WORKING PAPERS

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WORKING PAPER NO. 160

February 1988

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BUREAU OF ECONOMICS
FEDERAL TRADE COMMISSION
WASHINGTON, DC 20580

The Impact of Automobile Fuel Economy Standards

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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 Alvin Klevorick, Richard Levin, Merton Peck, and Robert Rogers for their help with this paper.

I. 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. CAFE (Corporate Average Fuel Economy) standards were intended to decrease energy consumption by automobiles. 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 cause 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 year 1987. Opponents of the petition claimed that granting the petition would generate a substantial increase in energy consumption with little or no gain to the economy. The auto manufacturers' requests were granted in both 1985 and 1986, but not before sparking heated public debate.

Stucker et. al [1980] have examined the equilibrium impact of CAFE standards on the market for automobiles and energy. They did not, however, investigate the effects of a one year change in the standard, such as the question facing NHTSA in various years. Kwoka [1983] derives a model of how a monopoly firm could be expected to react to the imposition of a CAFE standard.

Section II of this paper will present a brief outline of the CAFE program and debate. Section III extends the analysis of Kwoka to a competitive framework and demonstrates how CAFE standards can have several

perverse impacts. In particular, it is shown that CAFE standards discourage specialization among automobile firms and indeed, creates a special regulatory economies of scope. These, however, are not real economic efficiencies.

The magnitude of these effects is then presented in Section IV with a simulation of market performance. 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 CAFE standards are an extraordinarily expensive method of saving energy. The nature of the CAFE regulation, however, make it possible for certain automobile firms to increase their profits through the imposition of higher standards. The conclusion of this paper is that CAFE standard may or may not generate reductions in gasoline consumption. If they do, it is only at a very large 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 profitable.

II. 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. The measurement of a firm's CAFE level was not defined as the simple average of a manufacturer's fleet MPG. Instead, firm's CAFE level is the harmonic average of that firm's fleet

MPG[1] (discussed below). 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.

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 produced 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.[2] 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 year, if it can convince NHTSA that such an expectation was 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

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[1] Public Law 46:15-2003.

[2] General Motors and Ford have stated on numerous occasion in 1985 and 1986 before Congress and in submissions to NHTSA that they viewed the standards as binding and would not contemplate paying fines. The only firm that has actually paid CAFE fines is Jaguar. 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.

foreign cars of a firm were to be averaged separately.[3] This provision was designed explicitly to prevent U.S. manufacturers from meeting the CAFE standard by importing small foreign cars.[4]

NHTSA was given 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 veto by Congress. Such legislative vetoes were later declared unconstitutional by the Supreme Court.

III. THEORETICAL ANALYSIS OF CAFE STANDARDS

There was only a period of a few months between the time the CAFE relief was filed by GM and Ford and the beginning of the model year to which the CAFE standard was to apply. Indeed, in both model years 1986 and 1987 NHTSA did not announce that it was granting relief until the very start of the model year. In the short time available, the Big Two would not have been able to increase the fuel efficiencies of particular automobiles, for 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 petition, the only

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[3] 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.

[4] NHTSA annual report on fuel economy, 1982, at 9.

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. The next part of this section will extend Kwoka's analysis of a monopoly firm to a competitive market to show the reaction to a regulation that requires a short run adjustment to mileage standards through mix-shifting.

Reaction of a Firm to a Binding CAFE Standard

Consider a competitive firm that makes both large and small cars. Let Q_1 and q_1 stand for the quantities of large and small cars built 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. Assume that a firm has the following cost functions, which imply a linear, upward sloping marginal cost curve:

$$(3\text{-}1)\quad C(Q_1) = aQ_1 + .5bQ_1^2 \quad a,b>0$$

$$(3\text{-}2)\quad C(q_1) = eq_1 + .5fq_1^2 \quad e,f>0$$

The firm faces a CAFE standard S, $M_S>S>M_L$. This requires with harmonic averaging that

$$(3\text{-}3)\quad S \leq (Q_1+q_1)/((Q_1/M_L)+(q_1/M_S))$$

or

(3-4) $q_1 \geq RQ_1$

where $R = ((S/M_L)-1)/(1-(S/M_S))$. Note that as S approaches M_L, R approaches 0. As S approaches M_S, R approaches infinity. The firm thus has the objective function

(3-5) $\text{Max } \Pi = Q_1(P-a-.5bQ_1) + q_1(p-e-.5fq_1)$

$\text{s.t. } q_1 \geq RQ_1$

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

(3-6) $d\Pi/dQ_1 = P-a-bQ_1-RT = 0$

(3-7) $d\Pi/dq_1 = p-e-fq_1+T=0$

(3-8) $d\Pi/dT = q_1-RQ_1 = 0$

Solving (3-6) and (3-7) yields

(3-9) $P = MC(Q_1) + RT$

(3-10) $p = MC(q_1) - T$

where MC( ) stands for marginal cost. (3-9) and (3-10) 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. Solving the above equations for quantities Q_1 and q_1 yields

$$(3\text{-}11)\quad Q_1+q_1 = (P-a)/b + (p-e)/f + T(1/f-R/b)$$

where the shadow tax has the value

$$(3\text{-}12)\quad T = ((e-p)b+(P-a)fR)/(b+fR^2)$$

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

$$(3\text{-}13)\quad R < b/f$$

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. This can lead to the perverse effect Kwoka 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.

Note that as R approaches infinity (S goes to M_S), RT (the implicit tax on large cars) approaches (P-a) and no large cars are produced. The implicit subsidy on small cars, T, goes to zero as R goes to infinity. Thus, an extreme CAFE standard may not directly subsidize the production of small cars. An intuitive explanation of this is as follows: CAFE regulation implies a zero net subsidy to the firm. If the firm does not produce any large cars, it does not generate any tax revenue to use for subsidizing its small car production.

