Journal of Regulatory Economics; 2:151-172 (1990)

The Effect of Annual Changes in Automobile Fuel Economy Standards

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Abstract
Since 1978 the Federal government has regulated the fuel economy of new cars sold in the United States. The purpose of Corporate Average Fuel Economy (CAFE) standards is to lessen the national dependence on foreign oil. Through the use of theoretical and empirical models this paper examines the impact of CAFE standards on the automobile industry and on energy consumption. It is shown that CAFE standards may or may not save energy. If CAFE does save energy, it does so at a prohibitive cost to the economy. CAFE standards are also shown to have a number of perverse impacts on the automobile industry as well as consumers.

1. Introduction

Since 1978 the Federal government has mandated that new fleets of all firms selling over 10,000 cars per year in the United States reach a certain level of average fuel efficiency. Corporate Average Fuel Economy (CAFE) standards were intended to decrease energy consumption by automobiles to reduce the threat to national security from imported oil.[1] More recently, CAFE standards have been defended as a means of reducing environmental damage caused by automobile emissions.

In 1985, under an escape clause in the CAFE legislation, General Motors and Ford petitioned the National Highway Transport and Safety Administration (NHTSA) for relief from the standards. GM and Ford claimed that meeting the standards for model year 1986 would have caused significant economic damage and requested that the 1986 model standard be lowered from 27.5 to 26.0 MPG. GM and Ford repeated this process in 1986 for model years 1987 and 1988 and in 1988 for model years 1989 and 1990. Opponents of the petition claimed that granting the petition would substantially increase energy consumption with little or no gain to the economy. The auto manufacturers' requests were granted in 1985, 1986, and 1988, but not before sparking heated public debate.[2] It appears that CAFE standards will be with us as a controversial policy issue for the foreseeable future.

This paper will examine the costs (in terms of producer and consumer welfare and automobile industry employment) and benefits (in terms of changes in gasoline consumption) of imposing CAFE standards. Section 2 will present a brief outline of the CAFE program and debate. Section 3 examines CAFE in a competitive framework and demonstrates how CAFE standards can have several perverse impacts. The magnitude of these effects is then presented in Section 4 with simulations of the automobile market. In particular, Section 4 will examine the question faced by the federal government in 1988 on whether or not to lower the CAFE standard for model year 1989. The simulations demonstrate who gains and who loses from the imposition of various CAFE standards.

The results of the simulation in the automobile market are then used to estimate the savings in gasoline consumption from the imposition of CAFE standards. It is shown that it is likely that higher CAFE standards may actually *increase* gasoline consumption. Under circumstances where CAFE standards do save gasoline, they do so at an extraordinary cost to the economy. While the economy as a whole appears to be adversely affected, this analysis shows that firms that are in the proper position in the marketplace may find the imposition of CAFE standards to be highly advantageous.

2. Description of CAFE Regulations

The CAFE program, as enacted in 1975, called for all manufacturers selling more than 10,000 auto units per year in the United States to reach the mandated CAFE levels. CAFE levels were to rise from 18.0 MPG in 1978 to 27.5 MPG in 1985 and later years.

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 the fine is set equal to fifty dollars times the difference in MPG between the CAFE standard and the fuel economy actually reached by the firm times the number of automobiles sold by the firm in that year. For example, if the standard is 20 MPG and a producer makes one million cars with a harmonic average fuel efficiency of 18.5 MPG, that firm is liable for a fine of $75 million. Firms, however, are reluctant to be seen as lawbreakers; they therefore appear to view the standards as binding.[3] Apparently, the implicit cost of breaking the law is greater than the additional cost of reaching the CAFE standard.

Under the statute, a firm can apply credits earned during the three previous model years to its CAFE level in a given year. If no such credits are available, the firm has the option of using credits it expects to earn in the next three model years, if it can convince NHTSA that such an expectation is reasonable. This carry forward/back provision of the CAFE program was designed to increase firms' flexibility. The legislation divided a firm's fleet into two distinct groups. All domestic cars and all foreign cars of a firm were to be averaged separately.[4] This provision was designed explicitly to prevent U.S. manufacturers from meeting the CAFE standard by importing small foreign cars.[5]

The statute gives NHTSA the authority to modify the standard for model years after 1984, to the "maximum feasible average fuel economy," after taking into account four factors: technological feasibility; economic practicability; the effect of other federal motor vehicle standards, such as emissions controls, on fuel economy; and the need of the nation to conserve energy. NHTSA was given clear authority to modify the post-1984 standards between 26.0 and 27.5 MPG. Any modification outside this range was subject to a one house Congressional veto. (Such legislative vetoes were later declared unconstitutional by the Supreme Court.)

As noted above, the explicit fine on a firm is equal to

$$F = 50 * (Q_1 + q_1)*(S - MPG), \quad MPG < S \tag{1}$$

if the firm does not reach the standard, where S is the level of the CAFE standard, Q_1 and q_1 are the number of large and small cars sold by the firm, and MPG is the firm's average fuel efficiency.

The measurement of a firm's CAFE level was not defined as the simple average of a manufacturer's fleet MPG. Instead, a firm's CAFE level is the harmonic average of that firm's fleet MPG.[6] The harmonic average for the firm is calculated by

$$MPG = \frac{Q_1 + q_1}{\frac{Q_1}{M_L} + \frac{q_1}{M_S}} \tag{2}$$

where M_L and M_S are the fuel efficiencies of the two types of cars.

Using the harmonic average, the marginal CAFE fine to the firm of producing a large car is

$$\frac{\partial F}{\partial Q_1} = 50 * \left(S - 2MPG + \frac{MPG^2}{M_L} \right). \tag{3}$$

Assume now that the standards are binding. In that case $MPG = S$, the explicit fine of \$50 per MPG is replaced by a shadow tax L and the implicit CAFE tax on a car of type 1 becomes

$$\frac{\partial F}{\partial q_1} = L * S * \left(\frac{S}{M_L} - 1 \right), \tag{4}$$

where L is the value of the constraint discussed above.[7]

3. Theoretical Analysis of CAFE Standards

For model years 1985, 1986, and 1989, there were only a few months between the time CAFE relief was requested by GM and Ford and the beginning of the model year to which the CAFE standard was to apply. Indeed, in all three occasions NHTSA did not announce that it was granting relief until the very start of the relevant model year. In the short time available, the Big Two would not have been able to increase the fuel efficiencies of particular automobiles, because such technological changes generally take several years to put into place. GM and Ford had already exhausted their supply of credits earned in previous years. Thus, if NHTSA had denied the relief petitions, the only course of action available to these two firms would have been to "mix-shift," that is to sell more fuel efficient cars and fewer fuel inefficient cars to meet a CAFE standard of 27.5 MPG.

