A New Tax on Gasoline: Estimating Its Effect on Consumption

Abstract. *Based on extrapolation of a recent estimate of the elasticity of demand for gasoline, it is concluded that a tax of 5 cents per gallon per year over the period 1979 to 1988 can be expected to produce significant reductions in gasoline consumption, contrary to widely expressed opinions.*

In its year-long deliberations on energy legislation, Congress has shown little willingness to consider adding a tax to gasoline sales in order to reduce consumption. Many others undoubtedly agree with Senator Hayakawa, who said, "I do not believe a gasoline tax proposal will achieve the objective of conservation. . . . I believe a majority of Americans will continue to buy gasoline regardless of the price" (*1*).

My recent study of the changing patterns of gasoline consumption in California since the large price increase that followed the 1973 oil embargo provides a basis for estimating the effect that a future tax would have (*2*). In this report I give a short review of the methods and main results of that study and discuss some of the unfamiliar characteristics of the methodology used to measure elasticity. I then use the value of elasticity obtained therein to calculate the potential savings from a hypothetical new federal tax on gasoline. The reader who is specifically interested in the elasticity estimate should read (*2, 3*).

Elasticity estimate. In the study, the price elasticity of gasoline was calculated once for each of 24 months from April 1974 through March 1976, the "forecast interval," a period during which gasoline was readily available to the purchaser. The computation for any one month went as follows. First, a forecast was made of what the sales would have been if there had been no embargo and the dynamic mechanisms underlying the growth patterns of gasoline sales had continued unabated. This was done by using a Box-Jenkins seasonal-nonseasonal integrated moving-average model (*4*). The model had been derived to fit monthly sales over a 13-year period of growing consumption and decreasing real prices, 1960 to 1973, the "model-fitting interval" (*3*). Monthly forecasts were made for the forecast interval, using data up to and including October 1973, the last month of the "normal" pattern preceding the embargo. Next, the actual sales for the month, corrected for 3.09 percent savings (*5, 6*) due to slower freeway driving (the 55-mile-per-hour speed limit), were subtracted from the predicted sales to get the decrease in consumption, ΔC, attributable to price. This was divided by the predicted sales, C, to get the fractional decrease, $\Delta C/C$, for that month. The actual price in the same month, corrected for the inflation (*7*) that occurred since October 1973, was then compared to a forecast of what the real price would have been in the absence of an embargo (*8*). The forecast real price, P, was the price of October 1973, reduced by $^1/_{12}$ percent per month, reflecting a continuation of the trend in which the real price of gasoline dropped an average 1 percent per year over the model-fitting interval. This forecast price was consistent with the sales forecasts produced by the model. The difference ΔP between forecast real price and actual real price, divided by the former, gave the fractional change in price, $\Delta P/P$, for the month. The ratio of $\Delta C/C$ to $\Delta P/P$ gave the elasticity estimate E for the month. This process was repeated for each of the 24 months. No estimates of elasticity were made for the period November 1973 through March 1974 because gasoline was in short supply during that time.

The resulting 24 estimates of elasticity were plotted against time. A least-squares straight-line fit to these data had a slope of essentially zero, showing no major change in elasticity over the 24 months. The elasticity obtained was -0.2054, which is in line with estimates made by typical econometric methods, specifically the short-term elasticity of -0.07 to -0.14 and long-term ($2^1/_2$ year) elasticity of -0.24 to -0.32 of Verleger and Sheehan (*9*) and the short-term elasticity of 0.21 used in the Federal Energy Administration (FEA) model described by Hirst (*10, 11*). Hirst also cites a long-term value of -0.72 (the time period was not defined), which is numerically much larger than any effects I noted.

The Box-Jenkins model is dynamic. Without explicitly structuring the sources of growth, it captures the result of the processes of change acting during the model-fitting period, including the growth in population, the building of freeways and housing developments, changes in affluence, changes in the cost of gasoline relative to mass transit, and so on. Forecasts made with the model are valid to the extent that the same change processes, whatever they may be, continue over the forecast interval. The solid line of Fig. 1 shows the actual gasoline sales, and the dotted line shows the forecasts. Note that the forecasts capture the general upward trend of the 1960–1973 data and that the August 1975 forecast is the highest one. The yearly pattern, with dips in January and February and peaks in July and August, is also very well modeled. The model used is equivalent to fitting a 13th order difference equation to the underlying dynamic system. Loosely speaking, the forecasts are a representation of the system coasting under its own inertia, with zero values assumed for the unknown shocks in the forecast interval. The Box-Jenkins method also provides an estimate of the error in the forecasts, based on the residual errors over the model-fitting interval. In this case, the standard deviation of each monthly forecast is almost exactly 2 percent of forecast sales.

