In contrast, a gasoline tax would immediately give all drivers an incentive to drive less, but like the CAFE standards, would rely on changes in new-vehicle fuel economy to achieve its full effect. We compare the cost of tighter CAFE standards over a 14-year period with the cost of a gasoline tax designed to save the same amount of gasoline over that period.

Raising both car and truck standards by 3.8 mpg (a 14% increase in the existing car standard of 27.5 mpg and an 18% increase in the existing truck standard of 20.7 mpg) would lower the average rate of gasoline consumption for just-compliant cars by 12% (from 1/27.5 gallons/mile to 1/31.3 gallons/mile) while the rate for trucks would fall by 15%. Because not all firms would have to improve their average fuel economy by this much to comply with the new standards and because the higher fuel economy would encourage additional driving, we estimate that the overall reduction in gasoline consumption would be 10%.

The truck standard is scheduled to increase to 22.2 mpg in 2007; however, the car standard has remained at its current level since 1990. Increasing CAFE standards has traditionally been politically unpopular. Recently, however, there has been growing support for more stringent standards.[32]

(*footnote continued*)
elasticity of gasoline. Some analyses of gasoline taxes assume a perfectly elastic supply curve. Such an assumption would reduce the estimated welfare cost of the gasoline tax.

[31] For example, a 50-cent tax would impose a 7.5-cent cost on gasoline producers, with the remaining 42.5 cents passed on to consumers, based on a demand elasticity of -0.39. At an initial gasoline price of \$1.50 per gallon, the tax would cause a 28% increase in the price of gasoline and a 10.9% decrease in gasoline consumption. For initial annual gasoline consumption of 125 billion gallons, the cost of the 50-cent tax would be \$8.75 billion per year.

[32] See Congressional Quarterly, March 28, 2005 (www.cq.com). Our CAFE analysis considers equal-mpg increases in car and light-truck standards. Because of trucks' lower baseline fuel economy, raising the standards in this way requires greater fuel-economy improvements from trucks than from cars. Other combinations of CAFE standards could save the same amount of gasoline at slightly lower cost. In particular, in the absence of credit trading, some form of unifying the car and truck standards would minimize CAFE costs. The cost savings would not be dramatic or alter our basic conclusions, however.

Table 3
Annual costs of CAFE standards to achieve 10% reduction in gasoline consumption

	CAFE	CAFE with trading
Policy modeled	31.3 mpg for cars 24.5 mpg for light trucks	
Total cost	\$3.6 billion	\$3.0 billion
Producers	\$1.2 billion	\$0.8 billion
Consumers	\$2.4 billion	\$2.2 billion
Per-vehicle costs	\$228	\$184
Producers	\$75	\$42
Consumers	\$153	\$142

5.1. Long-run annual costs for CAFE

Higher CAFE standards would impose costs on consumers by raising the effective prices paid for new vehicles (net of fuel savings) and by discouraging some new vehicle purchases altogether. We measure the loss in consumer surplus due to simultaneous changes in both relative and absolute prices for new vehicles using *mutatis mutandis* demand schedules (in which prices for multiple products vary simultaneously) as demonstrated in [1]. Under that technique the loss in consumer surplus for each of the sixty individual products in our model (for example, Ford midsize car) is calculated based on the changes in price and quantity for that product resulting from the simultaneous change in the prices of all 60 products. The total loss in consumer surplus is the sum of the losses for each of the individual products.[33]

We measure producers' losses as the reduction in profits. An increase in the CAFE standards would raise average vehicle production costs more than prices. Thus, firms' profit margins and total vehicle sales would both decline. Increasing car and truck fuel-economy standards would impose annual costs of \$3.6 billion on producers and purchasers of new passenger vehicles. Once the existing vehicle fleet is fully replaced (after 14 years, by assumption), those standards would reduce total gasoline consumption by 10% (see Table 3).

