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THE EFFECTIVENESS OF MANDATORY FUEL EFFICIENCY STANDARDS IN REDUCING GASOLINE CONSUMPTION

A Thesis

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Degree

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ABSTRACT

The Energy Policy and Conservation Act was enacted in order to reduce the consumption of gasoline by automobiles by imposing mandatory fuel efficiency standards. This paper presents a model of gasoline consumption which includes the Corporate Average Fuel Economy (CAFE) standards as an integral part. The empirical results indicate that the CAFE standards are not statistically significant determinants of automobile fleet fuel efficiency. In addition, the results indicate that the price of gasoline and the per capita number of automobiles are statistically significant factors of the level of gasoline consumption.

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INTRODUCTION

In 1973, the Arab oil embargo and the subsequent shortages of oil caused the Congress to examine the problem of the U.S. dependence on imported petroleum. As a result of this investigation, the Energy Policy and Conservation Act (EPCA) was enacted. The authors of the EPCA, in their report accompanying the bill (U.S. Congress 1975b), stated as their goals the reduction in the dependence of the U.S. on imported petroleum, the minimization of any adverse economic effects on the poor and disadvantaged, and the continuation of the economic recovery from the recession of 1974. It now seems worthwhile, ten years after the passage of the EPCA, to examine the question as to whether the Act achieved its goals. Specifically, the effectiveness of the mandatory fuel efficiency standards, as set forth in the EPCA, will be examined for their effect on gasoline consumption and the overall efficiency of the U.S. automobile fleet.

Intuitively, it would seem that the imposition of mandatory fuel efficiency standards would have increased fuel efficiency, and, consequently, reduced the demand for gasoline. But several considerations have raised doubts about the effectiveness of these standards during the late 1970's and early 1980's. For example, consumer resistance toward buying smaller automobiles might result in fewer new, efficient automobiles sold, partially offsetting any potential increase in the fuel efficiency of the U.S. automobile fleet. Also, consumers, as the result of falling costs associated with increased efficiency, might drive their automobiles farther. Finally, enforcement of the Corporate Average Fuel Economy (CAFE) standards might be nullified by both the unwillingness of the Congress to impose rigidly the standards upon the automakers, and the statistical uncertainties associated with the measurement of the CAFE.

CHAPTER I

HISTORY OF THE EPCA

During the Arab oil embargo of 1973, the U.S. experienced a 14 percent reduction in its supply of petroleum (U.S. Congress 1975b). The shortages created widespread economic disorder. According to the Congressional Budget Office, two Federal reserve economists estimated that the 1973-74 oil price hikes lowered real GNP by about $16 billion after five quarters, raised prices by about 2.6 percent, and increased unemployment by 1.1 percent (U.S. Congress 1975b). In addition, the shortages of gasoline, caused partly by the oil embargo and partly by misallocation of petroleum supplies by the Federal Energy Administration, resulted in many man-hours lost by people waiting in long queues at gasoline stations.

The members of the 94th Congress were faced with two major alternative courses of action to take in order to respond to the oil shortages. The first would have been to enact (Republican) President Ford's "Project Independence" proposal. The second course, to enact the Energy Policy and Conservation Act of 1975, the product of the Senate and the House of Representatives (both under the control of the Democratic Party), was taken.

President Ford's proposal (U.S. President 1975) relied on the use of prices to control the demand for petroleum and to encourage the use of other types of fuel. Specifically, he favored the imposition of a two dollar-per-barrel tariff on imported oil, the gradual removal of price controls on domestic crude oil and natural gas, as well as voluntary improvements in automobile fuel efficiency. The revenues received from the tariffs would be transferred back to the public in the form of tax refunds and assistance to the poor.

The Congress, on the other hand, rejected the use of only prices to control demand and supply. Instead, they felt that regulatory control would bring quicker and more definite results. Indeed, according to the House Committee on Science and Technology (U.S. Congress 1975a) which drafted the bill which later was to become the EPCA, there was ". . .considerable doubt concerning the elasticity of petroleum demand in response to price." The Committee, in their final report on the necessity of enacting the Energy Conservation and Oil Policy Act (as it was then known), stated also that the economic burdens which would be imposed by President Ford's proposal could not be borne either by the economy, or by the poor. In political terms, chances for reelection are enhanced if a way can be found to disguise a tax as something else, and the members of Congress were well aware of this. Therefore, the Congress sought an alternative to the unpopular proposition of increased taxes on petroleum products.

General Motors (1974a) the largest of the domestic automobile manufacturers, felt that government legislation regarding fuel efficiency was unnecessary, as car designs evolve as a response to customer needs. GM stated, ". . .such a control effort is not needed because the marketplace can and is dealing with the problem much more effectively." Customers, GM added, are aware of the necessity to conserve fuel. In contrast, GM said, consumers may not be aware individually of the need for eliminating exhaust emissions, and that is why legislation was needed for control of exhaust emissions. Contrary to GM's view, however, consumers, though they may be aware of the need to conserve fuel, may not be willing to sacrifice their comfort or safety for the sake of conservation.

A survey of consumer attitudes (Cambridge Systematics, Inc. 1979), conducted for the Department of Transportion (DOT), reported that less than one-half of the consumers surveyed would reduce their driving to conserve fuel, even though two-thirds of them agreed that reduced consumption would be necessary. The perceived greater safety of large cars, the study found, was an important factor for the reluctance of consumers to buy smaller, more fuel efficient automobiles. Just as important, the survey also indicated that increases in the price of gasoline was a powerful agent in causing consumers to conserve fuel.

Despite the recognized need for automotive emission controls, GM (1974a) wanted air pollution standards eased so as to increase the efficiency of automobile engines. Recent emission controls had clearly reduced automotive efficiency. Lower compression ratios, exhaust gas recirculation, and retarded ignition timing all contributed to lower efficiency. Even automobiles equipped with catalytic converters have lower efficiencies than those of similar type without emission controls. Representatives of both General Motors and Chrysler, testifying before Congress (1975a), stated that emission controls had reduced fuel efficiency by about 14 percent. President Ford had proposed (U.S. President 1975) that the Clean Air Act be modified in such a way that the pollution standards for automobiles would be frozen at their 1974 levels until 1980. Concurring with the President, the

National Academy of Sciences (1974) estimated that the cost savings resulting from the maintenance of the 1974 level of controls would exceed the decrease in benefits coming from the higher levels of nitrogen oxides in the air.

