PRICE INCENTIVES FOR FUEL SWITCHING: DID PRICE DIFFERENCES SLOW THE PHASE-OUT OF LEADED GASOLINE?

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Price Incentives for Fuel Switching:

Did Price Differences Slow the Phase-Out of Leaded Gasoline?

by

Severin Borenstein*

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Abstract: In the U.S., the regulatory approach to automobile fuel choices has consisted almost exclusively of mandated changes in autos and fuel availability. This contrasts with Europe, where differential taxes and fees have been used to encourage the use of unleaded gasoline and diesel fuel. In this paper, I use data for 48 states from 1980 to 1989 to estimate the effect of price differences between leaded and unleaded gasoline on the rate at which leaded gasoline was abandoned. The estimates imply that a five cent additional tax on leaded gasoline may have caused a two-year acceleration in its phaseout and a ten cent tax may have caused leaded gasoline to virtually disappear by 1987, when it was still more than 20% of the gasoline supply.

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costs in the early and mid 1980s, and price discrimination in favor of leaded gasoline throughout the decade, resulted in higher prices for unleaded than for leaded gasoline.[1]

This paper examines the effect of price differences between leaded and unleaded gasoline during the 1980s on the rate at which leaded gasoline was phased-out of the U.S. automobile fuel market. In doing so, I attempt to shed light on the potential for tax policies to augment administrative approaches to implementing future automobile fuel policy.

II. Price Differences and Consumer Fuel Choices

Was the price difference between leaded and unleaded gasoline large enough during the 1980s for an effect on fuel switching to be statistically discernible? As a share of total operating costs, the fuel cost difference was small. If the total operating cost of an automobile averaged 25¢ per mile – the IRS-allowed operating cost in 1989 – and the average automobile was driven 10,000 miles per year (about the U.S. average), then the total annual operating cost was $2500. If that automobile averaged 20 miles per gallon, and thus purchased 500 gallons per year, then the average price difference during the 1980s of 6 cents per gallon (all monetary figures in constant 1989 prices) implied an operating cost difference of $30 per year, or 1.2% of total operating cost. If consumers, however, are more cognizant of or informed about differences in frequent and repeated costs than differences in less frequent expenses – *e.g.*, differences in costs of tune-ups, parts replacement, etc.– then the fuel price difference could carry greater weight.

Equally important for estimation of a price difference effect, the cross-sectional and time series variation in price differences between leaded and unleaded gasoline were substantial during the 1980s. Figure 1 shows the U.S. average retail price difference between unleaded and leaded gasoline ($PDIF$) for January of the years 1980 to 1989, and the high-low variation across states in each year. Average retail price differences peaked at about

[1] See Borenstein, 1991, for an analysis of price discrimination at the retail level against buyers of unleaded gasoline. Shepherd, 1991, also studies gasoline price discrimination, focusing on full-serv/self-serve price differences.

