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Potential Effect of Transport Fuel Price Increases on Energy Consumption

*by Joyce Mehring**

THIS PAPER presents estimates of the fuel price elasticity for gasoline, jet fuel and diesel fuel use in the transport sector.[1] Estimates are obtained from two sources: econometric models of transport fuel consumption and estimates derived using elasticities of transport demand on modes consuming the fuel. These latter estimates account for the effect of fuel price on average fuel used per mile by the fleet as well as the effects on fare and load factor. Auto and truck transport are the principal modes considered in developing estimates of gasoline price elasticity, truck and rail for diesel price elasticity, and passenger air service for jet fuel elasticity.

The most reliable price elasticity estimates presented are for gasoline. Greater confidence can be attached to estimates of short-run elasticity than to long-run.

The estimates developed in this study suggest that the most significant impact in the short run on the transport sector will result from gasoline price changes. Two factors are at work: gasoline accounts for about three-fourths of the fuel consumed in the transport sector and the short-run price response of gasoline is more elastic than those of jet or diesel fuel. In the long run, gasoline appears to be the fuel which will most significantly affect energy consumption, although jet fuel consumption is also expected to respond to price increases. Diesel fuel consumption will not respond significantly to price increases in either the short or long run: fuel cost is a small portion of total truck and rail operating costs and the diesel engine is relatively fuel efficient.

INTRODUCTION

The sensitivity of fuel consumption to fuel price changes is a topic of interest to policy makers involved with transport fuel conservation. While a variety of conservation tools are available (e.g., vehicle excise taxes, mandatory performance standards for new vehicles, speed limit decreases, parking taxes and the like), economists are in general agreement that conservation policies which make use of the pricing system, where they are feasible, are more efficient than rationing or prohibitionary schemes. Non-price policies may be preferable on other grounds, such as equity and administrative feasibility.

Therefore, estimates of the response of transport energy consumption to fuel price increases are desired both to evaluate the potential for energy conservation of price policies and to predict the effect of price changes occurring for other reasons. Of particular interest are the price elasticities of consumption for gasoline, jet fuel and diesel fuel, the three major fuels consumed in the transport sector (accounting for 76, 9, and 11 percent respectively of transport energy consumption in 1972 as shown in Table 1).

Most of the prior research on transport fuel price elasticities concerned gasoline. Several models that estimate gasoline consumption as a function of gasoline price and other variables provide direct estimates of fuel price elasticities. However, long-run elasticities of gasoline consumption have varied widely from model to model. Other studies have used urban travel demand models as a major component in deriving gasoline fuel price elasticities in urban areas. There has been little prior research on price elasticities for jet and diesel fuels. This paper presents estimates that synthesize and extend this prior research using available studies.

METHOD OF DEVELOPING ESTIMATES OF FUEL PRICE ELASTICITIES

Fuel price elasticities from two sources are considered. Estimates implicit in econometric models of transport fuel consumption are used as are estimates developed using elasticities of travel demand. In this latter approach, the elasticity of fuel consumption for a particular mode is expressed as a composite of elasticities of demand for transportation on the mode and other elasticities affecting fuel consumption. Short-run elasticities (the response to fuel price change when the stock of ve-

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TRANSPORT FUEL CONSUMPTION, TOTAL NON-MILITARY 1972

Fuel Type	BTU's ($x10^{12}$)	% BTU's Total	
Gasoline (includes			76
Passenger	12104	63	
Freight	10092	13	
Aviation Gasoline	46		
Passenger	46	.3	
Freight			
Diesel	1760		11
Passenger	83	.6	
Freight	1677	10.4	
Jet Fuel	1475		9
Passenger	1278	7.8	
Freight	197	1.2	
Residual Oil	490		
Passenger			3
Freight	490		
Electricity	99		.6
Passenger	11	.07	
Freight	88	.53	
TOTAL	15974		99
Passenger	11510	72	
Freight	4464	28	

SOURCE: Calculated from data in Tables C-1, D-8, and E-1 in FEA *Project Independence Blueprint: Project Independence and Energy Conservation Transport Sectors*, Washington, D.C., November 1974, and BTU content in FEA *Monthly Energy Review*, July 1975. (A BTU content of 4.674 million BTU/barrel was used for aviation gasoline).