Although the Administration had received written understandings from the majority of the domestic automakers and importers for a 40 percent increase over 1974 levels in the efficiency of their automobiles by 1980, the Committee (U.S. Congress 1975b) felt that ". . .the necessity for insuring major improvements in automobile fuel economy is so clear that legally enforceable requirement [sic] respecting improvement of fuel economy be imposed."

The Committee (1975b) used a variety of studies to set the fuel economy standards. For example, to set the 1980 benchmark standard, they used an Environmental Protection Agency - Department of Transportation study. This study (Southwest Research Institute 1974), conducted by the Southwest Research Institute (SwRI) examined the technologies available to improve the efficiency of automobiles. For gasoline-powered automobiles, SwRI found that a stratified-charge engine could improve miles-per-gallon efficiency by 55 percent, and improvements to conventional spark engines could increase mileage by 33 percent. They also found that turbocharging gasoline engines was not feasible, because of 'knock' problems. However, they estimated that a turbocharged diesel engine could improve mileage by 70 percent. The conclusions reached by this study were much later characterized (Russell 1983) as "preposterous" by Eric Stork who was the deputy administrator of the Environmental Protection Agency at that time. Moreover, criticism of the SwRI study was not limited to that of Mr. Stork.

General Motors (1974b) commented on several of the findings by the SwRI. GM considered the SwRI report to be too simplistic and optimistic, especially with regard to emissions control and "programmed inventions." With regard to SwRI's estimation procedure for determining the effects of emission controls on fuel efficiency, GM stated,

> The fuel economy analysis technique problem involves estimating the fuel economy penalty resulting from the addition of emission controls. In our experience it has been necessary to develop the required engine hardware first. . . .Assuming that emission controls can be developed without an economy penalty, or assuming an arbitrary economy penalty is not realistic.

Diesel engines, in particular, have characteristically high odor and particulate emissions. With regard to diesel engines, GM stated that with current technology, diesels did not have the performance capability in comparison with the current gasoline engines of comparable weight, and had serious, adverse emissions problems.

In contrast, the Chrysler Corporation (1974) reported that they had no "serious disagreement" with the findings of the summary. However, Chrysler did think that the study exaggerated the problem of knock in turbocharged engines. Knock, the engineers at Chrysler thought, could be controlled by reductions in compression ratio, rather than by water injection as mentioned in SwRI's report.

To set the 1985 mileage standard, then, the House committee (U.S. Congress 1975b), citing the large degree of uncertainty in forecasting technological improvements, decided arbitrarily to use ". . .the highest potential of fuel economy (28 miles-per-gallon) which any of the studies available to the Committee indicated was attainable." But the 1985 standard could be changed administratively, subject to Congressional approval, on the basis of improved information. In the final bill, the 1985 standard was reduced to 27.5 miles-per-gallon (MPG). This represents a 101 percent (in MPG) improvement in fleet fuel efficiency over the 1974 model-year level. In terms of fuel consumption (gallons-per-mile) efficiency, it is a 50 percent reduction.

CHAPTER II

PROVISIONS OF THE EPCA

The EPCA covers a large number of areas pertaining to energy conservation. Legislation regarding coal-land leasing, oil prices, and home-insulation credits are but a few of the many parts of the EPCA. This paper, however, will consider only the part that pertains to automotive fuel efficiency, Title V. Title V (Energy Policy 1975) sets forth the definitions, standards, and enforcement powers for improving automobile efficiency.

The automotive efficiency standards apply only to automobiles of standard size. Only vehicles of less than 10,000 pounds in weight, used primarily on public roads, and propelled by fuel come under the standards. But if the Secretary of Transportation determines that "significant energy conservation" would result, he can enlarge the definition to include other vehicles.

As originally written, the average fuel economy standards prescribed by the Act covered only the years 1978, 1979, 1980, 1985 and thereafter. For the intervening years, the Secretary of Transportation was to determine the standards, as long as they were higher than the previous year's. However, if it were felt that the 1985 standard could not be met without serious economic consequences, then the Secretary could reduce the standard by up to one mile-per-gallon.

The method for measuring the Corporate Average Fuel Economy (CAFE) is also specified in the Act. To determine the CAFE,

the total number of passenger automobiles manufactured in a given model year is divided by a sum of terms, each term of which is a fraction created by dividing
(i) the number of passenger automobiles of a given model year type manufactured by such manufacturer in such model year, by
(ii) the fuel economy measured for such model type.

The above method is known as harmonic averaging. This method makes it much more difficult for a manufacturer to meet the standards than of a simple averaging method. For example, to achieve an average of 30 MPG will require the sale of two cars, each with a fuel economy of 40 MPG, to balance each car sold with fuel economy of 20 MPG.

The penalties for failing to meet the standards are severe. For each 0.1 MPG in the CAFE that a manufacturer falls short of the standard, a five dollar penalty for each automobile the manufacturer sells is assessed. Thus, for example, for a large manufacturer such as General Motors which sells approximately four million automobiles annually, a 0.5 MPG deficiency in its CAFE would result in a penalty of about $100 million per year. As will be seen, however, the Environmental Protection Agency, which is responsible for measuring CAFE, cannot measure CAFE with sufficient precision to make enforcement of the Act possible.

There exists a flaw in the EPCA which could allow the automakers to avoid paying the penalty. The method with which the Environmental Protection Agency (EPA) estimates CAFE is a highly stratified approach, which came about as the result of emissions testing. As a result, this method of measuring CAFE cannot provide the necessary accuracy of 0.1 MPG.