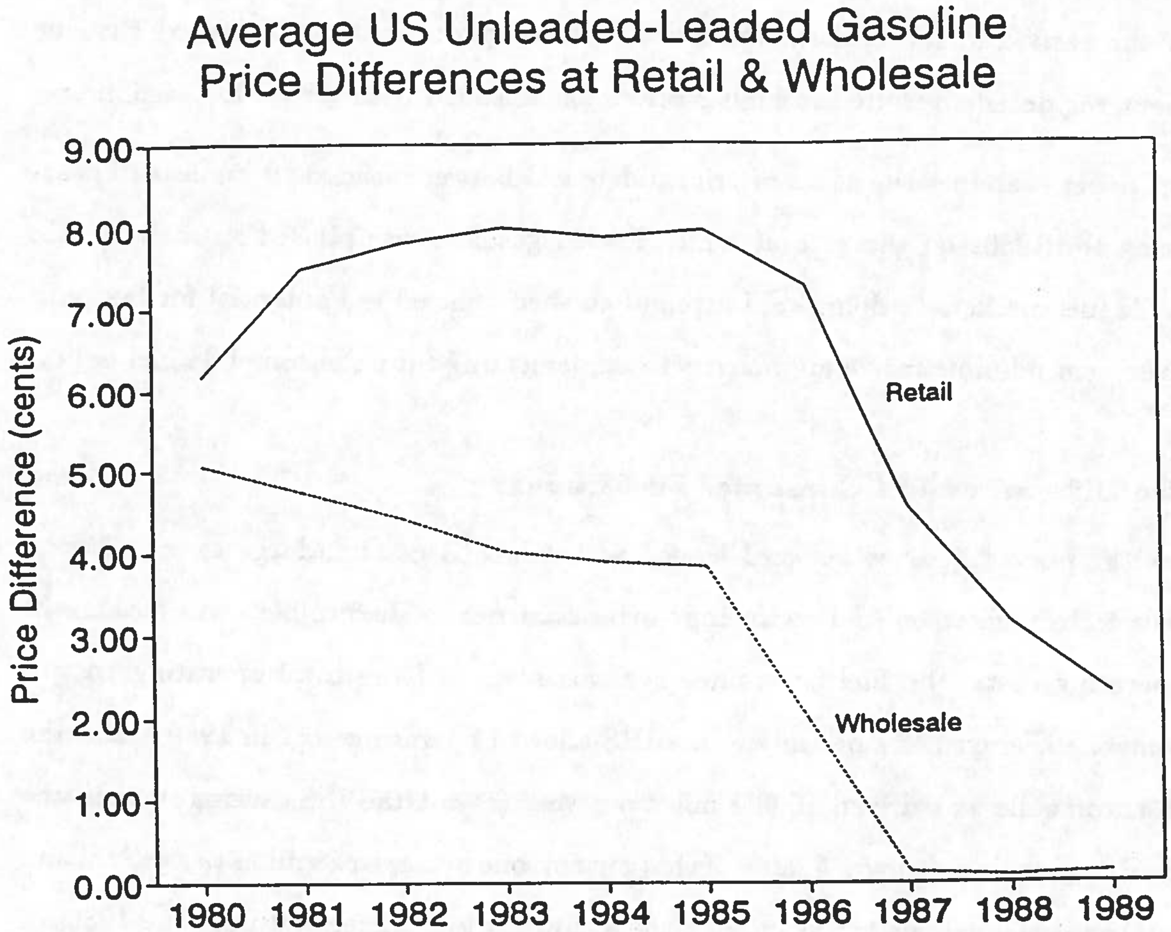

Figure 2

stock, including the preferred fuel for the automobiles chosen. Of course, many factors other than relative fuel prices – all of the characteristics of the possible automobiles that could be chosen – will also affect both the long-run and the short-run decisions.

In the short run, the choice of fuels can be altered by substituting among vehicles that are designed to take different fuels or by substituting fuels within a given auto. The former would occur if the consumer owned cars designed for the different fuels, leaded and unleaded gasoline, and decided which car to use in part based on the relative cost of their fuels. The latter would occur if the consumer could substitute fuels within a given auto. Such substitution was rare in the case of unleaded and leaded gasoline. Leaded regular gasoline was less expensive and had a higher octane level – which improves performance and