What the forecasts obtained by this method cannot capture (without outside help) are changes in sales that result from a change in the underlying process (a change in the structure of the dynamic

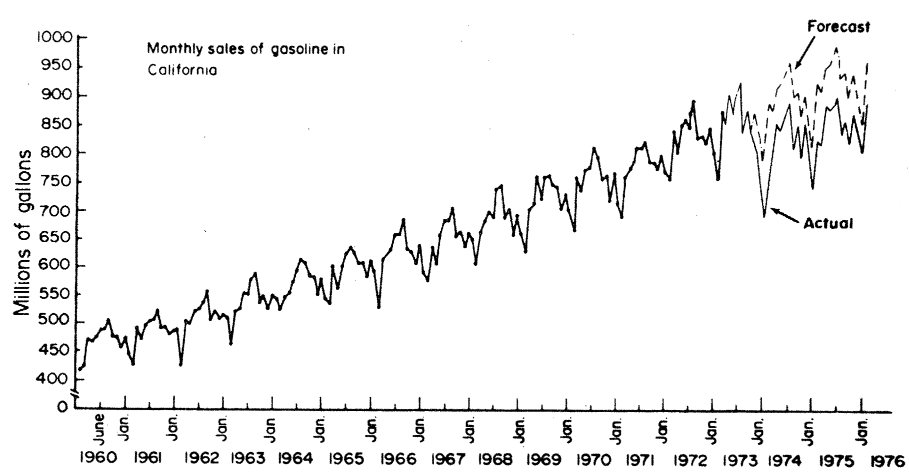

Fig. 1. Gasoline sales history in California for 1960 to 1976.

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system) during the forecast interval. For example, if a convenient, fast, zero-fare mass-transit system had been built in Los Angeles between November 1973 and March 1974, there could have been a major switch away from cars and a concomitant decrease in gasoline consumption not predicted by the model.

Looking over the forecast interval to ascertain the presence of such effects, I examined two possibilities. Of the average 7.8 percent drop in consumption, relative to what it would have been with stable prices, 3.09 percent was attributed to the lower driving speeds. This effect was fully corrected for, as described earlier.

The second effect was the possible decrease in gasoline sales due to (i) voluntary efforts following the President's pleas in 1974 to 1976 for energy conservation and (ii) the increase in unemployment in California that followed the embargo. This effect was not explicitly measured. Instead, a sensitivity analysis was performed in which it was found that a 1 percent decrease in gasoline sales due to voluntary conservation or unemployment, or both, would have revised the elasticity estimate to −0.1624. (The elasticity of −0.2054 corresponds to zero savings from voluntary conservation and unemployment.) However, the general lack of enthusiasm for the car-pool program (*12*), the public opposition to the ill-fated "diamond lane" experiment in Los Angeles (*13*), plus the suspicion on the part of many that there is no energy crisis (*14, 15*) strongly suggest that voluntary conservation contributed little, if anything, to the observed reductions in gasoline use. Although the savings due to voluntary conservation and unemployment may have been underestimated, it is even more likely that the savings due to the reduced speed limit have been overestimated. The latter savings, estimated in (*5, 6*) for 1974, were presumed to hold for 1975 and the first 3 months of 1976. However, most observers in California have noted that the freeway speeds have gradually edged upward above the speed limit (*16*). The net result is that if the elasticity is in error, it is probably numerically too small.

Table 1. Fuel economy standards for passenger cars (sales-weighted by manufacturer).

Model year	Miles per gallon*
1978	18.0
1979	19.0
1980	20.0
1981	22.0
1982	24.0
1983	26.0
1984	27.0
1985	27.5

*Data from (*24*)

The net reduction in gasoline consumption relative to what it would have been without the embargo, all other things remaining equal, was 4.78 percent (7.87 percent −3.09 percent). The real price rose between 18 and 30 percent, depending on the month, which is consistent with the averaged elasticity estimate of −0.2054.