As with many Congressional decisions, politics played an important role in giving the EPA the responsibility for measuring fuel economy. During the early 1970's, the EPA was fighting to retain the emissions standards for automobiles, as the result of increasing pressure to relax those standards so as to conserve fuel (Russell 1983). According to Mr. Stork (Russell 1983), many other Federal agencies were becoming interested in fuel economy as the result of the oil shortages, and the EPA was becoming worried that its data-base of fuel efficiency was in danger of being supplanted. Stork stated that, in 1974, the EPA succeeded in preventing the Bureau of Standards from taking control of the fuel economy data-base, thus possibly preventing the loss of emissions testing by the EPA.

A Department of Transportation (DOT) study by Rabe (1979) found that the estimating procedures used by the EPA are statistically biased, which damages the validity of conclusions based upon them. Two types of bias were found to exist:

(1) bias arising from using specially-made vehicles, i.e., selection bias, and

(2) bias arising from using a non-random method of sampling vehicle configurations, i.e., sample bias.

In comparison to the 0.1 MPG precision required by the EPCA, the statistical inefficiency of the sampling method causes the measurement errors to be large. Table 1 gives some of the estimated confidence interval widths. Obviously, the measurement errors are much larger than the interval required to assess penalties, and this in combination with

TABLE 1

ESTIMATED CONFIDENCE INTERVAL WIDTHS FOR THE 1978
FUEL ECONOMY DATA BASE (MILES PER GALLON)

Manufacturer	95% Interval
GM	0.68
Ford	0.90
Chrysler	1.22
AMC	2.80
Nissan	1.57
Toyota	1.12
VW	5.25

Source: F.T. Rabe, Review of Procedures for Determining CAFE (EIC Corporation for the DOT), 1979, p.5.

the bias in the measurement makes it doubtful that penalties could be successfully imposed.

Clearly, then, a better testing method should be used to make the EPCA standards meaningful. Since the present stratification method increases both the bias and the variance of the estimate, a new way subdividing the sample such that the vehicles have nearly identical characteristics should be implemented. Even this change, however, would not provide 0.1 MPG precision, according to Rabe, because of the small sample size currently used. Rabe stated that random selection of production vehicles would be a better and less expensive way to estimate CAFE. The cost would be about half of that required for the pre-production testing now used, according to Rabe, and the bias in the measurement would be smaller.

CHAPTER III

ECONOMIC EFFECTS OF THE EPCA

Studies concerning the economic effects of the EPCA fall into two major categories: consumer responses and automaker responses.

Consumer Responses

A study by William Wheaton (1982) used a cross-sectional method in determining which factors affect the demand for gasoline. Data from twenty-five countries were used to determine the components of demand. Using a microeconomic model which incorporated the structural relationships of ownership, driving, and vehicle efficiency, he found that, across countries, gasoline price differences primarily affect the consumption of gasoline through the amount of driving done. Price does affect fleet fuel efficiency, but the effect on consumption is much smaller than on the amount of driving done, according to his study. In addition, he found that the demand for gasoline in the long run is elastic with respect to income, with the income effect on gasoline consumption operating primarily through the level of automobile ownership. He pointed out, however, that the cross-national data used was not ideal, and the results of his study are more qualitative than quantitative. It might be thought that as income rises, the number of miles driven per automobile would also increase. His study, however, indicated that increased income increases the level of automobile ownership so much, that annual miles per vehicle are reduced!

Price, he found, affects gasoline consumption less than the income effect. In fact, gasoline prices were found to exert no influence on automobile ownership levels, but to influence only the level of fuel efficiency and the amount of driving done. The reduction in driving done as a result of higher gasoline prices is much greater than changes in either fleet fuel efficiency, or changes in the composition of the fleet.

With respect to the EPCA, Wheaton's multinational study determined that an increase in gasoline prices would cause only a minor sales shift from larger to smaller automobiles. Given an exogenous shift to smaller automobiles, the increase in additional driving in each automobile would be small, according to his study. The results of Wheaton's work would indicate the EPCA would reduce the overall level of gasoline consumption, the price of gasoline having only a minor effect.

A time-series study by Blair, Kaserman, and Tepel (1984) contradicted Wheaton's conclusion that the price of gasoline has little effect on the level of gasoline consumption. This study differed from other price-elasticity studies in that it examined the fuel-efficiency demand of gasoline, according to the authors. They stated, that an increase in fuel efficiency reduces the cost of travel, so that the number of miles driven per consumer increases.

To determine this fuel-efficiency elasticity, the authors separated two components of gasoline demand: fuel efficiency and vehicle miles traveled. In other words, the study looked at both the technological component and the behavioral component. The number of vehicle miles traveled depends upon consumer behavior, and is a function of the cost-per-mile, aggregate income, and the number of consumers of travel; the level of fuel efficiency depends upon the level of technology used. The cost per mile was assumed to be mainly the cost of fuel.

The vehicle-miles-traveled component was modeled using the equation

$$VMT = \beta_0 + \beta_1 CT + \beta_2 I + \beta_3 POP + \beta_4 M1 + \ldots + \beta_{14} M11 + e$$

where VMT is vehicle miles traveled in Florida; CT is the cost of travel; I is monthly personal income in Florida; and M1 - M11 are dummy variables to account for seasonal variations; and "e" is an error term.

The equation used for estimating fuel efficiency was

$$MPG = \gamma_0 + \gamma_1 P + \gamma_2 I + u$$

where P is the real price of gasoline in Florida (including taxes); u is an error term.

Both components were successfully modeled in the study by using a recursive scheme of analysis on the resulting two equations. Fuel efficiency, in this model, is a function of the price of gasoline and aggregate income. This provides a means for measuring more accurately the price elasticity of gasoline. Indeed, as the authors pointed out, studies previous to theirs could not provide accurate information regarding the price elasticity of vehicle miles traveled for precisely the reason that no one had ever estimated this component.

By using a time-series study of gasoline for the state of Florida, they concluded that the estimated price elasticity is -0.412; the income elasticity is 0.278; and the fuel-efficiency elasticity is -0.703.