3.1 Reaction of a Firm to a Binding CAFE Standard

Consider a competitive (price-taking) firm that makes both large and small cars.[8] Let Q_1 and q_1 stand for the quantities of large and small cars sold by the firm; M_L and M_S stand for the fuel efficiency of each type of car in miles per gallon. Large cars sell for price P and small cars for price p. Since the firm is a price taker, it treats these prices as exogenously determined. Assume that a firm has the following cost functions, which imply a linear, upward sloping marginal cost curve:

$$C(Q_1) = aQ_1 + .5bQ_1^2,\ a, b > 0 \text{ and} \tag{1}$$

$$C(q_1) = eq_1 + .5fq_1^2,\ e, f > 0. \tag{2}$$

The firm faces a CAFE standard S, $M_S > S > M_L$. With harmonic averaging:

$$S \leq \frac{Q_1 + q_1}{\dfrac{Q_1}{M_L} + \dfrac{q_1}{M_S}}. \tag{3}$$

For simplicity, (3) will be written as

$$q_1 \geq RQ_1, \tag{4}$$

where

$$R = \frac{\dfrac{S}{M_L} - 1}{1 - \dfrac{S}{M_S}}. \tag{5}$$

Note that R is positive monotonic in S, that is, $dR/dS > 0$. This allows us to focus on R as a proxy for the level of the CAFE standard. The firm thus has the objective function

$$Max\ \pi = Q_1(P - a - .5bQ_1) + q_1(p - e - .5fq_1)$$
$$\text{s.t. } q_1 \geq RQ_1. \tag{6}$$

Assume that the constraint is binding, and let T be the shadow cost of the constraint. Taking derivatives gives:

$$\frac{\partial\pi}{\partial Q_1} = P - a - bQ_1 - RT = 0, \tag{7}$$

$$\frac{\partial\pi}{\partial q_1} = p - e - fq_1 + T = 0, \tag{8}$$

$$\frac{\partial\pi}{\partial T} = q_1 - RQ_1 = 0. \tag{9}$$

Solving (7) and (8) yields

$$P = MC(Q_1) + RT, \text{ and} \tag{10}$$

$$p = MC(q_1) - T, \tag{11}$$

where $MC(\cdot)$ stands for marginal cost. Equations (10) and (11) demonstrate that, when the constraint is binding, CAFE standards act as a shadow tax on large cars and a subsidy on small cars, discouraging the production of the first and encouraging the production of the second. The only difference between the implicit taxes and subsidies generated by the standard and an explicit tax/subsidy scheme is that, under the CAFE standard, the producers get to keep the tax revenue. This tax revenue, however, must be used to subsidize the production of small cars.

Even though the regulation is a constraint on the firm, it can actually increase firm output, measured as $q_1 + Q_1$, above the level that would occur were the firm unconstrained. Solving the above equations for quantities Q_1 and q_1 yields

$$Q_1 + q_1 = \frac{P-a}{b} + \frac{p-e}{f} + T\left(\frac{1}{f} - \frac{R}{b}\right), \tag{12}$$

where the shadow tax has the value

$$T = \frac{(e-p)b + (P-a)fR}{b + fR^2}. \tag{13}$$

If CAFE standards are binding, T is positive. Therefore output rises if

$$R < \frac{b}{f}.$$

This points to an interesting feature of CAFE regulation. If the standard is binding, but at a low enough level, CAFE standards may actually increase firm output, and perhaps even employment (See Henderson (1985)). Output is more likely to rise the smaller f is (the flatter the slope of the marginal cost curve for small cars), as this implies that the CAFE subsidy on small cars will have a larger quantity impact. The larger quantity of automobiles can lead to the perverse effect Kwoka (1983) discussed, where a CAFE standard leads to an increase in the number of cars on the road and, therefore, to an increase in total gasoline consumption. This is actually one of several reasons discussed in Section 4 why higher CAFE standards can increase gasoline consumption. (Since there are a number of effects CAFE standards have on gasoline consumption, modelling them directly would not be straightforward and thus will not be done here.)

This simple model illustrates two important aspects of the CAFE program. First, the standards can act as an implicit tax on large cars and an implicit subsidy on small cars. Second, the industry output and employment effects of the CAFE program are indeterminate.

3.2 Reaction of Industry to Binding CAFE Standards

The model can be extended to cover all firms in a competitive sector. It will be shown that, under a binding CAFE standard industry, output and industry profits can rise. Let RT equal the tax on large cars and T equal the subsidy on small cars. T is determined endogenously as a function of R. R is a function of the CAFE standard S, set exogenously by the policy maker. Assume that there are N firms in the industry with cost functions identical to the firm described above. Let Q^T and q^T equal the industry output of large and small cars. ($Q^T = \Sigma Q_i$, $q^T = \Sigma q_i$, i representing an individual firm in the industry.) Industry supply functions are generated by horizontally adding each firm's marginal cost curve

$$P(Q^T) = MC(Q^T) = a + \frac{bQ_i}{N} + RT = a + BQ^T + RT, \text{ and} \tag{14}$$

$$p(q^T) = MC(q^T) = e + \frac{fq_i}{N} - T = e + Fq^T - T. \tag{15}$$

Industry demand curves[9] are

$$P(Q^T) = g - hQ^T, \text{ and} \tag{16}$$

$$p(q^T) = j - kq^T. \tag{17}$$

Solving for firm output and implicit subsidy levels, yields

$$T = T(R) = \frac{R(g-a)(k+F) - (j-e)(h+B)}{h + B + R^2(k+F)}, \tag{18}$$

$$Q^T = \frac{g-a-TR}{h+B}, \quad P = g - h\left(\frac{g-a-TR}{h+B}\right), \tag{19}$$

$$q^T = \frac{j-e+T}{k+F}, \quad p = j - k\left(\frac{j-e+T}{k+F}\right). \tag{20}$$

Total industry output $Q^T + q^T$ is

$$Q^T + q^T = \frac{g-a}{h+B} + \frac{j-e}{k+F} + T\left(\frac{1}{k+F} - \frac{R}{h+B}\right). \tag{21}$$

Similar to the results for one firm shown above, industry output will rise as a result of the shadow tax (given R constant) if and only if

$$R < \frac{h+B}{k+F}. \tag{22}$$

In a competitive industry CAFE standards may thus have the effect of raising firm output and perhaps employment. The reasoning is the same as in the single firm case. The steeper or less elastic the demand and supply curves for large cars (E and B), the less effect a CAFE tax will have on reducing large car output. The flatter or more elastic the demand and supply curves for small cars (k and F), the more a CAFE tax will increase the output of small cars. Similarly, the smaller R is (the farther large car MPG's are from the standard relative to small car MPG's), the more small car production will be necessary, and the greater the likelihood that total production will rise.