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 may be positive. These points are very important to the analysis of this regulation.

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 perhaps even 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. Assume that there are N firms in the industry with cost functions identical to those of 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

$$(3\text{-}14)\quad P(Q^T) = MC(Q^T) = a+(bQ_i/N) + RT = a+BQ_T + RT$$

$$(3\text{-}15)\quad p(q^T) = MC(q^T) = e+(fq_i/N) - T = e+Fq^T - T$$

Industry demand curves are

$$(3\text{-}16)\quad P(Q^T) = g-hQ^T$$

$$(3\text{-}17)\quad p(q^T) = j-kq^T$$

(Cross-price effects are omitted for the sake of simplicity. This omission does not significantly alter the results of this section.) Solving for firm output and implicit subsidy levels, we have

$$(3\text{-}18)\quad T = T(R) = (R(g-a)(k+F)-(j-e)(h+B))/(h+B+R^2(k+F)),$$

$$(3\text{-}19)\quad Q^T = (g-a-TR)/(h+B) \qquad P = g - h(g-a-TR)/(h+B),$$

$$(3\text{-}20)\quad q^T = (j-e+T)/(k+F) \qquad p = j - k(j-e+T)/(k+F).$$

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

$$(3\text{-}21)\quad Q^T+q^T = (g-a)/(h+B) + (j-e)/(k+F) + T((1/(k+F))-R/(h+B)))$$

Similar to the results for one firm shown in (3-13), industry output will rise as a result of the shadow tax (given R constant) if and only if

$$(3\text{-}22)\quad R < (h+B)/(k+F)$$

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 (h 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.

Industry profits in the model presented equal

$$(3\text{-}26)\quad \Pi = (g-a-TR)^2/(h+B) + ((g-a-TR)/(h+B))^2(-h-.5B) + (j-e+T)^2/(k+F) + ((j-e+T)/(k+F))^2(-k-.5F)$$

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

$$\begin{aligned}(3\text{-}27)\quad d\Pi/dR = & -2(T+RdT/dR)(g-a-TR)/(h+B) \\ & +(2h+B)(T+RdT/dR)(g-a-TR)/(h+B)^2 \\ & +2(dT/dR)(j-e+T)/(k+F) \\ & -(dT/dR)(2k+F)(j-e+T)/(k+F)^2\end{aligned}$$

where

$$(3\text{-}28)\quad dT/dR = (k+f)(g-a-2RT)/(h+B+R^2(k+F))$$

CAFE standards would increase profits if $d\Pi/dR > 0$, or (substituting in (3-19) and (3-20) in (3-27)),

$$(3\text{-}29)\quad Q^T(T+RdT/dR)(((2h+B)/(h+B))-2) + q^T(dT/dR)(2-(2k+F)/(k+F)) > 0$$

For instance (assuming $dT/dR > 0$, 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 Kleit [1987]), but not for the monopoly firm Kwoka described, since a monopoly is already maximizing 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]).

<u>The Mathematical Form of the CAFE Tax</u>

Recall from section II that the explicit fine on a firm is equal to

$$(3\text{-}30)\qquad F = 50*(Q_1+q_1)*(S-MPG) \qquad MPG<S$$

of 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 harmonic average fuel efficiency. The harmonic average for the firm is calculated by

$$(3\text{-}31) \qquad MPG = (Q_1+q_1)/((Q_1/M_L)+(Q_1/M_S))$$

where M_L and M_S are the fuel efficiencies of the two types of cars. Harmonic averaging has the following property: If the number of miles driven stays constant and fuel economy is doubled, fuel usage is cut in half.

Using the harmonic average, the marginal CAFE fine to the firm of producing a car of type 1 is

$$(3\text{-}32) \qquad dF/dQ_1 = 50*(S-2MPG+(MPG^2/M_L))$$

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

$$(3\text{-}33) \qquad dF/dq_1 = L*S*((S/M_L)-1)$$

where L is the value of the constraint discussed above.

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, the harmonic averaging used makes the CAFE standard more difficult to meet.

The Effects of CAFE Standards on Industry Structure

It would appear that firms feel themselves legally unable to pay CAFE fines and thus must meet the standard. Consequently, if a firm specializes in low mileage cars, it may seek to merge with a high mileage firm in order to meet the standard.

Merger is not the only way in which firms can react to the standard. It may be that for a variety of reasons a suitable merger partner is not available to a firm. In that case, a firm below the standard may resort to building its own high mileage cars, even though it has a comparative disadvantage in that segment.

Similarly, a high mileage firm may find it profitable to use its CAFE credits building low mileage cars because of the CAFE induced rise in the price of those cars, even though another firm may be able to build those cars at a lower cost. Indeed, it is possible that a high mileage firm may have to expand into low mileage cars in order to survive. Consider an industry structure consisting of two types of firms. One type produces both high and low mileage cars and is bound by a CAFE standard. Thus, these firms must lower the price of their high mileage cars. They are able to do this and stay in business because they are making higher profits in the low mileage segment. If the other type of firms produce only high

mileage cars they are at a serious disadvantage. They must sell their products in a market where their competitors are being subsidized by lucrative sales of large cars. Given this situation, a high mileage firm may have no choice but to expand into low mileage cars.

Thus, a binding CAFE standard creates what may best be described as regulatory economies of scope in the auto industry. No firm can legally be below the standard and no firm can afford to be above the standard. Therefore, in a regime of binding CAFE standards it could be expected that in the long run all firms in the industry will converge towards the CAFE standard. Thus, all firms will produce both large and small cars.

This result depends on three assumptions. First, standards must be binding. Second, CAFE credits must not be tradeable across firms. Third, it must be possible for all firms in one way or another to produce and sell cars that have mileage above the standard.