Consequently, they stated, an exogenous increase in fuel efficiency will cause a decrease in the amount of gasoline consumed. But the magnitude of the decrease will not be as great as the efficiency increase would indicate, because of the resultant increased vehicle usage. They estimated, using their results, that an exogenous ten percent increase in fuel efficiency (measured in miles-per-gallon) would cause only a 7 percent reduction in gasoline consumed. This reduces the effectiveness of the EPCA in achieving the stated goal of reducing gasoline consumption. To the extent that the Blair, Kaserman, Tepel results are applicable on a national level, the increase in vehicle miles traveled associated with increased efficiency would mitigate some of the fuel savings anticipated from the implementation of EPCA standards.

As part of an earlier study (Boyd and Mellman 1980a) to determine the effect of the EPCA on competition in the automobile industry, Boyd and Mellman (1980b) also examined the response of consumers and firms to mandatory fuel efficiency requirements. Using an hedonic-demand approach, they examined a data-base that contained total U.S. automobile sales and the attributes of 153 automobile sub-models for the 1977 model year. The attributes included values for purchase price, operating cost, fuel efficiency, acceleration, interior noise, styling, frequency-of-repair, and handling.

Although the hedonic model seemed to give an excessive worth to the attribute of fuel efficiency, the authors concluded that consumers are indeed willing to pay for fuel efficiency, ". . .consumers do trade off lifetime fuel cost and purchase price in choosing amoung competing models, other things being equal," they stated.

Attempts to increase fuel efficiency, however, may adversely affect other attributes. They concluded,

> Thus, consumer acceptance of cars of the 1980's, and the impact on their welfare of expected gains in average fuel efficiency, will depend critically on the ability of manufacturers to maintain traditional levels of style, luxury, performance and reliability in larger cars as they are downsized.

To simulate the situation in which a firm changes the price differential between large and small automobiles, they divided the market into two groups: subcompacts (the small cars) and cars larger than subcompacts. In this simulation, the price of the large cars increased by 10 percent, and the price of the small cars was reduced by 10 percent. The result indicated that the sales of small cars would increase by about 20 percent, but the weighted fleet fuel efficiency of the new automobiles sold would increase by only 2.4 percent. The authors did not make clear their method of weighting to obtain the average.

Next, they used their model to predict the effect of a doubling of gasoline prices. Their calculations showed that the larger automobiles lost market shares, while the subcompacts gained. Domestic manufacturers lost market shares, while importers gained. Average fuel efficiency increased by 6.3 percent, more than double than that achieved by sales-shifting.

From the above results, they further stated that changes in either the price of gasoline or new automobile prices will have little effect on CAFE. Instead, they asserted that automakers would have to rely on engineering and technological changes to reach the mandated 27.5 MPG by 1985. Other studies which examine automaker responses challenge this conclusion.

Automaker Responses

The automakers have three options to meet the EPCA standards:

(1) increase the efficiency of the automobiles sold

(2) alter the sales proportion of efficient to inefficient

(3) continue to make the same cars, i.e., do not make new models.

The third option has only been used recently. Since the EPCA specifies for which model year the standards apply, automakers can avoid being penalized by continuing to produce models which exceed the standard well into the new model year. These cars are included in calculating the old model year's CAFE. Because the automakers are allowed three-year carryforward/carryback mileage credits (again showing Congress' reluctance to impose penalties), and because the standards increase only until 1985, the 'mileage gap' can be greatly reduced. For example, if General Motors foresees a two mile-per-gallon shortfall in its CAFE for the 1984 model year, it can continue to produce high-mileage, 1984 model-year Chevettes well into the 1985 model year to raise its 1984 CAFE. If it can raise its 1984 CAFE enough to cover the 1985 shortfall, then it will avoid penalties for both 1984 and 1985.

A study by Sweeney (1979) asserted that the automakers could meet the 1985 standard without any technological improvements in their automobiles, simply by shifting sales from large cars to small. (Note, this contradicts the study by Boyd and Mellman). He calculated an equivalent tax for the potential penalties imposed if an automaker's CAFE fell short of a year's standard. By combining the effects of the equivalent tax with the response of consumers to more fuel efficient automobiles, analyzing the possible combinations of technology and market contributions, he was able to estimate the possible degree of compliance to the standards.

To connect the mean efficiency of automobiles to both technical efficiency and gasoline price, he chose a simple, constant-elasticity equation, using the equivalent tax as an integral part, to determine the elasticity of demand for fuel efficiency. His results gave the combinations of increases in technical efficiency and fuel-efficiency elasticity for the 1976 model-year automobile fleet necessary to meet the 1985 CAFE standard, and if no change in technical efficiency were to occur, the 1985 CAFE standard could still be met if the fuel-efficiency elasticity exceeded 0.68. An earlier, econometric study by Sweeney (1975) gave a value for the fuel-efficiency elasticity of 0.72; thus, Sweeney claimed, the fuel efficiency standard for 1985 could be met by firms with no further improvement in the technical efficiency of the 1976 model-year automobiles. Presumably, he meant that this compliance with standard would come about solely as the result of sales-shifting by the automakers. But which firms in 1976 had any automobiles with fuel efficiencies equal or better than 27.5 MPG? Certainly, the domestic firms did not. As late as the 1979 model year, the highest fuel efficiency for domestic subcompacts was less than 25 MPG (Kulp and

Holcomb 1982). Consequently, Sweeney's analysis holds only for foreign firms.

Kwoka (1983) approached the problem of the firm meeting the EPCA standards in much the same way as Sweeney. However, Kwoka looked at the mix of large and small automobiles that the firm would have to produce in order to meet or exceed the standards. He derived a quantity called the "mileage mix ratio," R. The value of R indicates the ease of complying with the EPCA standards. When $R > 1$, the firms have to sell more than one fuel efficient automobile for each inefficient one sold. As R increases, it becomes more difficult for the manufacturer to meet the standards.