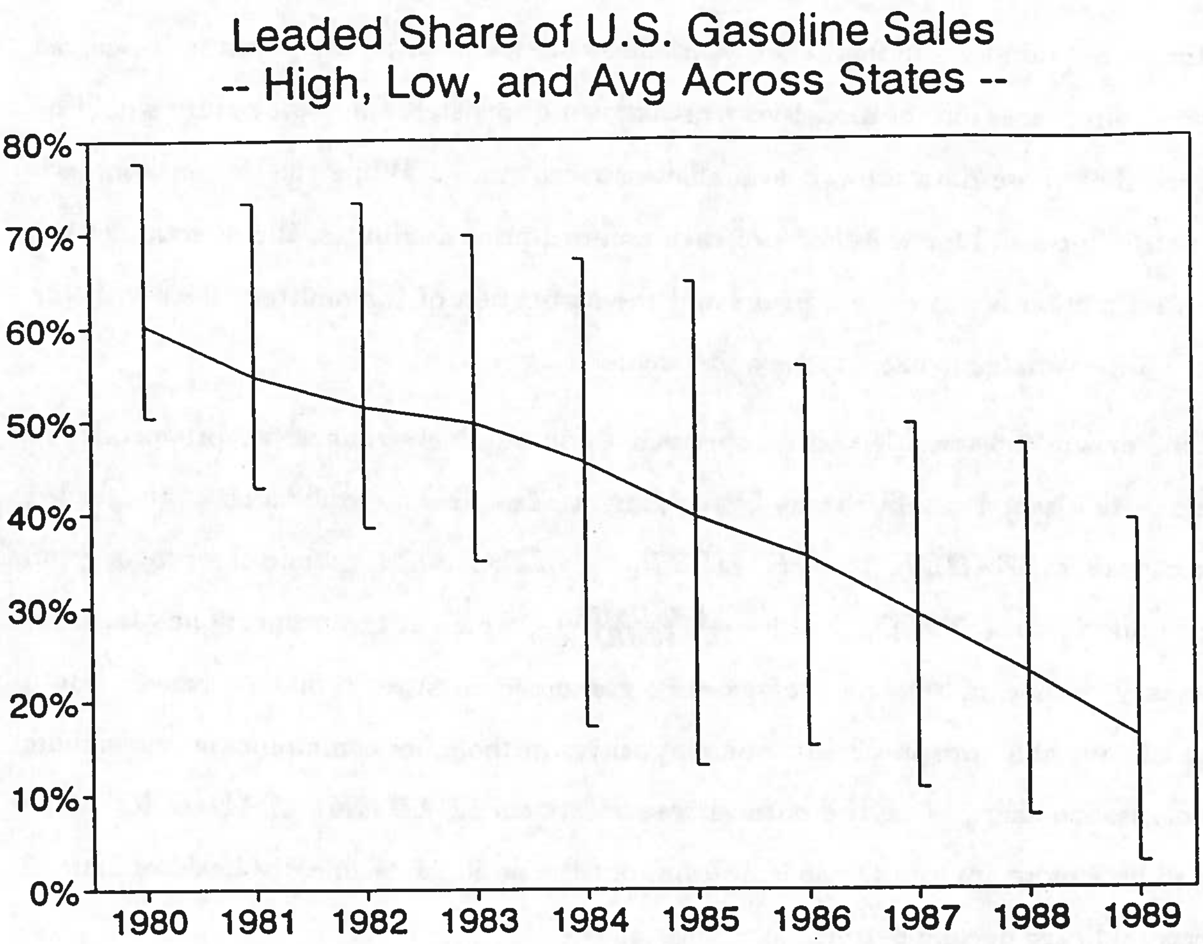

Figure 3

from the the Department of Energy's (DOE's) *Petroleum Marketing Monthly* and a study by Ethyl Corporation.[2] Figure 3 shows the leaded gasoline share of total gasoline sales (*LEADSHR*) in the U.S. for the 1980s, as well as the high-low variation across states.

The most accurate price data and the longest time series of prices is from Lundberg Survey, but these data, unfortunately, are collected by city, not state. The 65 cities surveyed cover 48 states, though not all cities are surveyed in all years. For those states in which only one city was surveyed in a given January, the city price was taken as representative for the state. For those states in which more than one city was surveyed, a

[2] The DOE source exists for 1983-89. Volume data for earlier years are from the Ethyl Corporation study. The two series overlap in 1983 and are highly correlated in that year.

over time more rapidly.[5] In fact, fixed year effects are found to be significant, as discussed below. A direct measure of model-year breakdown of registered autos by state would be preferred, but those data are not available for most states. While the chosen approach does not fully control for the effects of such non-fuel-price attributes, the direction of the bias in estimation is not clear *a priori* and the correlation of the omitted effect with the relative price variable is likely to be quite small.