IV. 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 whether if enforcing CAFE standards is likely to have the perverse effects on industry profits, structure and employment, that Section III indicates are possible. It will also examine if CAFE standards do indeed save energy. The simulation will make a cost-benefit analysis of the decision faced by NHTSA for model years 1986 and 1987. If NHTSA had not granted the relief petitions, firms would have been forced to "mix-shift" in the manner described above to meet the standards. In the short period available to

the firms to change their fleet MPG's, changing the fuel efficiency of various automobiles would not have been a viable option.

This section is divided into two parts. The first will analyze the results of a static model of CAFE standards. The effects of various binding CAFE levels 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.

Static Model

The comparative statics model used here is an extension of the 1985 Council of Economic Advisers model used to analyze the effects of import quotas on the total number of Japanese cars. Model year 1984 is used as the base period. In the model there are five types of automobiles: 1) Japanese Basic Small, which includes regular minicompacts and subcompacts such as the Sentra and the Corolla; 2) Japanese 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; 5) American Large, which includes intermediate and large cars such as the Cutlass and the LTD. Luxury European cars, which comprise about 3.5 percent of the market, are excluded from the model. Other European cars (Volkswagen-Audi and AMC-Renault) are included

in the American segments. On-shore Japanese production is included in the Japanese segments.

Each segment is divided into constrained and unconstrained production. Constrained are Japanese imports (by the quota) and General Motors and Ford (by CAFE standards). Unconstrained production includes on-shore Japanese output, Chrysler, AMC- Renault, and Volkswagen (which under the nuances of CAFE regulation includes on-shore VW production, off-shore VW production, and Audi). "Captive" imports (autos built in Japan but sold under American nameplates) are included in the Japanese segments. The quantities, prices, and fuel efficiencies for each type of car for model year 1984, are shown in Table 1.[5]

Equilibrium prices and quantities are computed through a series of five demand and five supply equations. Quantity demanded is determined by a set of linear demand curves[6]

$$(4\text{-}1)\quad Q = AP + B$$

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

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[5] Actual final mileage figures are somewhat above those reported in Table 1. There are two possible reasons for this discrepancy. First, EPA mileage figures are subject to revision for CAFE regulatory purposes. Second, Ward's segment data are calculated through registration data for calendar, not model years. Data included in the 1985 yearbook includes some sales for model year 1985 (fourth quarter 1984), which could have reflected as increased consumer demand for large cars.

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

Quantity supplied is determined by a set of linear supply curves

$$(4\text{-}2)\quad Q = C(P-T) + DP + E$$

where C is a diagonal five by five matrix of supply coefficients for constrained firms, D a diagonal five by five matrix of supply coefficients for the unconstrained firms, E a vector of supply curve intercepts, and T is a vector of implicit taxes, $T' = (T_1, T_2, T_3, T_4, T_5)$. Note that T is only applied to constrained firms. T_1 and T_2 are the implicit tariffs for each type of off-shore Japanese car, $T_1 = T_2$. T_3, T_4, T_5 are the implicit CAFE taxes applied to each type of American car produced by constrained firms GM and Ford.[7] The level of these taxes will be generated by the model.

During the 1980s, Japanese car sales in the United States have been restricted by import quotas (so-called "voluntary restraint agreements"). The implicit tariff generated by the quota is set at an initial level of $2400 and is assumed to be equal for each type of Japanese car. Given the elasticity assumptions of this model, a tariff of $2400 is consistent with Crandall [1984].[8] The quota is set at 1.85 million cars. CAFE standards are assumed to be just non-binding in the initial conditions and equally

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[7] Assume that under one scenario in the model the implicIt tariff on Japanese cars is $2500 and the implicit CAFE tax is $300 per MPG. Using the formula for calculating implicit CAFE taxes (3-33) and the MPG per class in Table 1 yields an implicit tax vector T' = (2500, 2500, 300*27.5*((27.5/33.30)-1), 300*27.5*((27.5/26.72)-1), 300*27.5*((27.5/22.30)-1)) = (2500, 2500, -1437, 241, 1924).

[8] Assuming a supply elasticity of 2, a demand elasticity of 3.5, and an increase in the price of Japanese cars of $872 yields an implicit tariff of $2400. Crandall estimates the price impact of quotas for Japanese cars as being from $800 to $1000.

binding on the "Big Two" (General Motors and Ford) if the policy is enforced.[9] This is likely to yield an underestimate of deadweight loss, as DWL is a function of the implicit tax squared and Crandall [1986] suggests that even without relief CAFE standards would be binding on GM and Ford. If CAFE standards are imposed, they are assumed to be binding, and the implicit tax per "Big Two" car is calculated according to equation [3-33]. The system of 12 equations (five demand curves, five supply curves, and two constraints) in 12 unknowns (five quantities, five prices, and two implicit taxes) is solved and the implicit tariff and the shadow tax per MPG are iterated until the desired quota and CAFE standard level are reached.

The point elasticities of demand at the original 1984 equilibrium are shown in Table 2. The own elasticity of demand for automobiles as a whole is assumed to be one. (This is consistent with the results reported in Irvine[1983].) It is assumed here that the demand for small cars is more elastic than the demand for large cars, though this is questioned by Langenfeld and Munger [1985]. The cross-elasticities shown are not meant to be accurate figures, but merely internally consistent. The method for the derivation of the cross-elasticities is presented in the technical appendix (which is available from the author).