Industry profits in the model presented equal

$$\pi = \frac{(g-a-TR)^2}{h+B} + \left(\frac{g-a-TR}{h+B}\right)^2(-h - .5B) + \frac{(j-e+T)^2}{k+F} + \left(\frac{j-e+T}{k+F}\right)^2(-k - .5F). \tag{23}$$

It may be that firms would actually desire that a higher CAFE standard be imposed on them. Looking at the derivative of profits with respect to a change in the standard R

$$\frac{\partial\pi}{\partial R} = -2\left(T + R\frac{\partial T}{\partial R}\right)\left(\frac{g-a-TR}{h+B}\right) + (2h+B)\left(T + R\frac{\partial T}{\partial R}\right)\left(\frac{g-a-TR}{(h+B)^2}\right)$$
$$+2\left(\frac{\partial T}{\partial R}\right)\left(\frac{j-e+T}{k+F}\right) - \left(\frac{\partial T}{\partial R}\right)(2k+F)\left(\frac{j-e+T}{(k+F)^2}\right), \tag{24}$$

where

$$\frac{\partial T}{\partial R} = (k+f)\left(\frac{g-a-2RT}{h+B+R^2(k+F)}\right). \tag{25}$$

CAFE standards would increase profits if $\partial\pi/\partial R > 0$, or (substituting (19) and (20) into (24)),

$$Q^T\left(T + R\frac{\partial T}{\partial R}\right)\left(\frac{2h+B}{h+B} - 2\right) + q^T\left(\frac{\partial T}{\partial R}\right)\left(2 - \frac{2k+F}{k+F}\right) > 0. \tag{26}$$

For instance (assuming $\partial T/\partial R > 0$, which is true at $T = 0$), the regulation would be more likely to increase profits the lower f (the smaller the increase in marginal costs for small cars). Or, the higher h (the lower the elasticity of demand for large cars), the more likely that CAFE standards will increase profits. Similar results can be derived for an oligopolistic industry (see Appendix 2) but not for the monopoly firm Kwoka described, since a monopoly is already maximizing industry profits. Intuitively, the standards act to impose a cartel-like restriction on the output of large cars, whose profits can outweigh the losses in the small car sector. This may explain why, in the early years of the CAFE program, GM and Ford were supporters of strict CAFE standards (See Yandle (1980)). Imposing CAFE standards can also increase consumer welfare, as the rents extracted from producers by consumers can outweigh the deadweight loss impact of the policy. This is likely to occur if the demand for large cars is elastic and the demand for small cars is inelastic (the opposite of the conditions necessary for firm profits to increase).

4. Simulation of the Effects of CAFE Standards

This section will simulate the effects of various CAFE levels on the automobile market and on energy consumption. The model presented analyzes the effects of CAFE on industry profits, structure, and employment. It will also examine whether CAFE standards do indeed save energy. The simulation will present an analysis of the decision faced by NHTSA for model year 1989.[10]

The first part of this section will analyze the results of a static model of CAFE standards. The effects of various binding CAFE levels on industry profits, employment, and structure will be calculated. The second part will generate any savings in gasoline that the results of the static model imply. It will chart the course of the fuel savings from the flow of new automobiles, adjusted for the changes induced by the imposition of CAFE standards, as well as the change in the stock of used automobiles due to the change in the price of new cars.

4.1 Static Model

The comparative statics model used here is an extension of the Council of Economic

Advisers (1985) model used to analyze the effects of import quotas on the total number of Japanese cars and is very similar to the simulations used by Rogers (1986) and FTC Staff (1988). Model year 1987 serves as the base period.

In the model there are five types of automobiles: (1) Asian Basic Small, which includes regular minicompacts and subcompacts such as the Sentra, the Corolla, and the Hyundai; (2) Asian Luxury Small, which includes specialty subcompacts and regular compacts such as the RX7 and the Stanza; (3) American Basic Small, which includes minicompacts and subcompacts such as the Cavalier and the Escort; (4) American Luxury Small, which includes specialty subcompacts and regular compacts, such as the Reliant K and the Mustang; and (5) American Large, which includes intermediate and large cars such as the Cutlass, the LTD, and the New Yorker. This breakdown is based on categories used by *Ward's Automotive Yearbook* (1988, 155 and 233). Luxury European cars, which constitute about 4 percent of the market, are excluded from the model. Volkswagen and Yugo are included in the American Basic small segment. On-shore Asian production is included in the Asian segments. "Captive" imports (autos built by Asian firms but sold under American nameplates) are included in the Asian segments.

During the 1980s, Japanese car sales in the United States have been restricted by import quotas ("voluntary restraint agreements"). For 1987 the quota was set at 2.3 million units. During the 1987 model year, however, Japanese imports were only about 2.25 million units.[11] Thus, the initial implicit tariff in the simulations is set to 0.

Each segment is divided into constrained and unconstrained production. Constrained are Japanese imports (potentially by the import quota) and General Motors and Ford (by CAFE standards). Unconstrained production includes on-shore Japanese (cars whose parts are made in Japan and assembled in the U.S.) and off-shore Korean output, Chrysler, Volkswagen, and Yugo.[12] The quantities, prices, and fuel efficiencies for each type of car for model year 1987 are shown in table 1.

Equilibrium prices and quantities are computed through a series of five demand and thirteen supply equations. Quantity demanded is determined by a set of linear demand curves[13]

$$\mathbf{Q} = \mathbf{AP} + \mathbf{B} \tag{1}$$

where $\mathbf{Q}$ is the vector of five quantities, $\mathbf{P}$ is the price vector, $\mathbf{A}$ is a five by five matrix of slope coefficients, and $\mathbf{B}$ is a vector of intercepts.

Quantity supplied is determined by a set of linear supply curves

$$\mathbf{Q} = \mathbf{C}(\mathbf{P} - \mathbf{T}) + \mathbf{D}(\mathbf{P} - \mathbf{V}) + \mathbf{EP} + \mathbf{F} \tag{2}$$

where $\mathbf{C}$ is a diagonal five by five matrix of supply coefficients for GM and constrained Japanese firms, $\mathbf{D}$ is a diagonal matrix of supply coefficients for Ford (with the first two diagonal elements equalling zero), $\mathbf{E}$ is a diagonal five by five matrix of supply coefficients for the unconstrained firms, $\mathbf{F}$ is a vector of supply curve intercepts, and $\mathbf{T}$ is a vector of implicit taxes, $\mathbf{T}' = (T_1, T_2, T_3, T_4, T_5)$. $\mathbf{T}$ is applied to General Motors and offshore Asian (Japanese) production. T_1 and T_2 are the implicit tariffs for each type of off-shore Asian car, $T_1 = T_2$. T_3, T_4, T_5 are the implicit CAFE taxes applied to each type of American car sold by GM.[14] $\mathbf{V}$ is a vector of implicit taxes applied to Ford. $\mathbf{V}' = (V_1, V_2, V_3, V_4, V_5)$, where $V_1 = V_2 = 0$. The level of these implicit taxes will be generated by the model.

CAFE standards are assumed to be just non-binding in the initial conditions (that is, that the levels reached by automobile companies under a lower CAFE standard are the same as those they would have reached without any CAFE standard at all), but differentially binding on the "Big Two" (General Motors and Ford) if the policy is enforced. This is likely to yield an underestimate of deadweight loss (DWL), as DWL is a function of the implicit tax squared. Crandall and Graham (1989) suggest that even with a 26.5 MPG standard, CAFE regulation would be binding on GM and Ford, meaning that an implicit tax already applies to these two firms. If CAFE standards are imposed, they are assumed to be binding, and the implicit tax per "Big Two" car is calculated accordingly. The system of 21 equations (five demand curves, thirteen supply curves, two CAFE constraints, and one import constraint) in 21 unknowns (five prices, thirteen quantities, and three implicit taxes) is solved by having the implicit tariff and the shadow tax per *MPG* for GM and Ford iterated until the desired quota and CAFE standard level are reached.