Expected savings from a gasoline tax. Let us now consider the reduction in consumption that would be induced by a hypothetical new federal gasoline tax of the following form: 5 cents per gallon in 1979, increased 5 cents each year to 50 cents per gallon in 1988. [This tax is similar to that proposed in the President's original energy package (*17*).] The following extrapolations and assumptions are made. First, the value of elasticity found in California is applicable to the nation as a whole. Second, the value of elasticity, computed for conditions in 1974 to 1976, will continue to apply under the anticipated altered conditions of 1979 to 1988—that is, higher energy prices, inflation, new mass-transit routes, improved new-car fuel economy, and so on. Further, the elasticity, which was found to remain constant for 2 years following a major price increase, will remain constant for 10 years following a price change—that is, there is no 10-year elasticity that is larger than that found over 2 years. Third, the elasticity obtained for a maximum real price change of 30 percent will continue to hold for larger changes, up to as much as 100 percent.

These assumptions are discussed in order. First, the demand for gasoline may be more elastic in the nation as a whole than in California because there are no viable mass-transit alternatives for many Californians, and also because of the long commuting distances found here. Second, it may be, as many economists believe, that the long-term elasticity is numerically larger than the short-term value, but that more than 2 years must elapse for the long-term effect to be seen. This could be due, for example, to automobile owners continuing to drive gas guzzlers as long as they perform satisfactorily, but buying fuel-economy cars when it is time to replace them. Also, over the long term, substitutes may become more practical and technological change can take place. Third, this assumption is conservative, as it is usually thought that a large price increase is more likely to stir responses than a small increase. The net result of these assumptions, if anything, appears to be conservative, tending to bias the results in the direction of underestimating the effect of the tax; if the elasticity is numerically larger than 0.2054 for any reason, the tax will have a greater effect than that shown below.

I now consider the historic record and future projections of annual gasoline use in the United States. Gasoline consumption from 1958 to 1978, in millions of barrels per day, is shown in Fig. 2. (*18–21*). A forecast for 1978 to 1988 (curve 1) is obtained by extrapolating from 1977 at an annual 3.4 percent growth rate. This

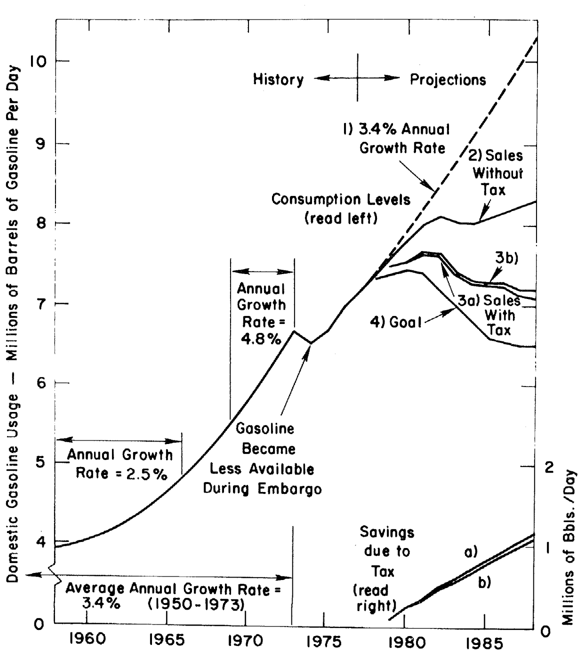

Fig. 2. Past and predicted future gasoline consumption in the United States.

is what consumption might be if no measures were taken to slacken its growth. It is the pattern of the past projected into the future. If anything, it is a low estimate of unrestricted growth, since the growth rate of the few years preceding the embargo was considerably higher than the 3.4 percent average growth rate of the 1950–1973 period. Curve 2 is an estimate, which I adapted from the PIES demand model of the Department of Energy (DOE), of what can be expected as a result of the automobile efficiency standards mandated by Congress and now existing in law (Table 1) together with expected gasoline price increases resulting from market actions, but otherwise no new legislative action. Curve 2 represents a significant decrease in consumption relative to curve 1.

Curve 4 in Fig. 2 is the year-by-year national goal established by President Carter in his energy proposal to Congress (*17*). It calls for 10 percent less gasoline consumption nationwide in 1985 than in 1977. A large gap remains between this goal and the best present forecast of future sales based on existing legislation.