According to Kwoka, when the EPCA standards were perceived to be binding, automakers did indeed effect a pricing strategy to shift the sales of their products toward the more efficient models. He measured this shift by noting the pattern of pricing between large and small automobiles as the EPCA standards became binding. According to his simple model of a two-car product line, Ford Motor, of all the manufacturers, should have had the greatest difficulty in meeting the 1979 CAFE value, since its R-value was nearly two, and thus, should have engaged in the greatest amount of sales-mix shifting. In fact, this is what occurred. Analyzing the ratio of the prices of the firms' largest to smallest automobiles for each of the manufacturers, Kwoka showed that the 'Big Three' automakers raised the relative price of large automobiles by a large amount in the beginning of the 1978 model year, but later lowered the relative price by raising the prices of their smaller automobiles when the Japanese yen appreciated against the dollar. At the beginning of the 1979 model year, both Ford and General Motors significantly increased the relative prices of their large cars. Indeed, Ford was notable in the extent to which it raised its relative prices. Ford also imposed a surcharge on it V8 engines at the time.

Given the results of the Boyd and Mellman tract (1980b), these efforts at achieving higher Corporate Average Fuel Economies were probably futile, and may have even increased fuel consumption, as we will see next.

Kwoka (1983) observed that compliance with the EPCA standards, alone, will not reduce gasoline consumption. He noted that since the total sales of automobiles is not constrained, an increase in the efficiency per vehicle, by itself, would not correspond to a reduction in the quantity of gasoline demanded. Thus, attempting to predict the course of gasoline consumption based solely on the EPCA standards and a fixed number of sales would be ridiculous. He proposed that three possibilities exist whereby the amount of fuel consumed could be greater than, less than, or the same as the fixed-sales case. If, under certain pricing schemes, the total number of automobiles sold is reduced, then the fuel savings will be greater than that of the EPCA standards alone would have achieved. If, however, the price elasticity of efficient automobiles is less than that of the inefficient, then the total number of automobiles sold would increase, causing the number of vehicles miles driven -- assuming a constant population for the time period -- to increase (Wheaton 1982), in turn causing the quantity of fuel consumed to be greater than that of the fixed-sales case. Also recall that consumers are reluctant to purchase smaller automobiles (Boyd and Mellman 1980b), and may choose to keep their older, less efficient automobiles for longer periods, thereby further enfeebling the CAFE standards. Therefore, surprisingly, the EPCA may actually increase gasoline consumption!

CHAPTER IV

THE EFFECTIVENESS OF THE EPCA STANDARDS IN REDUCING GASOLINE CONSUMPTION

Almost all of the studies cited in the previous chapter relied upon data for the years prior to 1974, the year of the first major increase in the price of gasoline in decades. The latest data used in any of these studies ended in 1976. During the period before the Arab oil embargo, the efficiency of automobiles -- with few exceptions -- declined continuously (American Petroleum Institute 1983). This slow decline in efficiency, coupled with nearly static real prices, made the accurate estimation of the price and income elasticities of gasoline demand very difficult. Indeed, it was this difficulty in estimating the price elasticity of gasoline demand that Congress (1975a) cited as a reason for using mandatory fuel efficiency standards. In addition, none of the studies attempted to measure the actual effect of the EPCA fuel efficiency standards on the consumption of gasoline. Between 1974 and 1982, in contrast, the real price of gasoline increased by more than 40 percent, and the fuel efficiency of automobiles (measured in miles-per-gallon) increased by nearly 70 percent (American Petroleum Institute 1983). Therefore, studies which include petroleum demand data for the years subsequent to 1974 should give better price and income elasticity estimates. The remainder of this paper will attempt to clarify the actual role that the EPCA standards have played in the reduced levels of gasoline consumption that have taken place since 1979. By incorporating data that includes these large changes in price and efficiency, it should be possible to make an accurate comparison of the two competing methods of reducing gasoline consumption that the Congress faced in the year 1974, and to determine whether an alternative course -- a combination of efficiency standards and taxes -- would have been more effective.

Of the domestic 'Big Three' automakers, only Chrysler has managed to exceed the EPCA standards every year. This achievement by Chrysler is remarkable, considering the fact that popular opinion during the 1970's held that Chrysler only produced 'gas guzzlers,' and the fact that the company nearly went bankrupt in the late 1970's. General Motors and Ford, on the other hand, managed to meet the standards only up to 1982, both failing to meet the 1983 and 1984 standards. In 1980, Congress amended the EPCA to allow three-year carryforward/carryback credits for exceeding the standards. This suggests a reluctance of Congress to impose the rigorous penalties set forth in the EPCA. Thus, no penalties have ever been assessed against a domestic automaker for failing to meet the EPCA standards.

To try to meet the standards, the automakers have used technological improvements and sales shifting between large and small automobiles. But, because the market for small automobiles is quite competitive (GM has only a 14 percent market share there), the amount of price reductions possible in the small-automobile market is limited. Indeed, since the profit margins on small automobiles for the domestic manufacturers are so small, it seems that the logical path would be to make the larger, higher-profit-margin automobiles more efficient.

The need for higher efficiency, coupled with more stringent exhaust emission rules, caused the automakers to invest heavily in engine and materials research, to make engines more efficient and automobiles lighter. Research into the properties of combustion and the increased use of electronics for engine control have resulted in engines of reduced displacement and higher efficiency. Contrary to the report by the Southwest Research Institute (1974), the stratified-charge engine has not become the dominant technology. Instead, the firms have relied on other methods for controlling the rate of combustion, to allow the use of higher compression ratios in engines. (The higher the compression ratio, other things being equal, the higher the efficiency of an internal combustion engine.) Turbocharging of engines, discounted by the SwRI as impractical for gasoline engines, is appearing in many more automobiles as a way to increase the power of smaller engines; detonation of fuel ('knock') is prevented electronically, the result of the miniaturization of computers. In addition, even though it is more expensive, fuel injection is replacing carburetors so as to increase further the degree of control over combustion.

The question to be addressed here is whether the increase in fuel efficiency of the U.S. automobile fleet came about as the result of higher gasoline prices, or as an effort to meet the EPCA standards, or both.

Blair, Kaserman, and Tepel (1983) pointed out that the quantity of gasoline consumed can be related to the amount of driving by the following expression:

$$(4.1)\ Q = DIST/EFF$$

where DIST is the distance that a fleet travels, and EFF is the miles per gallon for the fleet.