TABLE 1

hicles remains fixed) and long-run elasticities (the response when composition, technology and size of the vehicle fleet have been adjusted optimally) are both considered. The primary type of fuel price change considered is one in which the price of only one fuel changes. For example, a gasoline price elasticity is derived assuming only gasoline price changes; diesel, jet and other fuel prices remain constant. This approach could overestimate the fuel reduction. However, in carrying out the analysis, short-run elasticities are not significantly affected by changes in other fuel prices because of small cross-elasticities of demand between modes using competing fuels. In the long run, the relative prices of gasoline and diesel fuel would affect the relative attractiveness of gasoline and diesel technologies and hence consumption. These potential effects are best evaluated by simulating alternative fuel price scenarios.

PRICE ELASTICITIES FROM ECONOMETRIC MODELS OF FUEL CONSUMPTION

There are a number of models that describe gasoline consumption in the transport sector as a function of fuel prices. In some cases, these models describe the consumption of gasoline by both cars and trucks. In other cases, an attempt is made to estimate auto gasoline consumption alone. The published literature does not, however, contain such models for diesel and jet fuels.

The gasoline consumption models were reviewed[2] with regard to their structure and the statistical properties of their estimates. The short-run elasticities were found to be consistent and a high degree of confidence is attached to these estimates—most of the short-run elasticities considered are significant at the .01 level. The long-run elasticities vary considerably among models. Because of the difficulty of estimating the long-run response of fleet composition and fleet fuel consumption, the same level of confidence was not attached to the long-run estimates.

PRICE ELASTICITIES DERIVED USING TRAVEL DEMAND MODELS

Gasoline and diesel and jet are the principal fuels used in transportation modes. Gasoline is used primarily by autos and trucks, diesel by truck and rail, and jet fuel by passenger and cargo air service. The potential impact on energy consumption of fuel price changes depends both on the price elasticity for the fuel on each mode using it and the percentage of total transport fuel consumed by the model.

When several modes use the same fuel the change in that fuel's consumption is the sum of changes in each mode. Thus an elasticity for the total consumption is estimated as a weighted average of the elasticities on each mode.[3] For example, to derive the gasoline price elasticity using travel demand models, the gasoline price elasticity of each mode using gasoline is estimated. These estimates, multiplied by the fraction of gasoline consumed by the mode, are then summed to provide the estimate of gasoline price elasticity for transport use.

To develop the fuel price elasticity for a transport mode, various elasticities of transport supply and demand are combined. While a general expression for fuel price elasticities is quite complicated, the expression necessary to approximate the fuel price elasticity for a mode is usually fairly simple because many of the values used in the expression are zero or negligible.[4] The factors in the expression include:

- Elasticity of passenger (or ton) miles on the mode with respect to fare (or rate) per mile of travel on the mode and on competing modes;
- Elasticity of passenger (or ton) miles on the mode with respect to load factors on the mode and on competing modes;
- Elasticities of gallons per mile of the vehicle fleet for both own and competing modes with respect to fuel price;
- Elasticities of load factor for both own and competing modes with respect to fuel price;
- Elasticities of fare (or rate) for both own and competing modes with respect to fuel price;
- Elasticities of cost or fare for both own and competing modes with respect to output level.

Basically, the fuel price elasticity of fuel consumption on a mode consists of components of three types describing effects of fuel price changes. One describes changes in average gallons per mile consumed by the vehicle fleet due to changes in operation or technology of the fleet; another, changes in vehicle miles traveled on the mode as a result of changes in the cost or service quality of traveling on the mode; the other, changes in vehicle miles traveled due to changes in cost or service quality on competing modes. Changes in vehicle miles result, of course, from a variety of factors—changes in occupancy rate, changes in passenger (ton) miles traveled, changes in average length of trip.

Short- and long-run fuel price elasticities for a mode are evaluated by specifying values for the above elasticities that describe short- and long-run adjustments. For example, short- and long-run elasticities of passenger (or ton) miles with respect to fares should be used when available, reflecting in the long-run changes such as residential or business location. In the short run, the elasticity of average fuel consumed per seat mile reflects changes in vehicle operations, in the long run it reflects changes in the technology of the vehicle fleet.

Values for these elasticities were taken directly or derived from published studies with one exception, we estimated intercity passenger travel demand elasticities. The elasticities of travel demand with respect to fare were selected from published travel demand models[5] and the intercity model estimated in this study. Most of the selected elasticities were developed or taken directly from parameters of econometric models that were known to be significant at least at the .05 level. The other elasticities were derived, when possible, from available data; otherwise, an attempt was made to evaluate the magnitude of the elasticities. For example, the elasticity of average gallons per mile consumed by the fleet was estimated for autos by using data on speed reductions for short-run estimates. For long-run estimates, we used technology assessment studies. For long-run diesel and jet fuel consumed per vehicle or seat mile, only order of magnitudes were established because of the quality of the data. Since these derived estimates are not statistical estimates, but developed from actual data, there are no statistical confidence intervals associated with them. Because of differences in the quality of data, the certainty attached to the derived elasticities varies. In general, the data for short-run estimates are better than for long-run estimates and the data for auto elasticities better than that for other modes. As a result of the quality of the data and the statistical properties of the travel demand estimates, the most reliable fuel price elasticities developed using travel demand models are those for gasoline. Also, we have greater confidence in short-run than long-run elasticities.