How much additional conservation would the proposed tax stimulate? The elasticity is used to answer this question. Consumption without the tax is taken from curve 2. Price without the tax is extrapolated from the current average price for regular gasoline at full-service retail outlets, estimated [by extrapolating data from the last 4 years (*22*)] to be 66.5 cents per gallon. According to a DOE forecast (C forecast, middle values of supply and demand) the price will rise at nearly 1 percent per year, in 1978 dollars; at the highest, it may rise at an average rate of 1.93 percent (their F forecast, high import price) (*23*). Extrapolation using the two forecasts leads to 1988 prices of 73.5 and 80.5 cents per gallon without tax (123.5 and 130.5 cents per gallon with tax), respectively, bracketing the reasonably expected range of future prices. (Results obtained with lowest price forecast of DOE, their D forecast, are not significantly different from those obtained with the C forecast.)

The savings induced by the tax are shown by year in the lower right corner of Fig. 2. Curve a corresponds to the C forecast and curve b to the F forecast. When these savings are subtracted from the sales without tax, the results are curves 3a and 3b of Fig. 2. The savings induced by the tax are substantial; in 1988, for example, they amount to more than 1 million barrels per day, 14 percent of what would otherwise have been consumed. Futhermore, the savings are not very sensitive to the assumed future price without the tax. Thus, contrary to popular opinion, a tax of the kind proposed can be expected to provide a substantial reduction in gasoline consumption.

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7. For each month in the forecast interval, the actual price is deflated relative to the price for October 1973 by dividing by the ratio of the deflator for that month to the deflator for October 1973. The result is the "actual real price" relative to the price for October 1973. The quarterly implicit price deflators for the gross national product were obtained from *Survey of Current Business* (Department of Commerce, Washington, D.C., 1976), vol. 56, No. 1, p. 85; No. 4, p. 3.
8. It was assumed that personal income rose in proportion to inflation. Although this was not strictly true month by month, the real disposable income rose almost 2 percent from 1973 through the third quarter of 1976. Thus real income must have risen slower than prices at some times and faster at other times, approximately balancing out overall. The net effect on the elasticity estimate could not be appreciable.
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11. Alternatively, short- and long-term elasticities were calculated by making a least-squares estimate of β and γ in the dynamic consumption function $y_i = \beta y_{i-1} + \gamma x_i$, where x_i is the fractional change in price and y_i is the fractional change in consumption in month i. The results gave a long-term elasticity $\hat{\gamma}/(1 - \hat{\beta}) = -0.2007$ —essentially the same value; the system responds such that it has essentially reached its long-term value by the end of the fourth month following a step change in price. A copy of this analysis is available on request.
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9 September 1977; revised 1 August 1978

S-Adenosylhomocysteine Hydrolase Is an Adenosine-Binding Protein: A Target for Adenosine Toxicity

Abstract. *When adenosine deaminase activity is inhibited, low concentrations of adenosine are toxic to human lymphoblast mutants that are unable to convert adenosine to intracellular nucleotides. In order to identify the mediator of this cytotoxicity, we searched for a cytoplasmic protein capable of binding adenosine with high affinity. Such a protein was identified in extracts of human lymphoblasts and placenta as the enzyme* S*-adenosylhomocysteine hydrolase.*

The toxicity of adenosine to cultured mammalian cells, first described in the early 1960's (*1*), is now of interest largely because of its possible role in causing the severe combined immune defect in children with autosomal recessive deficiency of adenosine deaminase (ADA; E.C. 3.5.4.4) (*2*). Beyond relevance to this specific condition, study of this phenomenon with inhibitors of ADA activity has led to recognition of unexpected interrelationships between aberrant adenosine metabolism and several other metabolic processes. Thus when ADA is blocked, adenosine can induce pyrimidine starvation in cultured cells (*1, 3-5*), can increase adenosine 3',5'-monophosphate (cyclic AMP) concentrations (*6*), and can interfere with *S*-adenosylmethionine–dependent methylation (*7*) and with the hexose monophosphate pathway of carbohydrate metabolism (*8*). Deoxyadenosine, also a substrate for ADA, has long been known to inhibit DNA synthesis in cultured mammalian cells after conversion to deoxyadenosine 5'-triphosphate, an allosteric inhibitor of ribonucleoside diphosphate reductase (*9-14*). Which of these mechanisms contributes to the immune deficit in ADA-deficient children is still unknown.

In an attempt to identify an intracellular mediator of adenosine toxicity, we searched directly for a protein capable of binding adenosine with high affinity. Two lines of reasoning led to this approach. First, it appears that only small amounts of adenosine may be generated by cultured human lymphoid cells (*15*), and very little adenosine has been found in the plasma and urine of ADA-deficient children (*16*). Indeed, some have proposed that adenosine itself plays no role in causing the immune dysfunc-

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