To this author's knowledge, no study exists of short-run cost curves in the auto industry. Results of Friedlander et. al. [1983] indicate that the industry may have constant long-run marginal cost curves. In the short run, however, it seems likely that marginal costs are increasing. Thus, the

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[9] Chrysler is assumed not to be bound by CAFE regulations in the simulation. Its supply of credits earned in previous years are more than sufficient to cover any likely shortfall.

point elasticity of supply (marginal cost) in the model is set equal to 2, which assumes that while the industry has a competitive structure, there are rents to be earned in the sale of automobiles.

Results of Static Model

The most obvious conclusion to be derived from running the static model is that imposing CAFE standards can create tremendous losses for the economy. For instance, imposing an increase in fuel economy levels of 1.5 MPG costs the economy about $3.5 billion. This is of the same magnitude as the losses from import quotas on Japanese cars (See Crandall [1984]). As for winners and losers, it depends on how tight a CAFE standard is set.

Effects of Firms, Autoworkers, and Consumers

Figure 1 shows the changes in profits for the Big Two companies, Chrysler, and the Japanese firms. It turns out that it is not all that unlikely for the constrained firms to have increased profits as a result of increased fuel economy levels. At CAFE-imposed fuel economy increases of below 0.9 MPG profits of GM and Ford rise, reaching a level of $144 million with an increase of 0.5 MPG. Viewed in this context, Big Two support for higher CAFE levels in the 1970s is not at all surprising.

Unfortunately for the Big Two, profits turn sharply negative after 0.9 MPG. At increases of 1.5 MPG the Big Two suffer losses of almost $500 million, and at 2.5 MPG their estimated regulation induced losses are over $2 billion. This would seem to explain why GM and Ford were so eager to gain relief for both model years 1985 and 1986.

The impact of CAFE regulations on Chrysler's profits are quite different. Chrysler loses a little money (at most $10 million) at low CAFE increase levels as increased Big Two small car sales lower the price Chrysler can gain for its small cars. However, at higher CAFE levels Chrysler's profits are sharply positive as Chrysler increases its sale of large cars while GM and Ford are severely constrained in that segment. A CAFE increase of 1.5 MPG raises Chrysler profits by $386 million, while an increase in CAFE levels of 2.5 MPG reaps a windfall of over $1 billion for the nation's number three automaker. This may explain why Chrysler is such a vocal supporter of CAFE standards.

Japanese firms did 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 increase of up to 1.1 MPG the Japanese lose money as GM and Ford lower small car prices. However, as CAFE standards rise above that level, more and more would-be large car buyers switch into Japanese luxury small cars, resulting in increasing Japanese profits. With a CAFE increase of 1.5 MPG the Japanese gain $313 million in profits, and at 2.5 MPG they make about $1.8 billion. Given the inherent range of error in a simulation like this one, it is not at all clear whether Japanese firms stand to gain from an increase in CAFE levels of 1.5 MPG.

Figure 2 illustrates the effects of higher CAFE levels on automobile industry employment. Potential gains for autoworkers through CAFE regulation appear to be quite small. At most, imposing a higher CAFE level results in an increase of only about 4000 jobs. However, as the CAFE levels increases, the effect on autoworkers turns sharply negative. With a CAFE increase of 1.5 MPG 37,900 jobs are lost, and imposing an increase of

2.5 MPG results in the loss of 121,900 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 are the big losers when higher CAFE standards are imposed. An increase of 1.5 MPG leads to consumer losses of almost $3.4 billion, while an increase of 2.5 MPG costs consumers a staggering $8.8 billion. Oddly enough, at very low levels of CAFE increases, consumers, and the nation as a whole, actually benefit from the higher standards. What is occurring here is that the extraction of quota rents from Japanese firms outweighs the deadweight loss resulting from implicit CAFE subsidies and taxes.

Increasing Big Two CAFE levels by any significant amount generates large implicit taxes. Increasing CAFE by 0.5 MPG induces a shadow tax of $241 per MPG on Big Two cars. A CAFE increase of 1.5 MPG results in an implicit fuel efficiency tax of $646, while a shadow tax of $894 per MPG is required to increase Big Two CAFE levels by 2.5 MPG.

Not surprisingly, the fuel efficiency levels of non-constrained firms decrease as the CAFE levels of the Big Two increase. Non-constrained CAFE levels decline from 30.17 MPG to 29.43 MPG when the Big Two are forced to increase their CAFE levels by 2.5 MPG. The non-constrained firms expand their share in larger cars and decrease their presence in the small car market as higher CAFE levels are imposed. This can be taken as at least partial evidence that imposing CAFE standards creates economies of scope in the auto industry.

Gasoline Consumption Model

To measure the gasoline savings from CAFE standards, it is necessary to trace the consumption of new cars sold under the standards for their entire lifespan and to compare that to the consumption that would take place without the imposition of CAFE standards. It is also necessary to take account of the "scrappage effect," the change in the stock of used cars that results from a change in the price of new cars. Several studies, such as Gruenspecht [1982] have found that scrappage rates of used cars are significantly affected by new car prices.

The average miles driven and the scrappage rates for automobiles for fifteen years after they are sold, obtained from surveys of the Department of Transportation, are used in the model. The scrappage rates are adjusted for new car prices changes using the average of Gruenspecht's results. Gruenspecht showed that if the price of new cars is raised (lowered), it causes a significant decrease (increase) in the scrappage rates of used cars. This effect was so large, in fact, that it was shown that imposition of more stringent pollution controls would actually cause pollution to increase. It is assumed that Gruenspecht's results hold for each of the three classes of automobiles (Basic Small, Luxury Small, and Large). For purposes of the consumption model Japanese cars are combined with their corresponding American segments.