IMPACT OF PRICE CHANGES ON TRANSPORT FUEL CONSUMPTION

The Short Run

Of the three fuels considered, gasoline consumption is most responsive to fuel price changes in the short run.[6] With a great deal of confidence we estimate short-run gasoline elasticities at 1975 price levels to be in the range [–.15, –.36] likely falling between –.2 and –.3.[7] Jet fuel prices exhibit the next largest short-run response. While our confidence about the jet (and diesel) fuel elasticities is not as great as for the gasoline estimates, we find the short-run elasticity of jet fuel at 1975 price levels likely to fall in the range [–.10, –.25].[8] The estimate for the short-run diesel price elasticity is significantly smaller than either gasoline or jet fuel, falling in the range [–.02, –.08]. Thus, the potential for reduction in each of the fuels as a result of price policies is small, and for diesel fuel, negligible in the short run.

These short-run elasticities reflect primarily decreases in vehicle miles traveled as a result of the fuel price increases. In only a few cases, do we find short-run changes in average gallons of fuel consumed by the fleet: in intercity auto travel, some speed re-

PRICE ELASTICITIES OF FUEL CONSUMPTION

	Short Run		Long Run	
Gasoline Fuel	Auto	Truck	Auto	Truck
1972 Price Level ($.361/gallon)	(–.15, –.36)	(–.10, –.21)	(–.17, –1.01)[1]	N.E.
1975 Price Level[2] ($.445/gallon in 1972 dollars)	(–.16, –.39)	(–.11, –.22)	(–.17, –1.01)	N.E.
Jet Fuel				
1972 Price Level ($.114/Gallon)	(–.07, –.25)		(–.51, –.99)B	
1975 Price Level[3] ($.222/Gallon in 1972 dollars)	(–.13, –.35)[4]		(–.54, –1.12)B	
Diesel Fuel	Truck	Rail	Truck	Rail
1972 Price Level ($.282/Gallon)	(–.02, –.08)	(–.02)	(–.02, –.48)B	(–.02, –.41)B
1975 Price Level[5] ($.412/Gallon in 1972 dollars)	(–.01, –.09)	(–.09)	(–.01, –.49)B	(–.02, –.43)B

1 Expect result near upper end of bound in the current time frame.
2 Based on 25 percent increase in real fuel price.
3 Based on 100 percent increase in real jet fuel prices over 1972.
4 Elasticity is probably closer to —.18 than —.35 because of increases in all costs of supplying transportation, i.e., labor, etc.
5 Based on 50 percent increase in real diesel fuel price.
B—This range describes the magnitude of the elasticities, but there is insufficient data to develop a good estimate.
N.E.—This means not estimated.

TABLE 2

duction is justified for fuel price increase; in intercity air travel, adjustments in capacity and operations results in some increase in gallons per mile of fuel consumed. However, even for jet fuel the major short-run change is attributed to effects of fare increases resulting from fuel price increases. The relative magnitudes of these short-run fuel price elasticities results largely because of the different portion of total costs accounted for by fuel costs. Fuel costs for auto travel are approximately 47 percent of short-run costs per mile and 23 percent of fully allocated costs per mile; for jet aircraft, fuel costs are approximately 9.4 percent of revenues per seat mile; for truck, fuel costs are only 4.2 percent of revenues per ton mile and for rail 3.2 percent of revenue per ton mile. Thus although the cost elasticity of auto travel used in developing fuel price elasticities is less the price elasticity estimate for other modes, the cost structure determines their relative magnitudes.

The Long Run

There is a great deal of uncertainty about the long-run estimates developed here. Of the estimates for the various fuels, the most reliable are for gasoline price elasticity which we expect to fall in the range [–.7, –1.0].[9] This price response is significant from a policy making viewpoint.

The values for long-run estimates for jet and diesel fuel are rough bounds, the jet fuel elasticity [–.54, –1.12] is of a similar order of magnitude to gasoline fuel elasticity. The diesel fuel elasticity is smaller, of the order of [–.02, –.47]. The certainty of these elasticities could be improved by assessment studies that establish breakeven fuel prices for various technologies. Based on the available information on jet technology, the response of jet fuel consumption to fuel price increases appears significant.