Instituting fuel-economy credit trading would reduce the incremental cost of raising the standards by transferring the adoption of fuel-saving technologies from high-cost firms (that is, firms with lower fuel-economy ratings) to firms with lower costs. The magnitude of the cost savings from credit trading increases as tighter standards are imposed (see Fig. 1). For our benchmark increase in CAFE standards, which reduces long-run gasoline consumption by 10%, we estimate that trading would lower the cost to about \$3.0 billion per year, a savings of 16%.[34]

[33]Consumer surplus losses include the effects of higher prices as well as reduced sales. Consumer losses due to higher prices, however, are recovered by producers. (Inversely, prices that fall due to mix-shifting benefit consumers but reduce producer profits.) As a result, the total welfare loss (considering producer and consumer losses simultaneously) is analogous to the cost triangle calculated for the gasoline tax.

[34]Note that the results in this paper are annual and refer to vehicles produced in a single model year. The NRC's cost estimates assume that new CAFE standards would allow sufficient lag time for firms to redesign their products as necessary, in particular so that the new fuel-economy technologies would be available.

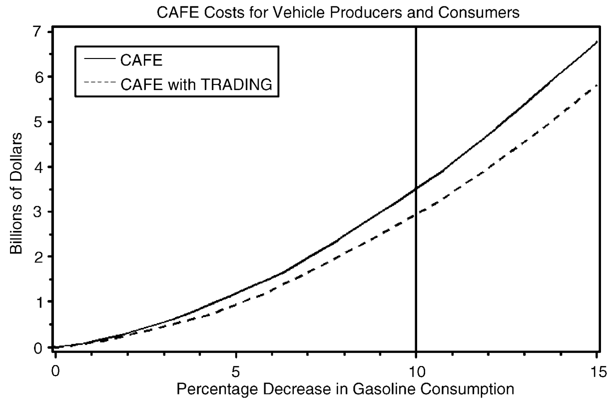

Fig. 1. CAFE costs for vehicle producers and consumers.

5.2. *Consumer and producer cost shares*

We estimate that consumers would bear the majority of the costs of higher CAFE standards and, relative to automakers, would share in few of the gains from credit trading. For example, meeting the benchmark target with CAFE standards (without trading) would impose $1.2 billion costs on vehicle producers. Trading would reduce producers' costs by roughly one-third, to $0.8 billion (see Table 3), but would reduce consumer costs only slightly (from $2.4 billion $2.2 billion).[35]

On a per-vehicle basis, our simulation model predicts that the average total cost associated with using CAFE standards to reduce gasoline consumption by 10% would be about $228, of which roughly $153 would come from consumers. Under the credit trading system, the average per-vehicle cost is predicted to be $184, with consumers bearing $142 of that cost.

5.3. *Could gasoline savings be obtained more cheaply through a gasoline tax?*

The increase in the CAFE standards described above is designed to reduce total passenger-vehicle gasoline consumption by 10% after 14 years, when by assumption all cars on the road would have been built after the more stringent standards were imposed. Annual gasoline savings gradually would increase over the initial 14 years, as more and more of the existing fleet was retired.

[35]There are various ways to structure a credit-trading program. The most important consideration is whether to award credits at the outset to firms whose baseline fuel economy would already be above the new standards. Doing so would mean that gasoline consumption would not actually drop in response to higher CAFE standards until those credits were used up. However, awarding credits only for improvements made after the standards were raised would effectively penalize firms for voluntarily over-complying with the existing standards. Our results are based on awarding credits for pre-existing over-compliance. Given that design, our analysis finds that Honda and Toyota could actually be better off if higher standards were imposed (with credit trading) because their initial over-compliance with the existing standard would allow them to meet the new standard at a lower marginal cost than their competitors and to sell excess credits (up to the market clearing price) at a profit. Most of the demand for credits would come from the domestic firms.