Much of the fleet changes analyzed above from large car buyers switching into new cars due to the change in relative prices. Smaller cars, however, are more fuel efficient, which lowers the marginal cost of driving, which will encourage more driving. Blair et. al.'s [1984] estimate of this effect will be used to adjust the miles driven for the new

cars coming onto the road. The values of MPG for the three classes can be determined from the information used in the static 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 calculated. It is also assumed that fuel efficiency grew exponentially for each class of car between 1973 and 1984. MPG's are then calculated accordingly. Fuel efficiency for cars made before 1973 is assumed to be equal to 1973 levels and fuel efficiencies after 1984 are assumed to be equal to 1984 levels.

Results of Consumption Model

The gasoline consumption results are summarized in Figure 4. The simulation was run with the CAFE increase of 1.5 MPG in force for one year and with the additional scrappage and substitution effects described above for various CAFE levels. A discount rate of 4 percent is used.

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 level increases of up to 0.5 MPG do lead to small increases in gasoline consumption (no more than 43 million gallons out of an annual automobile consumption of about 60 billion). As CAFE standards grow tighter, fuel savings turn positive,

reaching 712 million gallons at 1.5 MPG and 2.105 billion gallons with a CAFE increase of 2.5 MPG.

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 increase of 1.5 MPG is $4.87, which declines slightly to $4.61 with a CAFE increase of 2.5 MPG.

It is not appropriate to compare the CAFE-imposed cost of saving gasoline with the cost of the gasoline being saved. If gasoline costs $1 per gallon 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] at 61.) The true benefit from this policy is the reduction of the externality associated with gasoline consumption. This also implies that it is appropriate to discount future savings of gasoline in any cost-benefit analysis.

Sensitivity Analysis

Given the need to make a large number of assumptions when establishing this model, it would be informative to see how the robust the conclusions of this paper are. 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 3 shows the results of the model under various supply and demand elasticity conditions with an increase in CAFE of 1.5 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 reduced from 4.00 to 2.50 and the own elasticity of demand for large cars is increased from 2.50 to 4.00. New cross-elasticities are then computed using the different assumptions according to the method described in the technical appendix of this paper.

In five of the six scenarios examined GM and Ford lose a substantial amount of money, ranging from $234 million to $2.693 billion. Only when the supply elasticity is 4.0 (which given the circumstances of the industry would seem extremely high) and the basic scenario is used do they make money, and then only a bare $64 million.

The results for Chrysler are even more consistent. Chrysler makes money in every scenario examined, with profits ranging from $311 to $526 million. Thus, it would seem almost certain that enforcement of the higher standards results in a major windfall for Chrysler.

Japanese firms make money in five of the six scenarios, with profits ranging from $286 million to $1.903 billion. The most crucial factor for the Japanese is the elasticity of demand for large cars. If the large car elasticity is high, then many would be large car customers respond to higher prices by looking for alternatives. Japanese luxury small car prices rise in response to this additional demand, with resulting profits to Japanese firms.

The effect on consumers is always negative, with losses ranging from $2.347 billion to $4.646 billion. Auto industry employment declines as well, with from 25,600 to 59,00 workers being put out of work. From 532 million to 1.084 billion gallons of gasoline are saved, but at an exorbitant loss to the economy. Costs per gallon range from $3.71 to $6.29.

Thus, under a wide range of assumptions imposition of the higher CAFE standard saves gasoline at a large cost to consumers while benefitting Chrysler and Japanese firms. GM and Ford, would appear to lose millions and perhaps billions of dollars from higher standards while job losses in the auto industry measure in the tens of thousands.

V. 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. By placing a check on competition in large cars, CAFE regulation can serve to increase the profits of constrained firms. CAFE standards can also increase domestic employment in the auto industry and actually increase consumption of gasoline. The simulation model presented in this paper shows that these perverse effects can occur, but with varying likelihood. Auto employment can increase slightly when CAFE standards are imposed, but is more likely to decline as the standard level increase.

Results for gasoline consumption are similar, as Kwoka's hypothesis is borne out only at only at CAFE imposed fuel economy increases of less than 0.6 MPG. What does come out of the simulations is that unconstrained firms, if they can adapt to the changed marketplace, have the opportunity to make a good deal of money as a result of CAFE standards. The profit possibilities in the large car market can outweigh the losses in the small car segment. Thus, CAFE regulation encourages and perhaps even forces all firms to produce each type of automobile, creating regulatory economies of scope in the industry.

Table 1
Initial Conditions - Model Year 1984

	All Sales (mill.)	Non-Constrained Sales (mill.)	Price ($000)	Fuel Efficiency (MPG)
Japanese Basic Small	.900	.000	7.60	37.24
Japanese Luxury Small	1.067	.117	11.70	30.48
U.S. Basic Small	1.727	.450	7.90	33.30
U.S. Luxury Small	1.859	.559	10.00	26.72
U.S. Large	4.319	.423	11.70	22.30
Total	10.100	.939		26.38

Sources: Ward's 1985 Automotive Yearbook, Environmental Protection Agency, Council of Economic Advisers

Table 2

Parameters Used in Static Analysis

Cross and Own Point Elasticities of Demand

	Jpn. Bas. Sm.	Jpn. Lux. Sm.	U.S. Bas. Sm.	U.S. Lux. Sm.	U.S. Large
Japanese Basic Small	-4.000	0.867	3.105	1.209	1.075
Japanese Luxury Small	0.360	-3.500	0.682	1.661	2.369
U.S. Basic Small	0.784	0.412	-4.000	0.641	0.572
U.S. Luxury Small	0.230	0.755	0.482	-3.500	1.672
U.S. Large	0.021	0.111	0.045	0.173	-2.500

(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 Japanese small cars will change with respect to a change in the price of Japanese luxury small cars.)