Two determinants of long-run fuel price elasticities are the elasticity of average gallons per vehicle mile of the fleet and the cost or rate elasticity of vehicle miles traveled on the modes. The dominant factor is the former; the latter is of the same order of magnitude as the short-run rate elasticity of vehicle miles, considerably smaller than the long-run elasticity of average gallons per mile. In particular, the long-run elasticity of average gallons per vehicle miles for autos is estimated, from technology assessment studies, to be as elastic as –.9. For jet and diesel fuel, comparable technology assessment studies containing breakeven fuel prices were not available, hence there is a great deal of uncertainty associated with the

ELASTICITIES OF ENERGY CONSUMPTION
(1972 Price Level)

	Transport Energy Consumption		Total Energy Consumption	
	Short Run	Long Run^B	Short Run	Long Run^B
Gasoline	(–.11, –.27)	(–.12, –.76)[1]	(–.03, –.07)	(–.03, –.19)
Jet Fuel	(–.005, –.017)	(–.036, –.069)	(–.001, –.004)	(–.009, –.017)
Diesel Fuel	(–.002, –.009)	(–.002, –.054)	(–.001, –.002)	(–.002, –.014)

1 This estimate is based on estimates for auto consumption only.

TABLE 4

long-run estimates elasticity of average fuel consumption per seat mile of (–.47, –.72) for jet fuel and of –.4 for diesel technologies. The important point is that the long-run fuel reduction results from changes in technology, not changes in travel behavior, and that, in comparison, reductions in consumption through changes in travel patterns is small.

SUMMARY

To summarize, we note that diesel fuel price increases would have a negligible effect on diesel consumption in the short run. Jet fuel and gasoline have a somewhat larger but fairly small elasticity in the short run. In the long run, significant response in gasoline and jet fuel consumption could result from fuel price increases. The potential impact on diesel fuel is substantially less.

For example, if gasoline consumption is 100 billion gallon per year, and diesel consumption 15 billion, a 10 percent price increase over 1975 prices would bring a short-run reduction in expected gasoline consumption of 1.5 to 3.6 billion gallons per year and a diesel consumption of about .045 billion gallons. In the long run, a 10 percent increase in gasoline prices should reduce consumption by 10 billion gallons per year.

IMPACT ON ENERGY CONSUMPTION

While the preceding section puts in perspective the changes in consumption of different fuel types to be expected from price increases, it is also of interest in judging policies to investigate the impact of the price changes on total transport energy consumption and total energy consumption. Since diesel and jet fuel account for small portions of transport energy consumption relative to gasoline (11, 9 and 76 percent respectively), the elasticity of transport energy consumption for gasoline prices is significantly greater than that for either jet or diesel fuel.

As indicated in Table 4, the elasticity of short-run transport energy consumption is negligible for both jet and diesel fuel, with the elasticity of jet fuel less elastic than –.02, and diesel fuel less elastic than –.01. While gasoline has an elasticity of less than |–.3|,[10] it is significantly more elastic than the other two fuels. In the long run, the same relationship holds, the principal response in transport energy consumption is in the gasoline sector where the elasticity is up to ten times that with respect to either jet or diesel fuel consumption.

Since transportation energy consumption is about 25 percent of total energy consumption, the effect of transport fuel price increases on total energy consumption is quite small. As noted in Table 4, short-run elasticities for gasoline are less than |–.2|. For diesel and jet fuel short-run elasticities are less than |–.01| and long-run elasticities less than |–.02|.

FOOTNOTES

1 This paper is based on research carried out at Charles River Associates, Incorporated for the Federal Energy Administration.

2 Among the models reviewed are:

Burright, Burke and Enns, John, "Econometric Models of the Demand for Motor Fuels," Rand Corporation, April 1975.

Charles River Associates, Incorporated, The Effect of Automotive Fuel Conservation Measures on Automotive Air Pollution, report prepared for the Environmental Protection Agency (November 1975).

Data Resources Incorporated, A Study of the Quarterly Demand for Gasoline and Impacts of Alternative Taxes, report prepared for the Environmental Protection Agency and the Council on Environmental Quality (Lexington, Mass.: December 1973).

Robert McGillivray, "Gasoline Use by Automobiles," Urban Institute Working Paper 12126-2, August 1974.