Table 4
Present discounted costs, CAFE versus gasoline tax over 14 years: 3.8-mpg increase in CAFE standards versus "equivalent" gasoline tax

Discount rate	12%		6%	
VMT elasticity	−0.2	−0.15	−0.2	−0.15
Discounted gals saved, +3.8 mpg CAFE	41.7 bn	43.8 bn	64.5 bn	67.8 bn
"Equivalent" gasoline tax	30.0¢	33.7¢	32.7¢	36.3¢
Discounted welfare costs, CAFE	$21.5 bn	$21.5 bn	$29.2 bn	$29.2 bn
Discounted welfare costs, Gasoline tax	$6.3 bn	$7.4 bn	$10.5 bn	$12.3 bn
Reduction in cost, tax vs. CAFE	71%	65%	64%	58%

Note: Equivalence of gasoline tax with 3.8-mpg increase in CAFE standards is determined by total (discounted) gallons saved over 14 years.

Next, we consider whether those gasoline savings could be achieved at a lower cost by an alternative policy—a tax on gasoline consumption. Table 4 compares the present discounted value (PDV) of total costs for a 3.8-mpg increase in CAFE standards (with trading) and for a gasoline tax increase designed to save the same amount of gasoline over a 14-year period (41.7 billion gallons) when gallons saved (and policy costs) are discounted at 12%, the rate at which new-car buyers discount gasoline savings in our CAFE model. Using our baseline assumption for VMT elasticity (−0.2), we estimate that a 30 cents/gallon gasoline tax would save the same present discounted quantity of gasoline at a cost that is 71% lower than the comparable CAFE policy. Thirty cents per gallon would represent a 73% increase over the existing tax on gasoline in the US, which averages 41 cents including a federal tax of 18.4 cents and varying levels of state and local taxes. Like higher CAFE standards, gasoline tax increases have been politically unpopular. However, policy makers may become more supportive of higher gasoline taxes as pressure to reduce the federal budget deficit increases.

A tax designed to save the same amount of gasoline as the more stringent CAFE standards would accumulate savings much earlier because, as described above, the tax would immediately discourage driving of new and old vehicles alike, in addition to encouraging the purchase of more fuel-efficient vehicles. The two policies would also differ in the timing of the costs they would impose. The costs of the CAFE standards would be the same each year, while the costs of the gasoline tax would rise gradually as gasoline consumption continued to fall—due to the improved fuel economy of each year's new vehicles—until the steady state was reached in year 15 (see Fig. 2).[36]

[36]Annual costs are constant for CAFE, but gasoline savings rise as the existing fleet is replaced at a constant annual rate of seven percent (i.e., 1/14). The annual costs for the tax are determined by the size of the excess burden triangle corresponding to the rising level of gasoline savings over time. The size of that triangle increases each year (until the long-run steady state is reached) as the tax causes a growing share of the existing fleet to be replaced with more fuel efficient vehicles (this occurs at the same annual rate as we assume for CAFE; new-vehicle fuel economy responds to the tax according to its elasticity of 0.23 with respect to the price of gasoline). The fuel-economy elasticity, combined with the −0.2 VMT elasticity, yields gasoline savings (and corresponding welfare costs) that eventually correspond to a −0.39 long run price elasticity of gasoline.

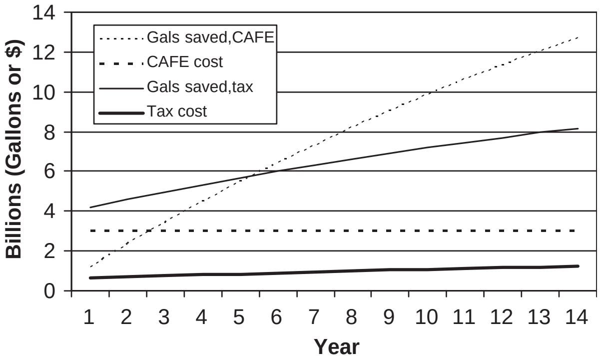

Fig. 2. Annual non-discounted costs and gallons saved. Note: 30¢ gasoline tax increase produces the same present-discounted gasoline savings over 14 years as does the 3.8-mpg increase in the CAFE standards.