Point Supply Elasticities

U.S. Production	Japanese Production
2.0	2.0

Employment Factors (Cars per job)

U.S. Production			On-Shore Jpn.
Bas. Sm.	Lux. Sm.	Large	Bas. Sm.
8.1	7.3	6.6	21.0

Table 3
Results of Alternative Scenarios

Imposing higher CAFE standard results in -

	GM and Ford Profits ($billion) Supply Elasticities			Chrysler Profits ($billion) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	-2.122	-0.497	0.064	0.479	0.386	0.311
Elast. Alternative	-2.693	-0.934	-0.234	0.526	0.421	0.327

	Jpn. Firms Profits ($billion) Supply Elasticities			Consumers' Surplus ($billion) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	0.661	0.286	-0.019	-4.450	-3.330	-2.347
Elast. Alternative	1.903	1.521	1.132	-4.646	-3.726	-2.865

	Employment (000 jobs) Supply Elasticities			Gasoline Saved (bill.gallons) Supply Elasticities		
	1.0	2.0	4.0	1.0	2.0	4.0
Demand Same	-52.428	-38.247	-25.652	0.971	0.743	0.532
Elast. Alternative	-59.024	-47.878	-37.764	1.084	0.886	0.694

	Cost Per Gallon ($) Supply Elasticities		
	1.0	2.0	4.0
Demand Same	6.28	4.63	3.71
Elast. Alternative	6.29	4.89	4.00

For the demand elasticities "Same" refers to baseline case where own demand for large cars is assumed to be -2.50 and own demand for small cars is -4.00. "Alternative" refers to the alternative scenario where the two numbers are reversed and new cross-elasticities are computed using the different assumptions.