This basic identity, given in (4.1), is suggestive of the appropriate approach to the question at hand. First, a demand function for distance traveled can be constructed. From standard economic theory, it would be expected that this demand would depend both upon the cost of driving and the amount of resources available to the consumer. The cost of driving any given distance depends, in turn, on the MPG efficiency of the consumers' automobiles and the price per gallon of gasoline. A third factor that determines, in part, the cost of driving -- maintenance costs -- are assumed here to be thought of as fixed, and, therefore, not relevant to consumer driving decisions. The resources available to any given consumer are broadly given by his or her wealth or permanent income. As a reasonable proxy for this measure, personal disposable income is used in this study. In addition to price and income, several other factors can be thought to affect the demand for driving. Given the results of Wheaton's Study (1982), the number of consumers of travel and the number of automobiles per consumer are also included in the model. The price of competing sources of travel service could also affect DIST. No reliable measure of prices for these sources, however, could be found so, consequently, the price of competing sources are not used. Finally, it may not be possible, given changes in these exogenous determinants of driving, for consumers to adjust to new optimal amounts of driving within a given time period. For example, a rapid increase in the price of gasoline may dictate that consumers relocate closer to their work sites, but not all consumers are likely to accomplish this within a year. As a result, then, of this inability to adjust miles driven to optimal levels within a single period, the amount of driving done in the previous year is included as an independent variable.

Given a demand function for miles of travel, information can be gleaned (via equation 4.1) about the demand for gasoline by examining the determinants of EFF. Based upon the work of Boyd and Mellman (1980a), it can be assumed that EFF is a positive attribute in consumers' preference function, and is likely to be sensitive to both the price of efficiency and the consumers' real income. The price of efficiency, in turn, depends upon the price of gasoline. Another factor that could potentially affect the overall efficiency of the U.S. automobile fleet is the average highway speed of passenger automobiles. It is certainly the case that, for any individual automobile, the efficiency achieved is at least somewhat sensitive to how fast the car is driven. For this reason, the average highway speed of passenger automobiles is included as a determinant of EFF. Note, however, that highway speed is, to some extent, a variable of choice by consumer, and may not, therefore, be appropriate for inclusion as an exogenous variable. To overcome this obstacle, and at the same time capture the effect of the reduction of top, highway speed limits to 55 miles-per-hour, a binary (dummy) variable, SPD is included which has the value zero before 1974 and the value one, thereafter. Still another factor which could influence the demand for efficiency would be the number of cars per capita, since consumers who have more than one car might choose to have a small automobile for driving short distances around town and a larger automobile for taking longer trips. However, the determination of the effect of the number of cars per capita on efficiency will be left to a future study.

Finally, since gasoline is consumed in long-lived durable goods that do not depreciate completely within a year, some account must be taken for the fact that the observed efficiency of automobiles is not likely to be optimal. This is especially likely to be the case during and immediately after periods in which the other determinants of EFF have radically changed. For this reason, it is postulated that the attained efficiency of the automobile fleet can be modeled as a partial adjustment process. Accordingly, EFF lagged one period, EFF_{t-1}, is included as an explanatory variable. This approach is similar to that used by Balestra and Nerlove (1966) in their analysis for the demand of natural gas and of Kaserman and Mayo (1985) in their study of residential electricity. An alternative approach would be to model directly the depreciation of the fleet of automobiles, but these data are not readily available for all the years studied.

The expressions used to model the two components take the form

(4.2) $DIST = f(CST, Y, POP, CPOP, DIST_{t-1})$, and

(4.3) $EFF = g(P, Y, SPD, EPCA) + EFF_{t-1}$.

Complete definitions of the variables used are given in table 2. The wholesale price of gasoline is used, because data for national retail prices were unavailable for the time period studied, and wholesale prices are closely correlated with retail.

TABLE 2

DEFINITIONS OF THE VARIABLES USED IN ESTIMATING THE CONSUMPTION OF GASOLINE

Variable	Definition
DIST	The distance traveled by the U.S. automobile fleet, in hundreds of thousands of miles[1]
P	The real (1972 base) wholesale price of regular gasoline, weighted by sales between leaded and unleaded, in cents per gallon[1]
Y	The real (1972 base), personal disposable income of the U.S., in billions of dollars[2]
EFF	The average fleet fuel efficiency, in MPG, of all automobiles in the U.S.[1]
CST	The cost of driving, found by dividing P by EFF
SPD	A binary variable representing the imposition of the national 55 m.p.h. speed limit
CPOP	The number of registered cars per capita in the U.S.[3]
POP	The population of the U.S., in millions[4]
EPCA	The fuel efficiency standards for the automobile model years 1978 - 1982, in MPG[5]

[1]American Petroleum Institute, Basic Petroleum Data Book, vol. 3, no. 3, (New York: American Petroleum Institute, 1983).

[2]U.S., Federal Reserve Board, Federal Reserve Bulletin (1960-84).

[3]U.S., Department of Transportation, Highway Statistics (1960-83).

[4]U.S., Department of Commerce, Bureau of the Census, Current Population Reports (1960-83).

[5]Energy Policy and Conservation Act, Statutes at Large 89, 870 (1975).

For this study, annual, national data for the U.S. are used. To ensure accurate, consistent, and reliable data, the time period of 1958-1982 was chosen. For equation (4.2), the double-logarithmic functional form is used, as is common in demand studies. Equation (4.3), because of the nature of the derivation of the stock adjustment model, a semi-logarithmic form is used.[1] For the two equations, then, the following expressions are used for estimation:

$$(4.4)\quad \ln(DIST) = \beta_0 + \beta_1\ln(CST) + \beta_2\ln(Y) + \beta_3\ln(POP) + \beta_4\ln(CPOP) + \beta_5\ln(DIST_{t-1}) + e$$

$$(4.5)\quad EFF = \gamma_0 + \gamma_1\ln(P) + \gamma_2\ln(Y) + \gamma_3\ln(EPCA) + \gamma_4(SPD) + \gamma_5 EFF_{t-1} + u$$

Since this study may be thought as an extension of the work of Blair, Kaserman, and Tepel (1984), it is expected that the signs of the coefficients of the estimated equations should closely match theirs. That is, for equation (4.4), the income and population explanatory variables should have positive coefficients, and cost should have a negative coefficient. In a like manner, in equation (4.5), both the coefficients for price and income should be positive. The coefficients of the explanatory variables that do not appear in the Blair, et al., work, namely CPOP, $DIST_{t-1}$, SPD, EPCA, and EFF_{t-1}, are all expected to be positive, with the exception of SPD which, from first principles of physics, should be negative. The symbols e and u represent the error terms.