The sensitivity analysis presented in Table 4 shows that the higher discount rate tends to favor the gasoline tax because it produces larger initial gasoline savings than CAFE and at lower initial costs. The relative advantage of the gasoline tax over CAFE standards also increases with the magnitude of the VMT elasticity. A higher VMT elasticity favors a gasoline tax in two ways. First, it means that the tax would achieve bigger reductions in driving. Second, it means that a given increase in CAFE standards would save less gasoline—because improved fuel-efficiency reduces vehicle operating costs, encouraging driving—so a smaller tax would be required to match CAFE's gasoline savings.

With a 6% discount rate and a VMT elasticity of -0.15, a 36 cent tax would be necessary to induce the same 14-year gasoline savings as the CAFE standards.[37] The discounted cost of that tax would be $12 billion, 58% less than the cost of CAFE standards for the same gasoline savings. If the VMT elasticity is -0.20, the required tax would fall to 33 cents, at a lower social cost of $10.5 billion, or 64% less than CAFE standards.

5.4. Limitations

Our assumption that manufacturers would not voluntarily use new technologies to improve fuel economy—which is consistent with consumers' preferences and producers' decisions over the past 15 years—is a key determinant of our cost estimates. Our analysis assumes a stylized new-vehicle market that is based on conditions currently observed in the vehicle and gasoline markets. If more fuel-efficient vehicles are introduced, if consumers begin to value fuel efficiency over vehicle size

[37]These calculations are based on a national average price of gasoline of $1.50. The percentage increase in the price of gasoline from a 30-cent increase in the federal tax would vary across the country due to differences in state and local gasoline taxes. The 6% discount rate in the final two columns of the table reflects the relative price volatility of petroleum: The "asset beta" for integrated petroleum is 0.74 (the covariance of returns to this asset with a broad market index). Assuming a short-term risk-free rate of 1% and a market risk premium of 7%, the implied social discount rate is $6.2\% = 0.01 + 0.74(0.07)$. We thank Deborah Lucas for suggesting this rate.

and power, or if gasoline prices rise significantly, then the costs of meeting higher standards could be less than we predicted. In that case, however, higher standards would also save less gasoline, because fleet fuel economy would tend to rise on its own.

Our analysis is limited to technologies that would improve the fuel economy of gasoline-powered vehicles. It thus excludes vehicles powered by, for example, gasoline-electric hybrid engines or by fuel cells. Such technologies as yet constitute a very small portion of the market, but to the extent that their rate of adoption grows (and is not offset by increases in the power or size of other vehicles), CAFE compliance costs would shrink.[38]

A significant limitation of our analysis is that we do not account for the effect that existing CAFE standards or gasoline taxes have on the cost of further policy increases. Accounting for existing policies would inevitably raise the cost of further increases. We do not account for the cost of the existing policies because we do not believe that there is any credible way to do so for the existing CAFE standards.[39] Accounting for the existing tax on gasoline, but not the existing CAFE standards, would result in an unfair comparison.

Further, this analysis only considers the direct effects that increases in CAFE standards or gasoline taxes would have on the vehicle and gasoline markets, respectively. Including effects on other markets—such as capital and labor markets—could significantly increase our estimates of the total cost of each of the policies.[40]

Finally, our analysis is a static one. While we project gasoline savings and policy costs over a 14-year period, we hold the sizes of the automobile and gasoline markets constant. This probably understates likely policy costs, since the size of each market is expected to grow over time. On the other hand, other factors described above (such as changes in preferences and increases in gasoline prices) could tend to lower costs.