FIGURE ONE
CHANGE IN CORPORATE PROFITS

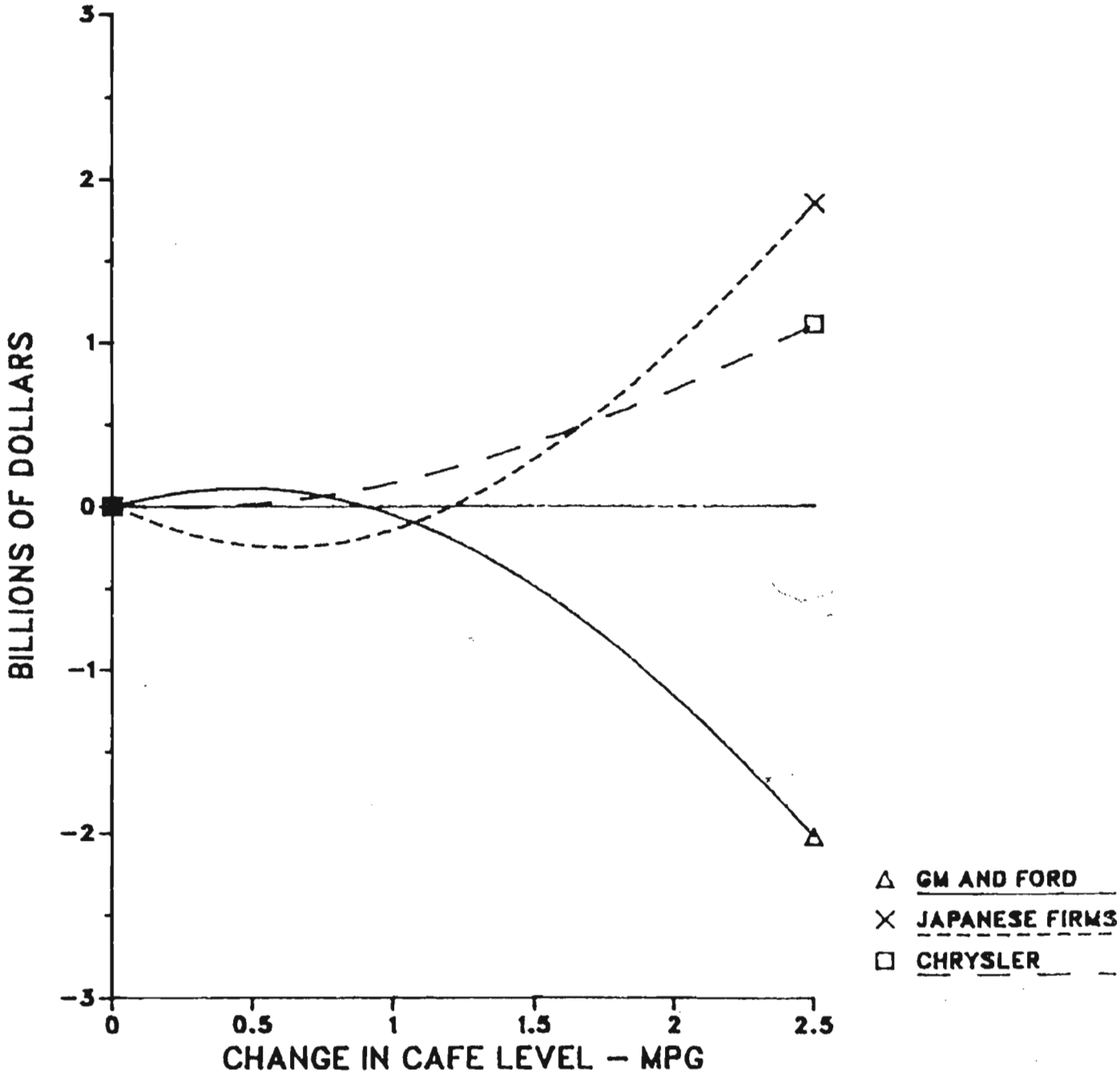


FIGURE TWO
CHANGE IN EMPLOYMENT

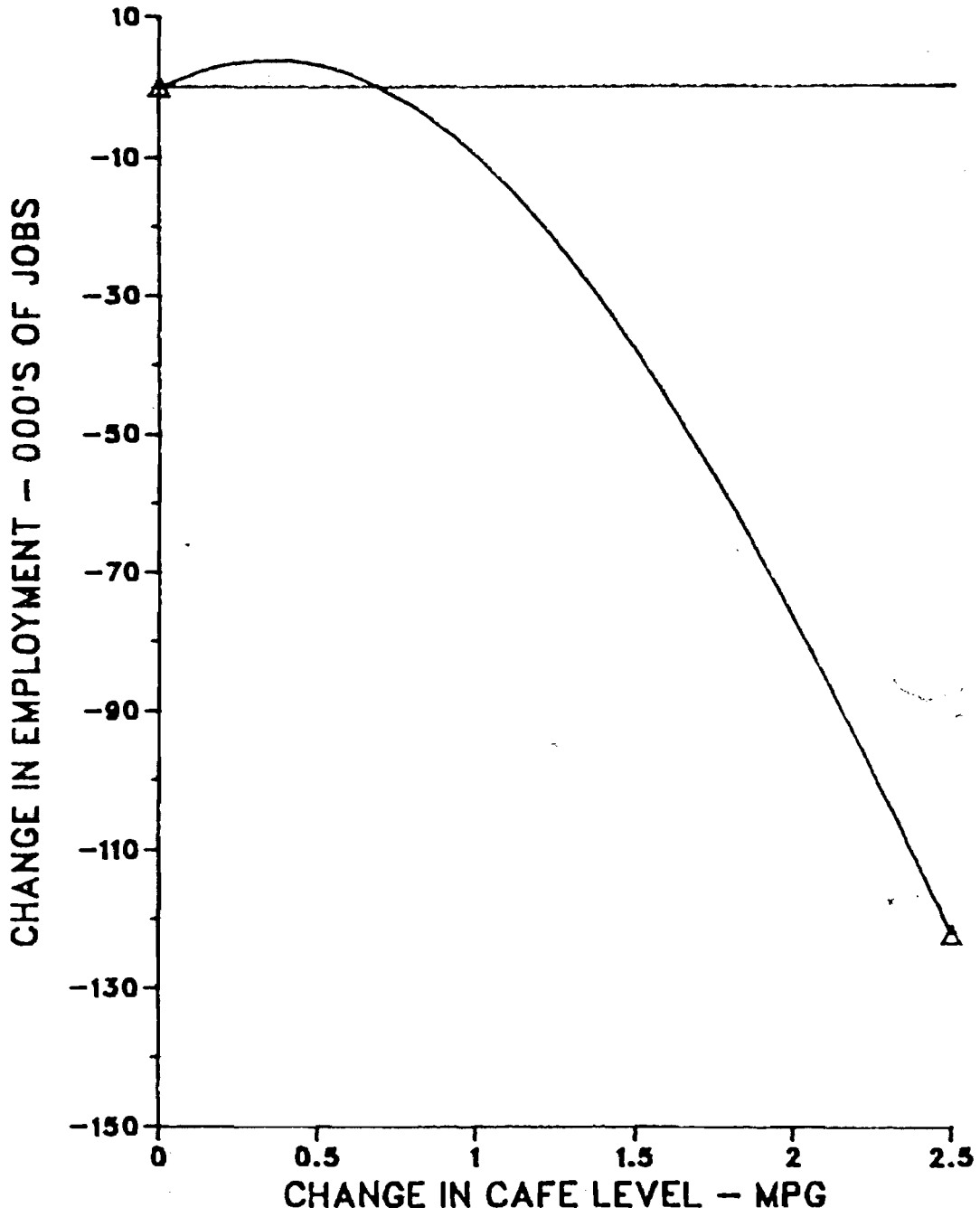


FIGURE THREE
CHANGE IN CONSUMER WELFARE