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[1]A linear estimation was also performed on equation (4.5) with insignificant differences in the results.

The equations were estimated using an ordinary least-squares algorithm developed by the author, on a Digital Equipment Corporation VAX 11/780, running on double-precision FORTRAN. The software was tested by comparing the results of an earlier study run on an International Business Machines 3081 computer, using Statistical Analysis System (SAS) software, to those run on the VAX. No difference was noted. The results of the estimations are given in tables 3 and 4.

For the equation estimating DIST, as expected, the coefficient of cost was negative, but surprisingly, so was the coefficient of income. Because the coefficients in this estimation represent elasticities of their respective variables with respect to DIST, one can quickly see which has the greatest impact on driving. In agreement with Wheaton's (1982) results, the number of cars per capita surpasses all the other variables in its effect on driving. For the equation estimating EFF, the most significant item is the statistical non-significance of the coefficient of the EPCA standards. Interestingly, the coefficient of income was also not statistically different from zero at the 10 percent level. The signs for all the statistically significant variables were as expected.

To determine whether the insignificance of the EPCA standards is influenced by deficiencies in this time-series model, two factors which affect the estimated variance -- serial correlation and multicollinearity -- were investigated. Since both equations (4.4) and (4.5) contain lagged dependent variables, the usual Durbin-Watson test for serial correlation is biased, and, therefore, inappropriate. Instead, the Durbin 'h' statistic is used. It has been shown (Durbin

TABLE 3

ESTIMATED COEFFICIENTS FOR THE EQUATION "ln(DIST)"

Variable	Estimated Coefficient	Standard Error	t-statistic
Constant	6.86	2.96	2.32
ln(CST)	-0.176	0.0492	-3.57
ln(Y)	-0.406	0.179	-2.27
ln(POP)	0.548	0.329	1.67
ln(CPOP)	0.870	0.335	2.59
$\ln(DIST_{t-1})$	0.522	0.161	3.24

$R^2 = 0.9970$; D.W. = 1.56; h = 1.85

TABLE 4

ESTIMATED COEFFICIENTS FOR THE EQUATION "EFF"

Variable	Estimated Coefficient	Standard Error	t-statistic
Constant	-4.58	2.97	-1.54
ln(P)	1.31	0.433	3.02
ln(Y)	0.0675	0.212	0.318
ln(EPCA)	0.0490	0.490	0.100
SPD	0.139	0.120	1.16
EFF_{t-1}	0.956	0.101	9.48

$R^2 = 0.9704$; D.W. = 2.80; h = 2.32

1970) that this statistic is approximately normally distributed, with a variance of unity. For equations (4.4) and (4.5), the values of 'h' are 1.85 and -2.32, respectively. At the 1 percent level, the critical values of the normal distribution are -2.575 and 2.575. Therefore, the null hypothesis of no serial correlation is accepted.

Multicollinearity can also affect the efficiency of the estimation. Multicollinearity describes the degree to which the independent variables affect each other, and the higher the degree of multicollinearity, the lower the efficiency of the estimation. To test for multicollinearity, the eigenvalues of the variance-covariance matrix are found after the independent variables have been scaled to unity; next, the square root of the first eigenvalue is successively divided by the square roots of the others; if none of these ratios exceeds thirty, then the degree of multicollinearity is small.[1] This procedure was follwed for the variables in this study, and none of the ratios exceeds the value of fifteen.

The determination of the price elasticity of gasoline is complicated by the fact that the consumption of gasoline given by equation (4.1) is a ratio, and that both DIST and EFF, in turn, are functions of price, via equations (4.2) and (4.3). In this case, price elasticity is given by

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[1]George G. Judge, W.E. Griffiths, R. Carter Hill, Helmut Lütkepohl, and Tsoung-Chao Lee, The Theory and Practice of Econometrics, 2nd ed., (New York: John Wiley and Sons, 1985), pp. 902-904.

(4.6) $e_P = \frac{P}{Q} \frac{\partial Q}{\partial P}$.

Therefore, the chain rule for differentiating a function is employed with the result that

(4.7) $e_P = \frac{P}{Q}\left[\frac{\partial Q}{\partial DIST}\frac{\partial DIST}{\partial CST}\frac{\partial CST}{\partial P} + \frac{\partial Q}{\partial EFF}\frac{\partial EFF}{\partial P}\right]$;

(4.8) $e_P = \frac{P}{Q}\left[\frac{1}{EFF}\frac{\partial DIST}{\partial CST}\left(\frac{1}{EFF}\frac{\partial P}{\partial P} - \frac{P}{EFF^2}\frac{\partial EFF}{\partial P}\right) - \frac{DIST}{EFF^2}\frac{\partial EFF}{\partial P}\right]$.

Simplifying,

(4.9) $e_P = \frac{CST}{DIST}\frac{\partial DIST}{\partial CST} - \left(\frac{CST}{DIST}\right)\left(\frac{\partial DIST}{\partial CST}\right)\left(\frac{P}{EFF}\right)\left(\frac{\partial EFF}{\partial P}\right) - \frac{P}{EFF}\frac{\partial EFF}{\partial P}$.

Note that the first and last terms are simply the elasticities of DIST and EFF with respect to CST and price, respectively, and that the middle term is the product of the aforesaid elasticities. Because equation (4.4) has a double-logarithmic form, the coefficient of CST is the cost elasticity of driving. To determine the price elasticity of fuel efficiency, the coefficient of price is divided by the average value of fuel efficiency.