The point elasticities of demand at the original 1987 equilibrium are shown in table 1. The own-price elasticity of demand for automobiles is assumed to be one. (This is consistent with the results reported in Irvine (1983).) Based on past studies of the demand for automobiles, an elasticity of demand for small cars of -2.0 and elasticity of demand for large cars of -3.0 is assumed, as in Langenfeld and Munger (1985). The cross-elasticities shown should not be interpreted as precise figures, but merely internally consistent with the overall market demand and the own-elasticities for each of the segments from 2 to 3. The method for the derivation of the cross-elasticities is available upon request.

To the author's knowledge, no study exists which estimates short-run cost curves for the production of automobiles. Results obtained by Friedlander et. al. (1982) indicate that the industry has constant long-run marginal cost curves. In the short-run, however, it seems likely that marginal costs are increasing. Thus, the point elasticity of supply (marginal cost) in the model is set equal to 2. This assumes that while the industry has a competitive structure, there are short-term economic rents available in the sale of automobiles. (A sensitivity analysis of these results is contained in Appendix 1.)

Without a higher CAFE standard, Ford expected to have a fleet MPG of 26.6 MPG in Model Year 1989 and GM expected to reach 27.2 MPG.[15] Thus, a 27.5 MPG CAFE standard would require a "stretch" of 0.9 MPG for Ford and 0.3 MPG for GM. It is assumed that GM and Ford meet the standard and do not choose to pay civil penalties. The economic effects generated in the model are therefore relative to those that would have occurred if NHTSA set the CAFE standard for the Model Year 1989 at 26.6 MPG or less.

Employment changes are calculated using data from the Congressional Budget Office (1982) that provides the hours of work required to produce an additional domestic automobile. From this information a coefficient is computed that shows the change in the number of jobs that would result from a given change in the number of each type of automobile produced. Such a coefficient is computed for the three types of cars sizes (see table 1). Multiplying these coefficients by the change in the sales of domestic small and large cars generates an estimate for the employment changes brought about by an adjustment to a 27.5 MPG CAFE standard. The employment effect is less favorable to autoworkers than would be suggested solely by examination of changes in total automobile production.

Table 1. Initial Conditions - Model Year 1989
Parameters Used in CAFE Simulation

Elasticity Table

Class	1	2	3	4	5
1) Asian Small	-2.000	0.243	0.334	0.355	0.704
2) Asian Luxury Small	0.217	-2.500	0.125	0.837	2.661
3) Domestic Small	0.856	0.446	-2.000	0.583	1.160
4) Domestic Lux. Sma.	0.165	0.539	0.103	-2.500	2.237
5) Large	0.015	0.083	0.010	0.103	-3.000

(The demand for each type of car is categorized by row. Thus, for example 0.867 (the value in the second row, first column) is a measure of how the demand for basic Asian small cars will change with respect to a change in the price of Asian luxury small cars.)

Totals by Class

Class	Price (Initial) ($000)	Quantity (Init.) (million)	MPG	Cars/Job
1	8.689	1.748	35.51	22.65
2	13.764	1.173	29.57	19.38
3	8.373	1.168	32.45	7.55
4	10.719	1.884	27.42	6.46
5	15.077	3.645	25.31	5.40

Initial Quantities by Firms (millions of units)

Class	GM	Ford	Chrysler	Other	Constrained Asian	Uncstr. Asian
1	0.000	0.000	0.000	0.000	1.343	0.405
2	0.000	0.000	0.000	0.000	0.909	0.264
3	0.416	0.461	0.150	0.140	0.000	0.000
4	0.884	0.466	0.534	0.000	0.000	0.000
5	2.234	1.128	0.283	0.000	0.000	0.000

Supply Elasticity: 2.0 (all firms and classes)

Source for prices: *Ward's Automotive Yearbook* 1988, pp. 216-221 and 287-293. Source for quantities and fuel efficiency: Patricia S. Hu and Linda S. Williams, "Light Duty Vehicle MPG and Market Shares Report: 1st Six Months Model Year 1988, " Oak Ridge National Laboratory (1988) E-41 to E-44.

This is because the production of large cars involves more domestic labor than the production of small cars. Since on-shore assembly requires approximately only one-third as much American labor per vehicle as would on-shore domestic production (most of the components for on-shore assembly are manufactured overseas), it will be assumed that the amount of domestic labor required is only one-third of what it would be for similar domestic segments.

4.2 Effects on Firms, Autoworkers, and Consumers

The most obvious conclusion to be derived from running the static model is that imposing CAFE standards can create tremendous losses for various parts of the economy. Imposing an increase in fuel economy levels to 27.5 MPG costs the economy about $1.006 billion in lost producers' and consumers' surplus. The complete details of the impact of a 27.5 MPG

Table 2. Simulation Results: The Effects of a CAFE Standard of 27.5 MPG for Model Year 1989

GM MPG Increase = 0.30 Ford MPG Increase = 0.90
GM Implicit Tax = $657.27/MPG Ford Implicit Tax = $1026.31/MPG
Japanese Implicit Tariff = $0.00

Price and Output Effects
(Prices in thousands and Quantities in millions)

Class	Price	Qty.	Pchange	Qchange
1	8.617	1.719	-0.072	-0.029
2	13.933	1.202	0.169	0.029
3	6.950	1.603	-1.423	0.435
4	10.699	1.996	-0.020	0.112
5	15.530	3.321	0.453	-0.333

Output Effects by Firms (in thousands of units)

Class	GM[1]	Ford	Other	GMChange[1]	FChange	OthChange
1	1.321	0.000	0.398	-0.022	0.000	-0.007
2	0.931	0.000	0.270	0.022	0.000	0.006
3	0.579	0.831	0.192	0.163	0.370	-0.099
4	0.946	0.518	0.532	0.062	0.052	-0.002
5	2.068	0.953	0.300	-0.175	-0.175	0.017

Welfare Effects on Consumers and Firms (in billions of dollars)

Class	Cons.	Firms	DWL	GMChange[1]	FChange	Othchange
1	0.125	-0.125	0.000	-0.096	0.000	-0.029
2	-0.201	0.201	0.000	0.156	0.000	0.045
3	2.244	-3.108	0.864	-0.958	-1.806	-0.344
4	0.050	-0.066	0.016	-0.030	-0.026	-0.010
5	-1.561	1.346	0.215	0.885	0.329	0.132

Economic Welfare Changes ($ billion)

Consumer Change = 0.657
American Firms Change = -1.663 Asian Firms Change = 0.076
GM Change = -0.103 Ford Change = -1.503
Chrysler Change = -0.057 Other Firms Change = -0.165
Gasoline Consumption Savings: -367 million gallons
Change in Employment(000s): 13.311

[1] The first two entries in these columns refer to on-shore Japanese production and profits.

CAFE standard are in table 2.

As for winners and losers, it depends on how tight a CAFE standard is set. Figure 1 shows the changes in profits for the Big Two companies, Chrysler, and the Asian firms. As the more tightly constrained firm, Ford's losses are much larger. At 27.5 MPG Ford loses $1.5 billion, while at 28.5 MPG Ford loses $3.6 billion. General Motors loses only $103 million at 27.5 MPG and $1.788 billion at 28.5 MPG.