The dependent variable can be specified as alternatively a linear or proportionally decline in the leaded gasoline share of the market. The linear specification of the leaded share change is $LEADDIF_{it} = LEADSHR_{it-1} - LEADSHR_{it}$, while the proportional specification is $LEADDROP_{it} = 1 - \frac{LEADSHR_{it}}{LEADSHR_{it-1}}$, which is the proportional January-to-January decline in the share of gasoline consumed in state i that is leaded. Both dependent variables are specified to be be positive in the more common case of declining leaded gasoline share. Due the natural constraints on $LEADSHR$, $LEADDROP$ may seem to be a more appropriate specification, but the national decline displayed in figure 3 indicates a linear decline pattern.

The decline of leaded gasoline will also depend on purchases of new vehicles for reasons that are independent of the relative merits of autos that take leaded and unleaded gasoline, such as macroeconomic fluctuations or weather conditions that influence auto longevity. The equation estimated includes two macroeconomic variables – the state unemployment rate during the year prior to the January observed ($UNEMP_{it-1}$) and growth rate in personal income ($INCGROW_{it}$) – the state level population density ($POPDEN_i$), and three weather variables – average snow fall ($SNOW_i$), subfreezing days ($COLD_i$), and 90+ degree days (HOT_i) in the major metropolitan areas in the state. Macroeconomic growth is expected to cause more new car purchases and a faster decline in leaded gasoline so the expected effect of $INCGROW$ is positive and $UNEMP$ is negative. Borenstein

[5] Registration data for California bear this out. Between 1980 and 1989, the difference in average model years of registered vehicles that used leaded versus unleaded gasoline increased from 8 years to 13 years.

Table 1: Summary Statistics

VARIABLE	MEAN	STD DEV	MINIMUM	MAXIMUM
LEADDIF	0.050236	0.040040	-0.10600	0.25000
LEADDROP	0.14417	0.15216	-0.41569	0.80588
LEADSHR	0.42429	0.14532	0.081000	0.77600
WDIF	2.46790	2.19416	-5.57000	10.53000
PDIF	6.28350	2.87169	-0.79000	13.60000
UNEMP	7.31963	2.27927	2.50000	15.50000
INCGROW	0.028833	0.026066	-0.061000	0.096000
POPDEN	623.13793	532.67075	28.00000	2269.00000
SNOW	2.10787	1.84585	0.00000	6.58333
COLD	0.25806	0.13734	0.00000	0.52603
HOT	0.096174	0.083694	0.010959	0.43014

order terms. The equation estimated for the decline in leaded gasoline share is:

$$\begin{aligned} LEADDIF_{it} = {} & \beta_0 + \beta_1 LEADSHR_{it-1} + \beta_2 LEADSHR^2_{it-1} \\ & + \beta_3 LEADSHR^3_{it-1} + \beta_4 LEADSHR^4_{it-1} \\ & + \beta_5 PDIF_{it-1} + \beta_6 PDIF_{it} + \epsilon. \\ & + \beta_7 UNEMP_{it-1} + \beta_8 INCGROW_{it} \\ & + \beta_9 POPDEN_i + \beta_{10} SNOW_i \\ & + \beta_{11} COLD_i + \beta_{12} HOT_i \\ & + \sum_{t=1982}^{1989} \gamma_t I_t + \epsilon. \end{aligned} \quad (1)$$

The same equation is also estimated with $LEADDROP_{it}$ as the dependent variable. The I_t are indicator variables equal to 1 in year t, zero otherwise. Inclusion of lagged variables reduced the sample from 10 to 9 years. Absence of price data for certain state/years further reduced the total number of observations to 377. Table 1 presents summary statistics of the variables.

Econometric Issues

The econometric concerns with estimation of this equation fall into two areas: endo-

Furthermore, the constraints on *LEADSHR* do not seem to play an important role. In only 1 observation is the absolute value of *LEADDROP* greater than 0.5. Thus, I proceed with the estimation under the assumption that the residuals are normally distributed.