As a result,

(4.10) $e_P = 0.252$.

The determination of the fuel-efficiency elasticity is done in a like manner. Again, using the definition of elasticity,

(4.11) $e_E = \frac{EFF}{Q}\frac{\partial Q}{\partial EFF}$.

Incorporating equations (4.2) and (4.3) into the above equation, and using the chain rule gives

(4.12) $e_E = \frac{EFF}{Q}\left[\frac{\partial Q}{\partial DIST}\frac{\partial DIST}{\partial CST}\frac{\partial CST}{\partial EFF} + \frac{\partial Q}{\partial EFF}\frac{\partial EFF}{\partial EFF}\right]$.

Rearranging terms one finds that

$$(4.13)\quad e_E = \frac{-CST}{DIST}\,\frac{\partial DIST}{\partial CST} - 1,$$

In numerical terms,

$$(4.14)\quad e_E = -0.824$$

Both of the above elasticities for price and efficiency are point elasticities.

Proceeding in a similar manner, one finds that, because efficiency appears in both equations (4.2) and (4.3), the income elasticity of gasoline demand is given by

$$(4.15)\quad e_Y = \frac{Y}{DIST}\left[\frac{\partial DIST}{\partial Y} + \frac{\partial DIST}{\partial CST}\left(\frac{-P}{EFF^2}\right)\frac{\partial EFF}{\partial Y} - \frac{DIST}{EFF}\,\frac{\partial EFF}{\partial Y}\right].$$

Rearranging and collecting terms,

$$(4.16)\quad e_Y = \frac{Y}{DIST}\,\frac{\partial DIST}{\partial Y} - \left(\frac{CST}{DIST}\,\frac{\partial DIST}{\partial CST}\right)\left(\frac{Y}{EFF}\,\frac{\partial EFF}{\partial Y}\right) - \frac{Y}{EFF}\,\frac{\partial EFF}{\partial Y}.$$

With the result that

$$(4.17)\quad e_Y = -0.409$$

The values obtained by Blair, Kaserman, and Tepel (1984) for the elasticities of price, efficiency, and income were -0.412, -0.703, and 0.278, respectively. With the exception of the income elasticities, these estimates are qualitatively similar. Possible reasons for the discrepancy are the different sizes of the samples (Florida vs. U.S.), the use of more recent data, and the wider range of disposable income in the present study. It is also possible that automobile driving is an inferior good compared to other forms of transportation, such as airplane travel.

Given the premise that a reduction of highway speed limits from a range of 65-75 miles-per-hour to 55 miles-per-hour would bring about considerable savings of gasoline, it is interesting to note that the results of this study indicate that the 1974 reduction in highway speed limits to 55 miles-per-hour caused no statistical increase in the average fuel efficiency of the U.S. car fleet. This could be due to the fact that most automobile travel is done within urban areas where the speed limits are much lower than those of highways.

It is also worth noting that, similar to the Wheaton study (1982), the results here indicate that gasoline consumption is highly sensitive to the number of cars per capita. The elasticity corresponding to this variable, 0.870, is larger than any other.

CHAPTER V

CONCLUSIONS

Given the results of this study showing that the CAFE standards have had no statistically perceptible effect on the level of fuel efficiency of the U.S. automobile fleet, it might seem that the Congress was foolish to impose mandatory fuel economy standards to reduce the dependence of the U.S. on imported petroleum, especially in light of some of the results of studies cited in this paper. But hindsight is usually better than foresight, and there was a great deal of uncertainty in 1974 regarding the best course of action to take. Besides, there was a precedent for forcing technological change upon reluctant U.S. automakers: the success of almost a decade of enforcing emissions laws. Moreover, the EPCA is a theoretical law -- it has never been enforced or challenged in court, and enforcement of the Act would be difficult because of the large statistical uncertainties associated with the EPA's measurement of fuel economy.

The serious shortcomings in the way in which the EPA measures CAFE raises the question as to whether the EPCA <u>is</u> enforceable. To take a realistic example, suppose that Ford falls short of the standard by one mile-per-gallon. According to table 2, located on page 10, the 95 percent confidence interval width for Ford is about 0.9 MPG. So, is the assessed penalty based upon a shortfall of 1.0 MPG or 0.1 MPG? Rabe (1979) has also shown that the EPA's measurement method is biased as well as inefficient, so that the true shortfall would be even more in doubt.

No domestic manufacturer has had to pay any penalties for failing to meet the CAFE standards, despite the fact that both General Motors and Ford Motor failed to meet both the 1983 and 1984 CAFE standards by substantial margins. It seems questionable whether any penalties will ever be assessed against a domestic manufacturer for falling short of the standards. Although the automakers could have challenged the EPCA in the courts, they, instead, lobbied the members of Congress for relief. In terms of public relations, it seems, it would be better to have the standards eased, rather than be penalized. The members of Congress, on the other hand, recognize the importance of the automobile industry to the U.S. economy, and would be loathe to be responsible for throwing thousands of workers out of their jobs just because the automakers could not make fuel efficient automobiles. Consequently, when it was apparent that General Motors and Ford would have trouble meeting the CAFE standards in the late 1970's, the Congress amended the EPCA to allow carryforward/carryback credits.

Even before the CAFE standards took effect, the fleet fuel efficiency was steadily increasing (American Petroleum Institute 1983) due partly to higher gasoline prices; it might be argued that had it not been for the large price increases for gasoline which occurred during the late 1970's, the CAFE standards would certainly have had an effect on the overall level of fuel efficiency. Although perhaps true, this argument ignores the alternative policy position of President Ford who advocated taxes and price decontrol at the same time the Congress was drafting the EPCA. The question of the effect of higher gasoline prices on the poor and disadvantaged was outside the realm of this study, and was a major concern of the committee (U.S. Congress 1975a) which drew up the EPCA. However, the counter-argument could be given that the Organization of Petroleum Exporting Countries reaped oil revenues from the U.S. which could have been used in benefiting the poor of the U.S.

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