3 The expression for the own fuel price elasticity for energy consumption for transport fuel F used on N modes is:

$$\eta^{E_F}_{P_F} = \sum_{K=1}^{N} \frac{E_K}{E_F} \eta^{F_K}_{P_F}$$

where

E_F = the total energy content of fuel F in transport uses. Note $E_F = e_F F$ where e_F is the energy content (BTU's) unit of fuel F measured in gallons;

F_K = the gallons of fuel F consumed on mode K;

E_K = the energy content of fuel F used on mode K;

P_F = the price of fuel F;

$\eta^{F_K}_{P_F}$ = the fuel price elasticity of the fuel F consumed on mode K;

$\eta^{E_F}_{P_F}$ = the fuel price elasticity of energy consumed by fuel F in the transpor…

4 For example, to evaluate short-run elasticities of auto gasoline consumption using travel demand models, we use the following expression

$$\eta^{E_M}_{P_G} = \eta^{G_M}_{P_G} + \eta^{VM_M}_{C_M} (\eta^{C_M}_{P_G} + \eta^{C_M}_{G_M} \eta^{G_M}_{P_G}) \quad \text{or}$$

$$\eta^{E_M}_{P_G} = \eta^{G_M}_{P_G} + (\eta^{D_M}_{C_M} + (\eta^{D_M}_{L_M} - 1)\eta^{L_M}_{C_M}) (\eta^{C_M}_{P_G} + \eta^{C_M}_{G_M} \eta^{G_M}_{P_G})$$

where the terms in the expression are all elasticities. $\eta^{E_M}_{P}$ is the gasoline price elasticity of gasoline consumption by autos. The variables in the expression are E_M, energy consumption of gasoline by autos; P_G, price per gallon of gasoline; G_M, average gallons per mile consumed by the auto fleet; VM_M, auto travel demand measured in vehicle miles; C_M, short-run marginal cost of auto travel per vehicle mile; D_M, auto travel demand measured in passenger miles; L_M, average occupancy of the vehicle or the ratio of passenger miles to vehicle miles.

5 The studies reviewed included:

Urban Travel Demand

Adler, Thomas J. and Ben-Akiva, Moshe, "A Joint Frequency, Destination and Mode Choice Model for Shopping Trips," MIT Department of Civil Engineering, 1974.

Charles River Associates, Incorporated, A Model of Urban Passenger Travel Demand in the San Francisco Metropolitan Area (Cambridge, Mass.: Charles River Associates, 1967).

Charles River Associates, Incorporated, "A Disaggregated Behavioral Model of Urban Travel Demand," report submitted to the Federal Highway Administration, March 1972.

McFadden, D., "The Measurement of Urban Travel Demand," Journal of Public Economics 3 (1974).

Intercity Passenger Travel Demand

Brown, Samuel and Watkins, Wayne S., "The Demand for Air Travel: A Regression Study of Time-Series and Cross-Sectional Data in the U.S. Domestic Market," Highway Research Record No. 213 (Washington, D.C.: Highway Research Board, 1968), pp. 21-34.

Lave, Lester B., "The Demand for Intercity Passenger Transportation," Journal of Regional Sciences, Vol. 12, No. 1 (April 1972), pp. 71-84.

Systems Analysis and Research Corporation. Demand for Intercity Passenger Travel in the Washington-Boston Corridor (Cambridge, Mass.: SARC 1963).

Intercity Freight Demand

Morton, Alexander, "A Statistical Sketch of Intercity Freight Demand," prepared for the Annual Meeting of the Highway Research Board, January 1969.

Perle, Eugene D., "The Demand for Transportation. Regional and Commodity Studies in the United States," University of Chicago, Department of Geography, Research Paper No. 95 (Chicago, Illinois: University of Chicago Press, 1964).

6 See Table 2 for estimated ranges of fuel price elasticities derived from travel demand models.

7 As indicated in Table 3 between 1972 and 1975 gasoline price increased approximately 24 percent in 1972 dollars. With this fuel price and with other costs constant, the elasticity increases slightly but not significantly. If other costs increase disproportionately, the elasticity increase will not be as great.

8 These elasticities are less than those given in Table 2 for 1975 price levels. We expect the upper bound presented there would overestimate the elasticity since it reflects some short-run adjustments in average fuel consumed per mile which could be achieved only in the initial adjustment to fuel price increases.

9 The upper range of the elasticities presented in Table 2 are applicable since the new technologies with reduced fuel consumption have not yet been adopted.

10 That is, the absolute value of the elasticity is less than .3, or in other words, the elasticity likely falls in the range [—.3, 0].