The use of a panel data set raises the obvious issue of correlation among residuals of the same time period or the same state. Once the polynomial function of $LEADSHR_{t-1}$ is included in the regression, however, state effects are not evident. The F-test for inclusion of 47 fixed state effects yields a test statistic of 0.86, which is distributed F(47,312) and is not significant. The F-test for inclusion of 8 fixed year effects gives a test statistics of 3.54, which is distributed F(8,360), and is significant at the 1% level. Thus, the estimation includes fixed year effects.[8]

IV. Results

The results of estimating equation (1) with each specification of the dependent variable are presented in table 2. In the *LEADDIF* regression, three of the four parameters of the fourth order *LEADSHR* polynomial are statistically significant. All are significant in the *LEADDROP* regression. Fifth and higher order terms are not statistically significant when included in either regression and have virtually no effect on the other parameter estimates. The estimated effect of $PDIF_{t-1}$ on either of the dependent variables is of the expected sign. As the amount by which the price of unleaded regular gasoline exceeds the price of leaded regular gasoline expands, there is a decline in the speed with which the leaded share of gasoline shrinks. The estimated effect of $PDIF_t$ on the decline in leaded gasoline is of the expected sign in only the estimate of the linear decline model and is not statistically different from zero in either regression. The steady state effect of price difference on the decline in leaded gasoline, the sum of the coefficients on $PDIF_t$

[8] Tests for inclusion of both year and state fixed effects were carried out against restricted regressions in which the fixed effects were excluded, but were still included in the instrument set. The test for inclusion of state fixed effects was carried out excluding the weather and population density variables, which do not vary over time.

Table 2: Results from 2SLS Estimation of Equation (1)

Dependent Variable:	*LEADDIF*	*LEADDROP*
CONSTANT	0.161***	1.346***
	(0.058)	(0.199)
$LEADSHR_{t-1}$	−0.851	−8.954***
	(0.638)	(2.188)
$LEADSHR^2_{t-1}$	4.425*	31.919***
	(2.625)	(9.002)
$LEADSHR^3_{t-1}$	−7.127*	−46.147***
	(4.431)	(15.196)
$LEADSHR^4_{t-1}$	3.650	23.201***
	(2.633)	(9.031)
$PDIF_{t-1}$	−0.0077*	−0.0395***
	(0.0040)	(0.0137)
$PDIF_t$	−0.0004	0.0078
	(0.0038)	(0.0130)
$UNEMP_{t-1}$	−0.0031**	−0.0079*
	(0.0014)	(0.0048)
INCGROW	0.0689	0.3119
	(0.1155)	(0.3960)
POPDEN	0.0079	0.0166
	(0.0056)	(0.0193)
SNOW	0.0011	0.0053
	(0.0021)	(0.0071)
COLD	−0.0667*	−0.2062
	(0.0370)	(0.1270)
HOT	−0.0672**	−0.1668
	(0.0313)	(0.1074)
Observations	377	377

Both regressions estimated with fixed year effects.
***** = significant at 1% ** = significant at 5% * = significant at 10%**

Price Differences, Price Discrimination, and the Decline of Leaded Gasoline

The estimates in table 2 allow predictions of the rate of leaded gasoline decline that would have occurred under alternative pricing regimes. One obvious comparison is to what might be considered the benchmark – the decline of leaded gasoline that would