The impact of CAFE regulations on Chrysler's profits are quite different. Chrysler loses a little money (at most $97 million) at low CAFE increase levels as increased Big Two small car sales lower the price Chrysler can gain for its small cars. At higher CAFE levels, however, Chrysler's profits are sharply positive as Chrysler increases its sale of large cars

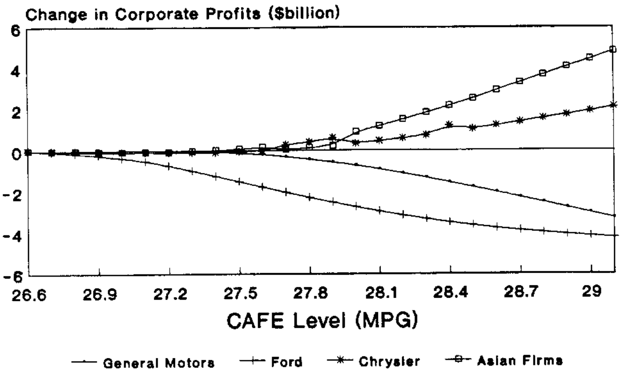

Figure 1. Change in corporate profits.

while GM and Ford are severely constrained in that segment. A CAFE standard increase to 28.0 MPG increases Chrysler profits by $326 million, while a CAFE standard of 28.5 MPG increases Chrysler profits by $1.032 billion.[16]

Asian firms do not produce any large cars and hence would seem to be more vulnerable in the short run to CAFE increases than Chrysler. With a CAFE standard of up to 27.6 MPG Asian firms lose money as GM and Ford lower small car prices. As CAFE standards rise above that level, however, more and more would-be large car buyers switch into Asian luxury small cars, resulting in increasing Asian profits. With a CAFE standard of 28.0 MPG Asians gain $877 million in profits, and at 28.5 MPG they make about $2.5 billion.

Figure 2 illustrates the effects of higher CAFE levels on automobile industry employment. The potential gains for autoworkers through CAFE regulation appear to be quite small relative to the potential losses. At most, imposing a higher CAFE level results in an increase

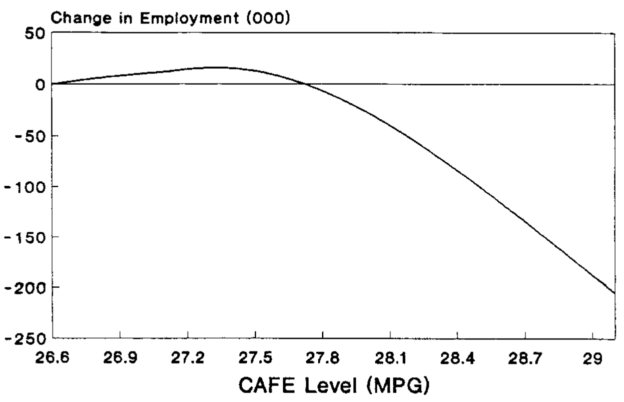

Figure 2. Change in employment.

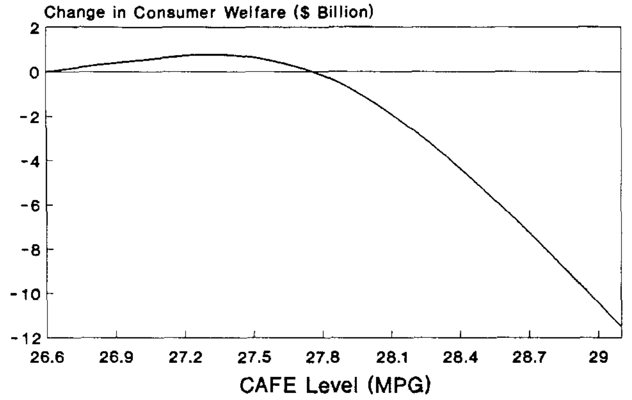

Figure 3. Change in consumer welfare.

of only about 16,000 jobs. A CAFE standard level of 27.5 MPG leads to an increase in employment of 13,300. As the CAFE level increases, however, the effect on autoworkers turns sharply negative. With a CAFE standard of 28.0 MPG 27,400 jobs are lost, and imposing a standard of 28.5 MPG results in the loss of 100,200 jobs. Thus, while it is possible CAFE standards can serve as a means of domestic content legislation to protect industry jobs, they are more likely to reduce auto employment.

Figure 3 illustrates that consumers can gain from higher CAFE standards. At 27.5 MPG, consumer welfare rises $657 million. The effect on consumer welfare, however, turns sharply negative as the CAFE standard rises. A CAFE standard of 28.0 MPG decreases consumer welfare by $1.2 billion while a CAFE standard of 28.5 MPG decreases welfare by $5.3 billion.

Increasing Big Two CAFE levels by any significant amount generates large implicit taxes. A CAFE standard of 27.5 MPG induces a shadow tax of $1026 per MPG on Ford cars and $657 per MPG on GM cars. A CAFE standard of 28.5 induces a shadow tax of $2050 per MPG on Ford cars and $1962 per MPG on GM cars.

4.3 Gasoline Consumption Model

To measure the change in gasoline consumption that will result from changing the CAFE standard, it is necessary to estimate and compare (1) the lifetime gasoline consumption of new cars sold under the standard, (2) the estimated gasoline consumption of the cars that would have been sold had the higher CAFE standard not been imposed, and (3) the "scrappage effect" (the change in the stock of used cars that results from a change in the price of new cars) to determine the total stock of cars in operation.[17] Many of the changes in fleet composition reflect large car buyers switching to new small cars in response to changes in relative car prices. But because smaller cars use less fuel, the marginal cost of driving declines, and driving is encouraged. The model uses Blair et. al.'s (1984) findings to adjust for changes in the rate of use of new cars induced by higher CAFE standards.

Data on miles driven and scrappage rates are incorporated into the gasoline consumption calculations.[18] The scrappage rates are adjusted for new car price changes using Gruenspecht's (1982b) estimates. It is assumed here that Gruenspecht's results can be applied to each of the three classes of automobiles (Basic Small, Luxury Small, and Large). In the gasoline consumption model, Asian cars are combined with their corresponding American segments.[19] A real discount rate of 4 percent is used.

4.4 Results of Consumption Model

The gasoline consumption results are summarized in figure 4. The simulation was run with various CAFE MPG levels in force for one year and with the additional scrappage and substitution effects described above for various CAFE levels.

As noted before, Kwoka hypothesized that CAFE standards could increase gasoline consumption by placing more cars on the road. Gruenspecht reached a similar conclusion when he showed that pollution standards could actually increase pollution levels by raising the price of new cars and hence decreasing the scrappage rates of old cars. Figure 4 shows that CAFE standards can indeed have such a perverse effect. CAFE standard of up to 28.1 MPG (CAFE level increases of up to 1.5 MPG above the market level) do lead to increases in gasoline consumption (no more than 370 million gallons out of an annual automobile consumption of about 60 billion). As CAFE standards grow tighter, fuel savings turn positive, reaching 505 million gallons at 28.5 MPG and 1.356 billion gallons with a CAFE standard of 29.0 MPG.