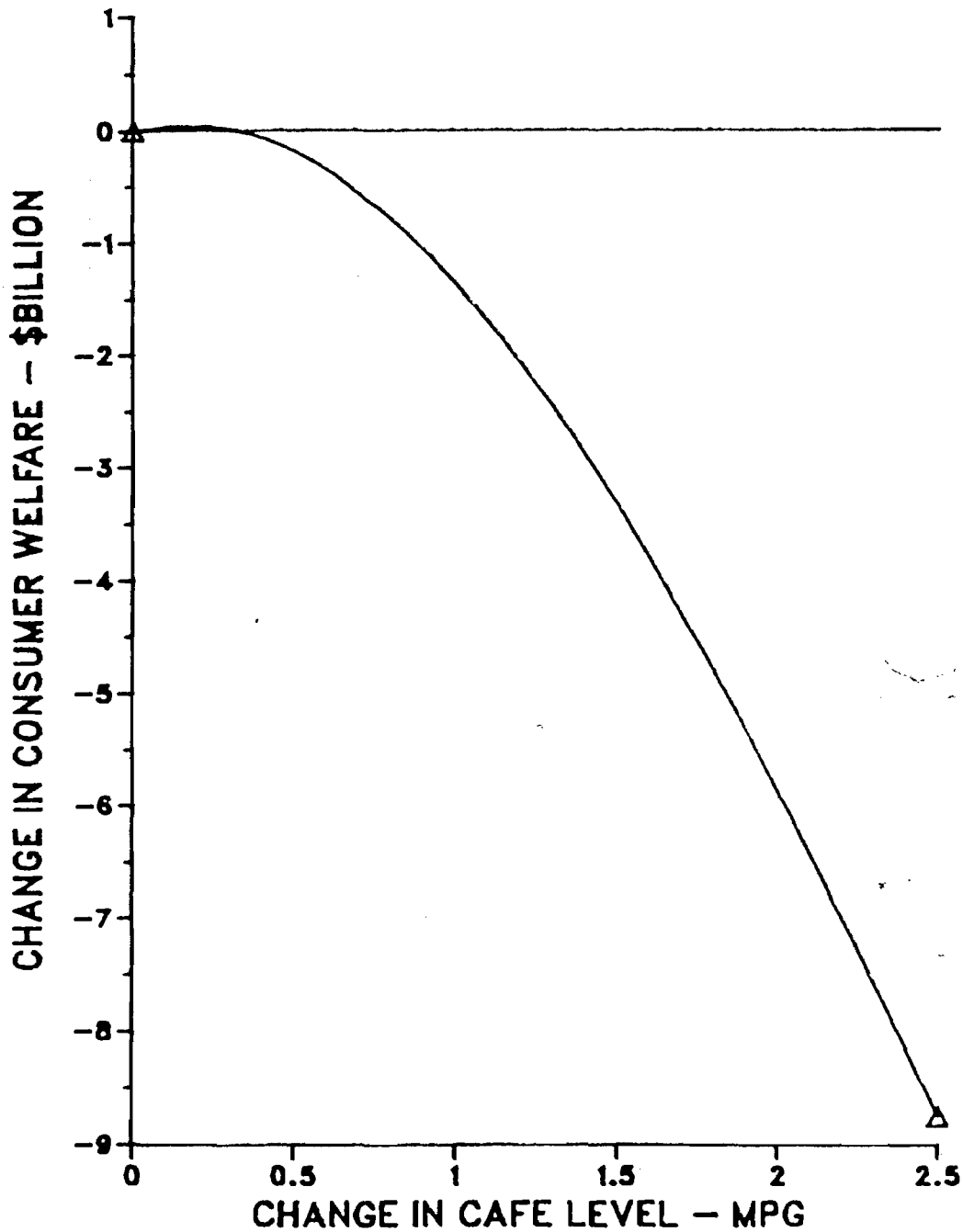
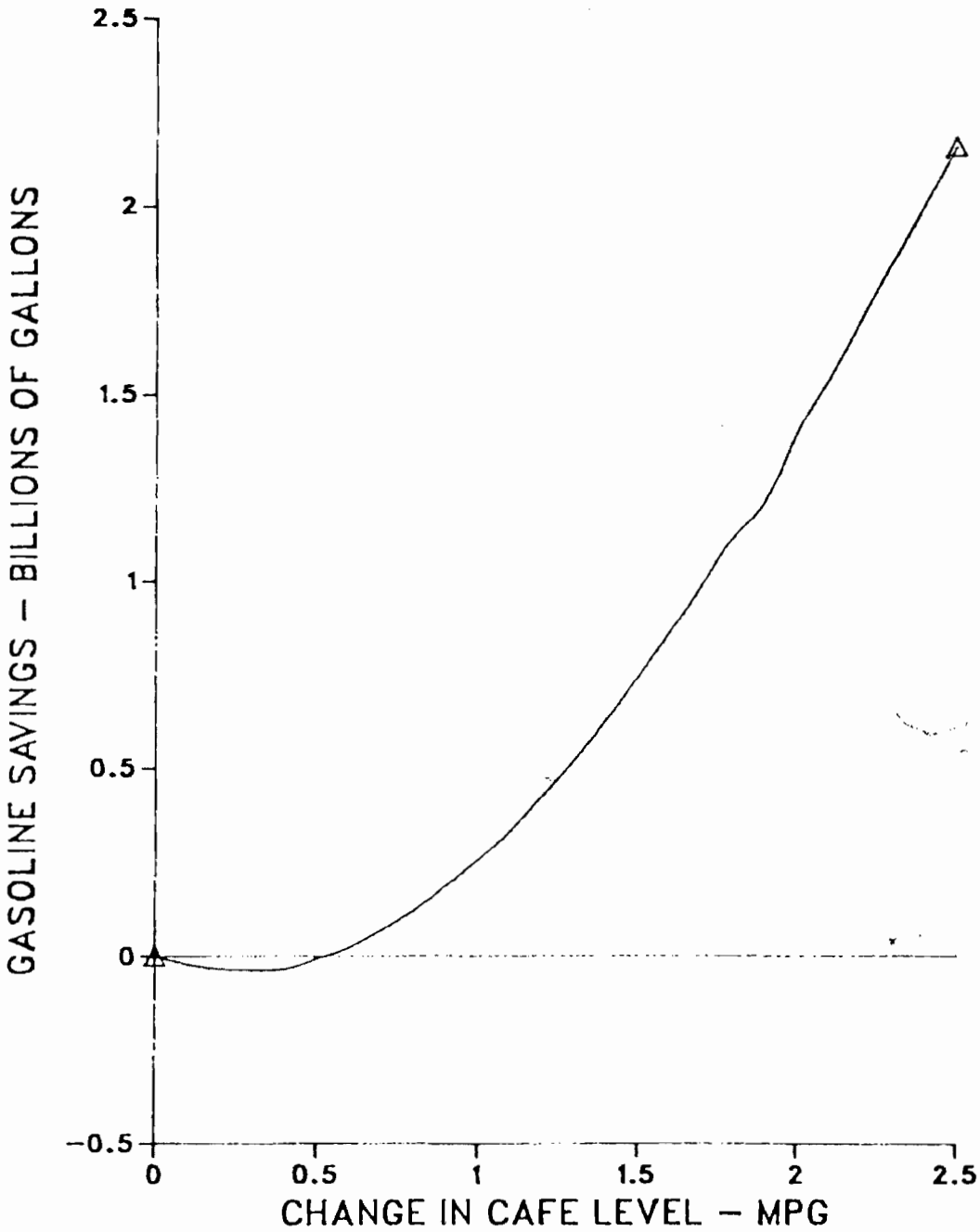


FIGURE FOUR
GASOLINE SAVINGS FROM CAFE



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