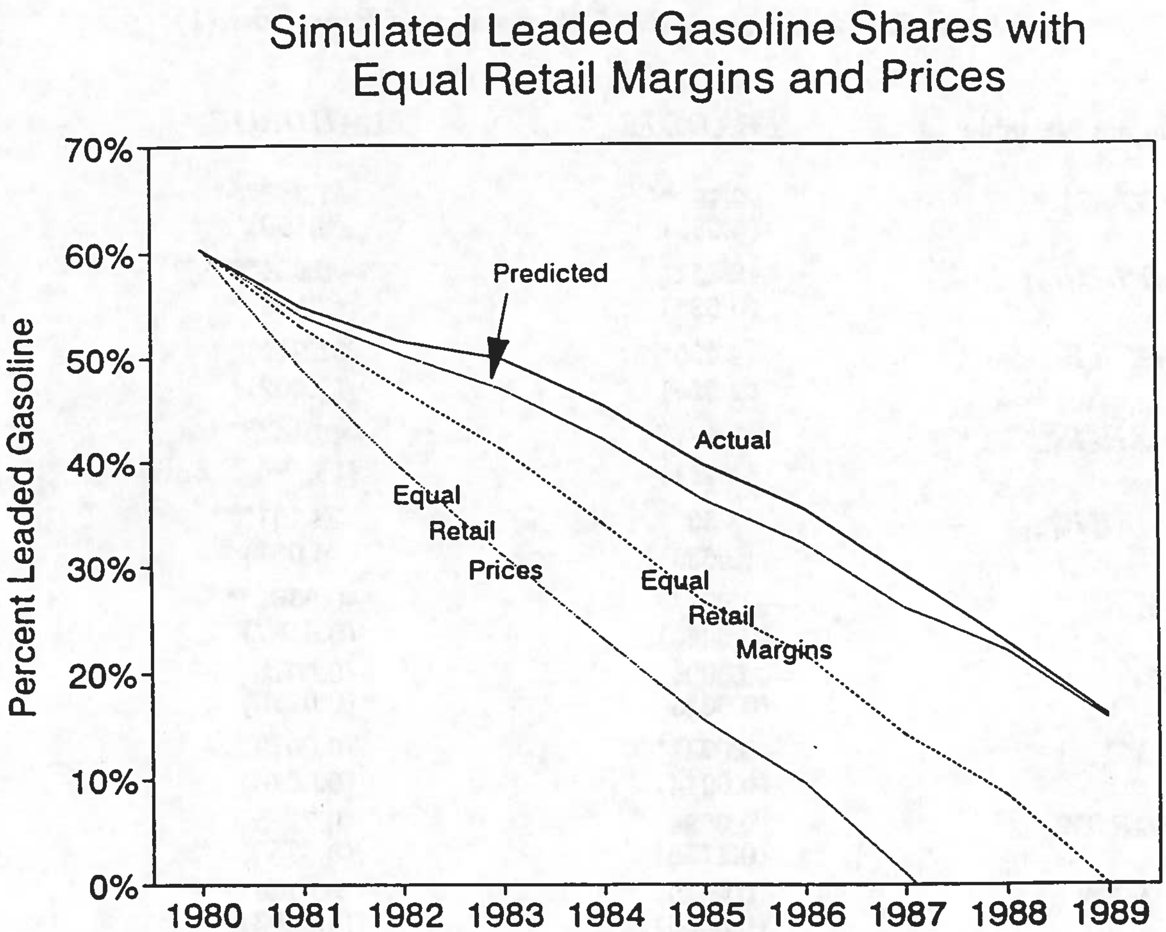

Figure 4

The welfare effects of non-discriminatory pricing or equal pricing of the fuels are ambiguous. A faster decrease in the leaded fuel use may not have been welfare improving. Clearly, instantaneous removal of leaded fuel in 1980 would have had significant costs, and the optimal rate of leaded fuel decline may have been no faster than actually occurred. In fact, given the competitive structure of the retail gasoline industry, it is not clear how such discrimination could fail to exist in equilibrium without direct government controls on retail margins, an idea that generally wins little support.