While our results are subject to several limitations, the qualitative conclusions are robust. Fuel-economy credit trading has the potential modestly to reduce CAFE compliance costs. A gasoline tax, however, would achieve the same amount of gasoline savings at a much lower cost. As described below, a gasoline tax offers other advantages as well.

[38]Like the NRC, we do not consider reductions in vehicle weight or performance (such as acceleration) as possible strategies for improving average fuel economy. If consumers were to become willing, on average, to sacrifice some weight or performance in exchange for higher fuel economy, our compliance-cost estimates would fall, but true costs would include the value of the surrendered attributes.

[39]Data do not exist with which to estimate the extent to which current CAFE standards constrain the choices of new-vehicle producers and consumers. Kleit [14] does attempt to calculate a "CAFE tax" as the residual of a regression of price on marginal cost. However, this "CAFE tax" is likely a proxy for several things, especially the higher mark-ups on bigger cars (such as popular SUVs) that face more inelastic demand curves. Below, we discuss the implication of the existing gasoline tax for raising the CAFE standards.

[40]Goulder and Williams [11] propose a formula that can determine the increase in the total welfare cost that commodity taxes, such as a gasoline tax, would have if effects on the labor market were considered. On that basis, the total welfare cost of a 30-cent increase in the gasoline tax could be more than twice as high as we estimate. That research is based on the average cross-price elasticity between all goods and leisure. Subsequent work by West and Williams [21], however, showed that gasoline is a relative complement to leisure, suggesting that increases in gasoline taxes could actually reduce distortions in the labor market by increasing the labor supply. Unfortunately, no equivalent formulas are available for environmental standards, such as CAFE, so we compare the two policies on a partial-equilibrium basis.

6. Could increases in CAFE standards or gasoline taxes improve social welfare?

Would the benefits of raising the CAFE standards outweigh the costs? In the absence of existing policies to discourage the use of gasoline (and other complications described below), the optimal increase in CAFE standards could be determined by setting incremental costs equal to the incremental benefits of reducing gasoline consumption. Since existing policies—such as federal, state, and local taxes on gasoline—already discourage gasoline consumption, the picture is more complicated.[41]

If the existing gasoline tax rate were equal to (or greater than) the external costs of consuming a gallon of gasoline, then there would be no need to raise the CAFE standards. Higher CAFE standards would force further reductions in gasoline consumption beyond those induced by the existing tax, which would already be inducing consumers to reduce their consumption by the optimal amount (or more). In that case, the per-gallon costs of increasing the CAFE standards would start off at the existing tax rate and rise from there, and would thus exceed the benefit of avoiding the externalities.[42]

Since the average gasoline tax in the US is 41 cents/gallon, the key question is how that compares to the social cost of consuming a gallon of gasoline. In its recent report on CAFE standards, the National Research Council suggested that the external cost of gasoline consumption is roughly 26 cents/gallon: 12 cents for the social cost of carbon emissions from one gallon of gasoline (equivalent to a cost of $50 per metric ton of carbon), 12 cents/gallon (or $5 per barrel of oil) for the energy security cost of increasing the US's dependence on oil—and therefore the vulnerability of its economy to disruptions in world oil supply—and 2 cents/gallon for air pollutants released in the production and distribution of gasoline.[43]

If this estimate is correct, then the existing average gasoline tax of 41 cents/gallon already provides consumers with an incentive to pursue new-vehicle fuel economy up to a cost that exceeds the benefits by 15 cents. In that case, higher CAFE standards would add to an existing over-consumption of fuel economy and impose unwarranted costs on new automobile buyers and producers. In addition, higher CAFE standards could increase other external costs—such as traffic congestion and the incidence of traffic accidents—by encouraging more driving.[44] While

[41]Portney et al. [19] also considers whether increases in CAFE standards would be welfare improving. The article offers an informative discussion but the authors did not reach agreement on this question.