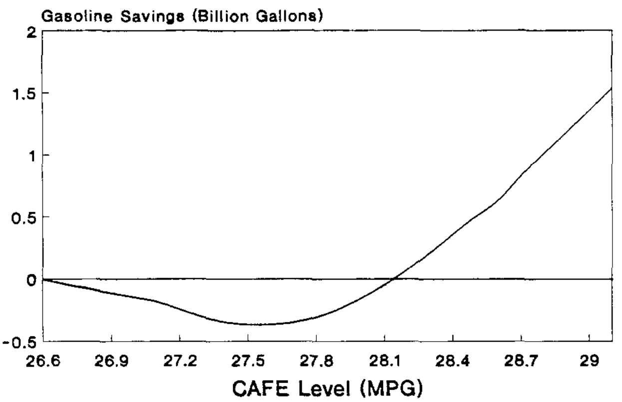

Figure 4. Gasoline savings from CAFE.

While CAFE policy can save gasoline, it does so at a prohibitive cost to the economy. The average cost per gallon saved with a CAFE standard of 28.5 MPG is $19.17, which declines slightly to $11.59 with a CAFE standard of 29.0 MPG.[20]

It is inappropriate to compare the CAFE-imposed cost to the economy with the cost of any gasoline saved. If gasoline costs $1 per gallon to produce and consumers give up 1 gallon of gasoline, consumers lose, at the margin, $1 worth of consumption. The loss per gallon noted here is in addition to this even tradeoff. (See Stucker *et. al.*, 1980, 61). The true benefit from this policy is the reduction of any externality associated with gasoline consumption. This also implies that it is appropriate to discount future savings of gasoline in any cost-benefit analysis.

5. Conclusion

While CAFE standards were originally designed to decrease consumption of gasoline in this country, they can have other effects that perhaps were not considered by the authors of the legislation. Small increases in CAFE standards can increase consumer welfare by hundreds of millions of dollars, while large increases in the CAFE standard can decrease consumer welfare by several billion dollars. CAFE standards can increase domestic employment in the auto industry and by placing a check on competition in large cars, CAFE regulation can also serve to increase the profits of unconstrained firms.

As Kwoka suggested, it is indeed quite possible that CAFE standards can increase gasoline consumption. The simulations run show consumption increasing for CAFE standards of 28.1 MPG or greater. While CAFE standards can save energy at levels above 28.1 MPG, they do so at an very large cost (over 10 dollars per gallon) to the economy. This suggests that should policy makers desire to reduce gasoline consumptions for reasons of national security or environmental concerns, they should do so with more direct methods, such as additional taxes on gasoline.

Appendix 1. Sensitivity Analysis

Given the need to make a large number of assumptions when establishing this model, it would be informative to examine the robustness of the conclusions reached above. The most important assumptions of the model are the relative elasticities of demand (whether demand for small cars is more or less elastic than the demand for small cars) and the elasticity of supply.

Table A1-1 shows the results of the model under various supply and demand elasticity conditions with a 1989 CAFE standard of 27.5 MPG. Supply elasticities are set at 1.0, 2.0, and 4.0. A demand elasticity of "same" refer to the same demand elasticity being used as in the base case. "Alternative" refers to alternative demand elasticities where the own elasticity of demand for small cars is increased from 2.00 to 3.0 and the own elasticity of demand for large cars is decreased from 3.00 to 2.00. New cross-elasticities are then computed using the different assumptions according to the method described in the technical appendix of this paper.

In each of the scenarios presented, Ford loses money. The loses range from $875 million to $2.305 billion. The most favorable circumstance for Ford comes with a supply elasticity of 4 (making substitution into small cars relatively easy) and under the alternative demand elasticity conditions which require a smaller price decrease for small cars. General Motors, which is less constrained, has its profit affected from positive $144 million to negative $304 million. GM makes money in three scenarios and loses money in three scenarios.

Asian firms increase their profits by small amounts ($54 to $83 million) in three scenarios. These scenarios are under the "same" elasticity conditions in which enough buyers switch from American large cars to Asian luxury small cars. Asian firms lose a good deal larger amounts ($192 to $457 million) under the alternative elasticities. The results for Chrysler

Table AI-1. Results of Alternative Scenarios						
Imposing a 27.5 MPG CAFE standard results in -						
	GM Profits ($billion) Supply Elasticities			Ford Profits ($billion) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	-0.304	-0.103	0.009	-2.305	-1.503	-1.017
Alt. Elast.	-0.003	0.118	0.144	-2.025	-1.287	-0.875
	Asian Firms' Profits ($billion) Supply Elasticities			Chrysler Profits ($billion) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	0.083	0.076	0.054	-0.073	-0.057	-0.033
Alt. Elast.	-0.457	-0.322	-0.192	-0.074	-0.062	-0.041
	Consumer's Surplus ($billion) Supply Elasticities			Employment Change (000 jobs) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	0.772	0.657	0.527	15.537	13.311	10.546
Alt. Elast.	0.621	0.536	0.444	21.982	22.846	22.385
	Gasoline Saved (billion gallons) Supply Elasticities					
	1.0	2.0	4.0			
Demand Same	-0.384	-0.367	-0.330			
Alt. Elast.	-0.378	-0.351	-0.311			
For the demand elasticities "Same" refers to baseline case where own demand for large cars is assumed to be -3.00 and own demand for small cars is -2.00. "Alternative" refers to the alternative scenario where the two numbers are reversed and new cross-elasticities are computed using the different assumptions.						

are more consistent. Chrysler loses small amounts of money in every scenario examined, with losses ranging from $33 to $74 million.

The effect on consumers is always positive, with gains ranging from $444 to $772 million. Auto industry employment rises as well, with from 10,546 to 22,846 workers being added on. Gasoline consumption increases range in the narrow band of 311 to 384 million gallon.

Thus, under a wide range of assumptions, imposition of the higher CAFE standard increases gasoline consumption and automobile employment, while harming Ford stockholders a great deal and Chrysler stockholders by a much smaller amount. The effects on General Motors and Asian firms are mixed.

Appendix 2. Results of the Oligopoly Model

A. Theoretical Oligopoly Model

In the previous examples of competitive and monopoly industry structures, the effects of a binding CAFE standard on output, employment, and industry profits are uncertain. Similar results can be obtained in the oligopoly case.

Assume as before that there are two types of cars, large and small. There are two identical firms in the industry. Each firm can build large cars at cost C and small cars at cost c. Let Q_1 and q_1 be the large and small car output of firm 1, and Q_2 and q_2 be the corresponding output for firm 2. Let RT be the implicit CAFE tax on large cars and T be the implicit subsidy on small cars.