More importantly, the price discrimination that was observed against the buyers of unleaded gasoline is likely to occur with the introduction of any new fuel that is sold through the same outlet as the old fuel. Poorer people will likely be disproportionately

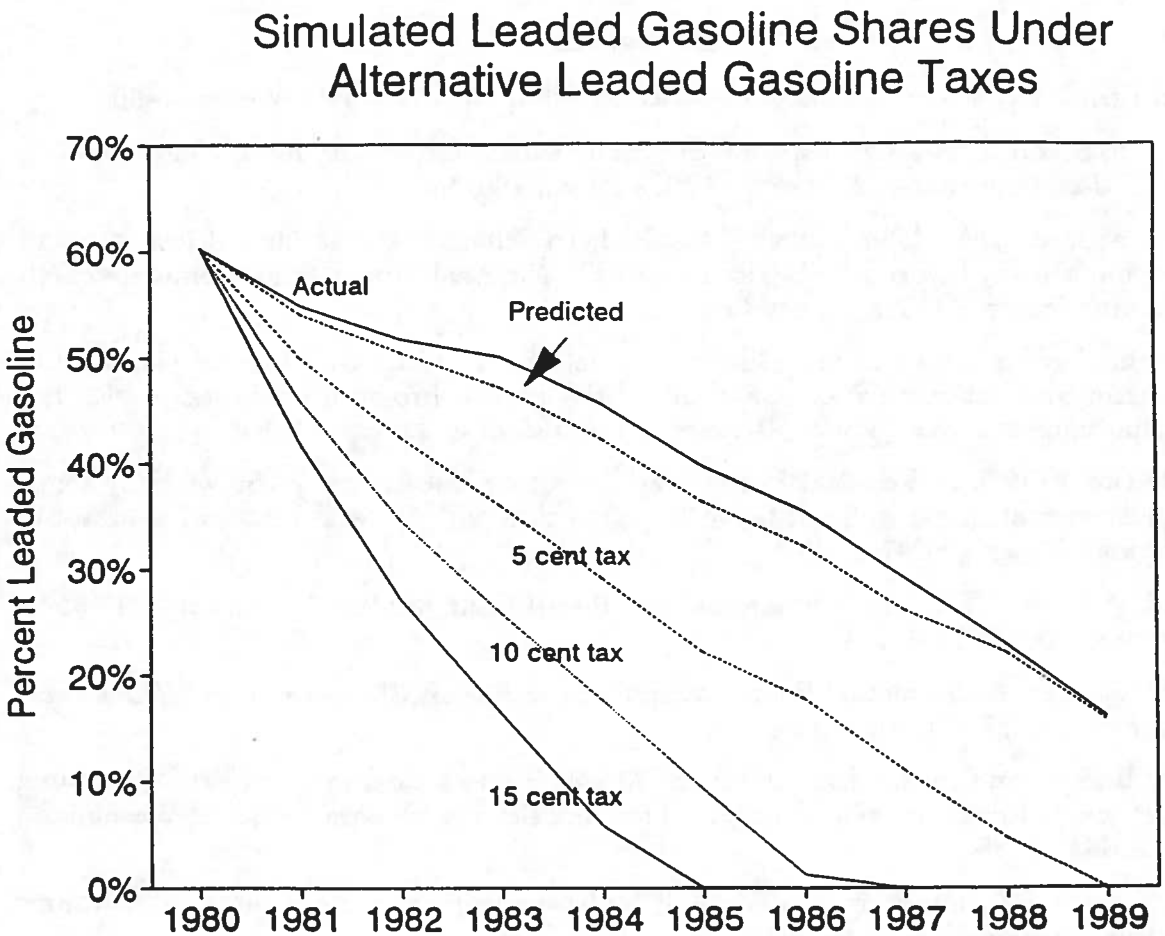

Figure 5

Conclusion

Though the U.S. government has been quite willing to intervene in the transportation fuel market in order to protect the environment, it has been reluctant to do so through price incentives. Instead, it has used administrative intervention to force the market to a different fuel choice. This paper indicates that in the case of the U.S. switch from leaded to unleaded gasoline, price incentives played a role in the rate at which consumers switched to the new fuel. The long-run effect of price differences – on the rate at which autos that used leaded gasoline exited the fleet – seems to have been more significant than the short-run effect – on the choice of which cars among the available fleet to use or which fuel to use in a given car.

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