[42]Failure to account for the incentives created by the existing gasoline tax can lead to incorrect policy recommendations. For example, Gerard and Lave [8] conclude that increasing the tax on gasoline (to discourage driving) would also reduce the cost of complying with CAFE. That is, as a result of a tax-induced increase in the price of gasoline, more people would choose more fuel-efficient vehicles, making it easier for manufacturers to meet higher CAFE standards. Their conclusion fails to recognize, however, that the combination of policies that they advocate would shift compliance costs from CAFE onto the gasoline tax but would *not* reduce the combined marginal social cost of reducing gasoline consumption. A correct assessment would balance the marginal benefits of saving gasoline against the marginal costs of *both* policies.

[43]See NRC [16, p. 8].

[44]Some analysts believe, further, that higher CAFE standards might increase the injury risk of an accident by encouraging the production of lighter, smaller vehicles. That claim is controversial, however. Some members of the NRC panel argue that the "relationships between vehicle weight and safety are complex and not measurable with any degree of certainty at present." See NRC [16, p. 117].

the increase in driving could be relatively small, some analyses indicate that it could yield relatively large additional costs.[45]

However, the fact that existing taxes on gasoline exceed the NRC's estimate of external costs of gasoline consumption does not mean that the federal tax is too high. A higher gasoline tax would discourage driving and thus reduce costly driving-related externalities. Furthermore, gasoline taxes are a source of government revenue, and their efficiency in this capacity—relative to other sources of revenue such as taxes on capital and labor—must be considered. Parry and Small [17] find that the social benefits of taxing gasoline, taking into account the relative efficiency of the tax as a source of revenue and its likely impact on all external costs, may justify a tax rate significantly higher than the existing average of 41 cents/gallon.

Acknowledgments

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Appendix. Sensitivity of CAFE cost estimate to assumption that firms will not voluntarily boost fuel economy

Based on observed behavior over the last 15 years, we assume that producers would not voluntarily use new technologies to boost fuel economy. Rather, they would use them to boost other measures of performance, such as size and power, while holding fuel economy constant. We assume this reflects consumer preferences. Thus, a CAFE increase would result in foregone producer and consumer surplus because it would constrain producers from using new technologies to provide vehicle attributes that consumers prefer to fuel economy. With characteristics such as size and performance held constant in our model, we impose this *de facto* technology constraint by eliminating any technologies that appear to pay for themselves in the sense of yielding savings greater than costs. This prevents the possibility of "free" increases in CAFE—that do not impose some kind of cost on producers and consumers. This assumption has significant implications for our CAFE cost estimates. Without it, the first 4.5 mpg increase in the CAFE standard for cars—to 32 mpg—would appear to be free. (There would also be "free" mpg increases for light trucks.) In our calibrated model, however, setting car CAFE standards to 32 mpg would actually cost automakers and new-vehicle buyers about $1.5 billion per year (see Fig. A1).

[45] For example, Parry and Small [17] estimate that the external congestion cost of an additional mile driven is 3.5 cents, and that the externality risk of accidents has a cost of 3 cents/mile.

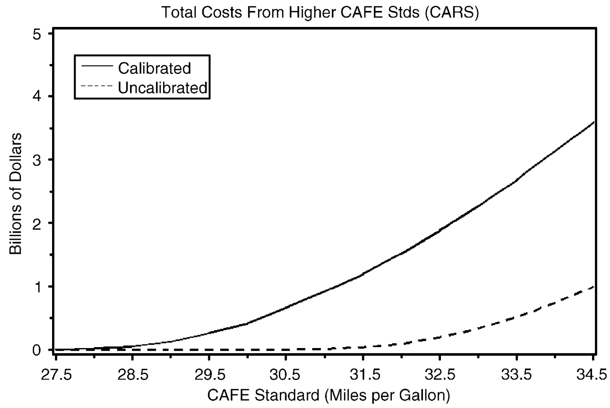

Fig. A1. Total costs from higher cafe standards (CARS).

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