The demand curves for large and small cars are

$$P = a - bQ = a - b(Q_1 + Q_2) \text{ and} \tag{1}$$

$$p = d - eq = d - e(q_1 + q_2)\,. \tag{2}$$

Assume that each firm has Cournot conjectures about the other firm's output. Firm 1's profit function is

$$\begin{aligned}\pi &= PQ_1 - CQ_1 - TRQ_1 + pq_1 - cq_1 + Tq_1 \\ &= (a - b(Q_1 + Q_2))Q_1 - CQ_1 - TRQ_1 + (d - e(q_1 + q_2)q_1 - cq_1 + Tq_1\end{aligned} \tag{3}$$

Taking derivatives

$$\frac{\partial\pi}{\partial Q_1} = a - 2bQ_1 - bQ_2 - C = TR \text{ and} \tag{4}$$

$$\frac{\partial\pi}{\partial Q_2} = d - 2eq_1 - eq_2 - c + T. \tag{5}$$

Since the firms are identical, $Q_1 = Q_2$ and $q_1 = q_2$. Solving for $Q = Q_1 + Q_2$ and $q = q_1 + q_2$ yields

$$Q = \frac{2(a - C - TR)}{3bP} = a - \left(\frac{2}{3}\right)(a - C - TR), \text{ and} \tag{6}$$

$$q = \frac{2(d - c + T)}{3ep} = d - \left(\frac{2}{3}\right)(d - c - T)\,. \tag{7}$$

Total industry profits are

$$\begin{aligned}\pi &= Q(P - C) + q(p - c) \\ &= \frac{2}{9}\left((a - C - TR)\frac{a - C + 2TR}{b} + (d - c + T)\frac{d - c - 2T}{e}\right).\end{aligned} \tag{8}$$

Taking derivatives of profits with respect to the CAFE tax T

$$\frac{\partial\pi}{\partial T} = \frac{2}{9}\left(\frac{R(a - C - 4TR)}{b} - \frac{d - c + 4T}{e}\right). \tag{9}$$

CAFE will thus increase industry profits if

$$\frac{e}{b}\left(\frac{a - C - 4TR}{d - c + 4T}\right) > 1. \tag{10}$$

Upon inspection, it can be seen that the larger the ratio e/b, the more likely it is that the imposition of a CAFE standard will increase industry profits. In other words, if the demand for large cars is inelastic relative to the demand for small cars, CAFE is more likely to be advantageous for firms in the industry. This conclusion depends on keeping the value of T relatively low, as the derivative of the above equation with respect to T is negative.

B. Simulation of Oligopoly Model

The model of Section 4 has been adjusted to assume that General Motors and Ford are playing a Cournot quantity setting game in the face of a competitive fringe (Asian firms, Chrysler, Volkswagen, and Yugo). Instead of elasticities of supply for GM and Ford, the

Table A2-1. Simulation Results: The Effects of a CAFE Standard of 27.5 MPG for Model Year 1989 (Oligopoly Model)

GM MPG Increase = 0.30 Ford MPG Increase = 0.90
GM Implicit Tax = $633.02/MPG Ford Implicit Tax = $1051.09/MPG
Japanese Implicit Tariff = $0.00

Price and Output Effects
(Prices in thousands and Quantities in millions)

Class	Price	Qty.	Pchange	Qchange
1	8.602	1.713	-0.087	-0.035
2	13.895	1.195	0.131	0.022
3	6.891	1.609	-1.482	0.441
4	10.647	2.004	-0.072	0.120
5	15.490	3.347	0.413	-0.307

Output Effects by Firms (in thousands of units)

Class	GM[1]	Ford	Other	GMChange[1]	FChange	OthChange
1	1.316	0.000	0.397	-0.027	0.000	-0.008
2	0.926	0.000	0.269	0.017	0.000	0.005
3	0.587	0.834	0.188	0.171	0.373	-0.103
4	0.954	0.523	0.527	0.070	0.057	-0.007
5	2.093	0.955	0.299	-0.150	-0.173	0.016

Welfare Effects on Consumers and Firms (in billions of dollars)

Class	Cons.	Firms	DWL	GMChange[1]	FChange	Othchange
1	0.150	-0.150	0.000	-0.115	0.000	-0.035
2	-0.156	0.156	0.000	0.121	0.000	-0.005
3	2.322	-1.488	-0.834	-0.378	-0.755	-0.355
4	0.098	0.222	-0.320	0.196	0.065	-0.038
5	-1.706	0.496	1.210	0.353	0.023	0.120

Economic Welfare Changes ($ billion)

Consumer Change = 0.708
American Firms Change = -0.599 Asian Firms Change = 0.006
GM Change = 0.171 Ford Change = -0.667
Chrysler Change = -0.103 Other Firms Change = -0.171
Gasoline Consumption Savings: -419 million gallons
Change in Employment(000s): 12.975

[1] The first two entries in these columns refer to on-shore Japanese production and profits.

Table A2-2. Results of Alternative Scenarios, Oligopoly Model

Imposing a 27.5 MPG CAFE standard results in -						
	GM Profits ($billion) Supply Elasticities			Ford Profits ($billion) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	0.102	0.171	0.157	-1.083	-0.667	-0.484
Alt. Elast.	-0.067	0.025	0.047	-1.365	-0.873	-0.626
	Asian Firms' Profits ($billion) Supply Elasticities			Chrysler Profits ($billion) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	-0.086	0.006	0.027	-0.154	-0.103	-0.057
Alt. Elast.	-0.526	-0.357	-0.207	-0.109	-0.086	-0.056
	Consumer's Surplus ($billion) Supply Elasticities			Employment Change (000 jobs) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	1.306	0.708	0.271	19.595	12.975	8.170
Alt. Elast.	0.529	0.276	0.057	19.252	19.069	18.210
	Gasoline Saved (billion gallons) Supply Elasticities					
	1.0	2.0	4.0			
Demand Same	-0.485	-0.419	-0.358			
Alt. Elast.	-0.432	-0.383	-0.329			

For the demand elasticities "Same" refers to baseline case where own demand for large cars is assumed to be -3.00 and own demand for small cars is -2.00. "Alternative" refers to the alternative scenario where the two numbers are reversed and new cross-elasticities are computed using the different assumptions.

inverse of their elasticity of marginal cost with respect to quantity is used. In the base case this is set to 2. The fringe firms are assumed in the base case to have an elasticity of supply of 2.

The results of the base case for the oligopoly model are set out in table A2-1, while table A2-2 gives the results of the simulation of the oligopoly model using various assumptions. Because the level of the standard sets the same constraint on firm behavior in both industry structures, many of the results are similar to the competitive model. In particular, enforcement of the standard in all scenarios leads to increased gasoline consumption of about 400 million gallons (as opposed to about 360 million in the competitive model). The reason for this slight increase is that because they are facing a more elastic demand curve in small cars as a result of stronger fringe competition, the two oligopolistic players, GM and Ford, are more prone to increase car production in that segment as a response to a binding CAFE standard. This acts to put more cars on the road and thus leads to slightly higher gasoline consumption.

There are two important different results in this model from the competitive one. First, because GM and Ford are not price takers, they can respond to a constraint at less cost. In particular, increased production in the small car market does not reduce profits as greatly as it does in the competitive model. Since the firms have restricted small car output initially, they lose less money on their incremental small car sales.

Second, imposition of the standard can result in a *decrease* in deadweight loss in the domestic small and domestic luxury small categories. Prior to the standard, the oligopoly market structure generated a deadweight loss because GM and Ford were selling cars at prices above their marginal costs. If the shadow CAFE subsidy on these cars is not too large, it pushes output closer to the optimal level and reduces deadweight loss. It is theoretically possible that with such market imperfections a CAFE standard could act as a second best policy and increase domestic welfare. (See Kleit (1987, 49-53) for a discussion of this possibility.) In the oligopoly model simulation presented in table A2-1, net welfare declines slightly ($68 million), while U.S. welfare increases slightly ($109 million). This difference is largely accounted for by a loss of $171 million in small car profits by "Other" firms (Volkswagen and Yugo.)

This result is not robust to the assumption of the model. For instance, with the base case demand elasticities and a supply elasticity of 4, net welfare declines $271 million, while U.S. welfare declines $181 million. Using the alternative demand elasticities and a supply elasticity of 4, net welfare declines $1.705 billion, while U.S. welfare declines $1.012 billion. Raising the CAFE standard 0.1 MPG to 27.6 MPG and using the base demand elasticities generates an estimate welfare loss of $498 million and a loss to the U.S. of $379 million.

Notes

The views presented here are solely those of the author and not those of the Federal Trade Commission or any of its members. The author would like to thank Paul Godek, Robert Hahn, Alvin Klevorick, Richard Levin, Merton Peck, Robert Rogers, Mike Vita, and two anonymous referees for their help with this paper.

1. See "Passenger Automobile Average Fuel Economy Standards for Model Year 1989," 53 Federal Register 39275 (October 6, 1988).

2. In May of 1989, NHTSA rejected the GM and Ford petitions for a model year 1990 rollback, largely on the grounds that a 27.5 MPG standard would not be binding in that year. See "Passenger Automobile Average Fuel Economy Standards for Model Year 1990," 54 Federal Register 21985, 21991 (May 22, 1989).

3. General Motors and Ford have stated on numerous occasion in 1985, 1986, and 1988 before Congress and in submissions to NHTSA that they viewed the standards as binding and would not contemplate paying fines. The only firms that have actually paid CAFE fines are Jaguar and Mercedes-Benz. However, when Jaguar was spun off from British Leyland it was explicitly stated in Jaguar's articles of incorporation that Jaguar expected to pay CAFE fines. This apparently reduced the legal cost to Jaguar of paying the fines.

4. Under a provision in the 1980 amendments to the CAFE law, Volkswagen's domestic production is included with its foreign output when determining VW's CAFE level.

5. NHTSA "1982 Annual Report on Fuel Economy," at 9.

6. Public Law 46:15-2003. One property of a harmonic average is that, if it is doubled, fuel consumed by driving the same number of miles in each type of car is halved.

7. The marginal fine derived above presents a more difficult problem to manufacturers than would occur with a standard based on simple averaging. Consider a firm that is deciding whether or not to produce an additional car with fuel efficiency equal to 20.0 MPG where the binding CAFE standard is 27.5 MPG. If simple averaging were used, the firm would have to offset that additional unit by producing one car with fuel efficiency of 35.0 MPG (or the equivalent). Under harmonic averaging, however, to produce another unit of 20.0 MPG, the firm must also produce the equivalent of one unit with fuel efficiency of 44.0 MPG. Thus, compared to simple averaging, harmonic averaging makes the CAFE standard more difficult to meet.

8. The assumption of competitive conditions is made for ease of presentation. All of the following results hold qualitatively if the firms in the industry have market power. See Appendix 2 for a presentation of the effects of

CAFE standards in an oligopolistic model.

9. Cross-price effects are omitted for the sake of simplicity. This omission does not significantly alter the results of this section.

10. Imposing a higher CAFE standard for one year may also have a longer term effect in terms of greater innovation, if it signals to automobile manufacturers the willingness of decision makers to act irrationally on future CAFE decisions. The effects will depend on the structure of the regulatory game being played. See Kleit (1988b). For an empirical analysis of the effects of CAFE standards on vehicle technology and weight see Crandall and Graham (1989).

11. In model year 1988, Japanese imports fell to 2.05 million units, as on-shore Japanese production increased. Data received from Oak Ridge National Laboratory.

12. The closest of these producers to being constrained by CAFE standards is Chrysler, which generally obtains CAFE ratings in the range of 27.5 to 28.5 MPG. Godek (1989) indicates that for model year 1989 Chrysler would have approximately 5.6 MPG worth of CAFE credits available. In other words, if the standard for model year 1989 were set at 27.5 MPG, Chrysler could have a CAFE rating as low as 21.9 MPG before it would run out of credits. Chrysler could also borrow credits from the future. Thus, the model will assume that Chrysler is unconstrained by a 27.5 MPG CAFE standard.

13. With the imposition of a standard, linear curves generate less deadweight loss than constant elasticity curves.

14. Assume that under one scenario the implicit tariff on Japanese cars is $500 and the implicit CAFE tax is $300 per MPG for General Motors. Using the formula for calculating implicit CAFE taxes (see above) and the MPG per class in table 1 yields an implicit tax vector $T' = (500, 500, 300 * 27.5 * ((27.5/32.45) - 1), 300 * 27.5 * ((27.5/27.42) - 1), 300 * 27.5 * ((27.5/25.31) - 1)) = (500, 500, -1258, 24, 714)$.

15. NHTSA Final Rule, 53 Federal Register 39282 (October 3, 1988).

16. Chrysler was a strong opponent of CAFE relief in 1985 and 1986. See "Passenger Automobile Fuel Economy Standards Model Year 1986," 50 Federal Register 40528 (October 4, 1985). A simulation of the effect of the 1985 standard (Kleit 1988b) shows that raising the standard would have unambiguously increased Chrysler's profits for MY 1985. Much of Chrysler gain came from increased sales of mid-size "K cars" being bought by consumers driven out of the large car market. By the late 1980's, however, Chrysler's mid-size car sales had dropped relative to the rest of its fleet, accounting for the results on Chrysler's profits shown here. Chrysler does not appear to have taken a position on CAFE relief for model year 1989. See 53 Federal Register 39275 (October 6, 1989).

17. Several studies, such as Gruenspecht (1982a; 1982b), have found that scrappage rates of used cars are significantly affected by new car prices. See also Berkovic (1985) and Parks (1977).

18. Figures obtained from the Motor Vehicle Manufacturer Association, *Motor Vehicle Facts and Figures* (1987).

19. The MPG values for each of the three classes can be determined from the information used in the automobile market model. The entire fleet fuel efficiency for 1973 is known to be about 14.2 MPG. The model assumes that the ratio of fuel efficiencies between classes is the same for each year. With this assumption, knowledge of the fraction of cars in each class for 1973, and the entire fleet fuel efficiency for 1973, the fuel efficiency for each class of new car in 1973 can be estimated. It is also assumed that, for each class of car, fuel efficiency grew at a constant rate between 1973 and 1987. MPG's are then calculated accordingly. The fuel efficiency of cars produced before 1973 is assumed to be equal to the 1973 level.

20. The costs of generating gasoline savings through direct taxation is much lower. If gasoline supply and demand curves are assumed to be linear, and costs are constant, welfare loss is equal to $.5\,dQ\,dP$ and average welfare loss is equal to $.5\,dP$. Assume dQ is 505 million gallons (the savings from a CAFE standard of 28.5 MPG). dP is calculated as $dP = P\,dQ/Qe$, where e is the elasticity of demand. A demand elasticity of -.7 is used. (See Bohi (1981).) Q in the first year of this model is approximately 60 billion gallons. Gasoline is assumed to cost $1. Under these conditions, a tax increase of 1.20 cents is required. If there are no previous taxes on gasoline this implies an average deadweight loss per gallon saved of 0.60 cents. Gasoline, however, is heavily taxed by both federal and state authorities. Thus, the deadweight loss per gallon through new taxes to save 505 million gallons is 0.60 cents plus the level of the previous combined taxes. In Connecticut, for example, that combined tax in 1987 was 25 cents.

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