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Price Incentives for Fuel Switching: Did Price Differences Slow the Phase-Out of Leaded Gasoline?

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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. 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. My 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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Air pollution from automobile exhaust and refueling remains a primary focus of environmental regulators and activists. To curb pollution, many alternative automobile fuels have been suggested, ranging from methanol, ethanol, MTBE, and other gasoline additives to electricity. Under most regulatory scenarios, the traditional gasoline products will be allowed to coexist with new fuels during a transition period. Exactly how that transition will take place and how long it will take will depend on the new fuels that regulators choose and the regulatory approach to imposing the fuel switch.

The regulatory approach to automobile fuel choices in the U.S. has consisted almost exclusively of mandated changes in autos and fuel availability. Currently, the additive MTBE is required for all gasoline sold in certain metropolitan areas during the winter months. In the mid-1970s, when the U.S. decided to phase out leaded gasoline, it did so essentially by requiring that all new cars built after 1975 use only unleaded fuel and by mandating that all gas stations sell unleaded gasoline.

This administrative approach contrasts with the various European policies towards automobile fuels. The Europeans, who have very high gasoline taxes to begin with, have attempted to encouraged the phase-out of leaded gasoline by imposing higher taxes on gasoline with lead and lower taxes on automobiles that use unleaded gasoline. The European efforts, which began much later than the U.S., have had mixed results. The most effective programs, in Germany and the Scandanavian countries have achieved approximately the same progress in lead phase-out that the U.S. had in the same number of years after the programs began. In southern Europe, however, there has been very little movement away from leaded gasoline.

While the European experience makes clear that implementing automobile fuel policies through a price mechanism may not be the comprehensive solution, it also highlights the potential effects of price incentives on the fuel switching process. In the U.S., these effects have been largely ignored at the regulatory level. No tax policy was implemented to encourage the switch from leaded to unleaded gasoline. As a result differences in production 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.

8¢ in 1983 (1989 constant prices) and fell to 2.3¢ by 1989. In any given year, the cross-state variation in price difference was also considerable, with the minimum to maximum difference in $PDIF$ ranging from four cents in 1980 to ten cents in 1987. Figure 2 shows the U.S. average leaded/unleaded wholesale price differences ($WDIF$) during the decade next to the average retail price differences, demonstrating that some of the difference in retail prices in the early and mid 1980s and most of the difference in the late 1980s was due to different retail margins.

Differences in fuel prices can affect consumer decision making both in the short run and in the long run. The short-run decision is the choice of fuel given the automobile stock that the consumer owns, while the long-run decision is the consumer's choice of automobile 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 gas mileage – than unleaded gasoline throughout the 1980s, so cars that could take leaded gasoline would not be fueled with unleaded gasoline. While the price and performance difference did give some incentive for consumers to fuel cars designed for unleaded gasoline with the leaded product, this was illegal and caused permanent damage to the catalytic converter. EPA figures show that such "misfueling" was not common during the 1980s. Only 3% to 7% of randomly checked autos that were built to use unleaded fuel exhibited signs that they had ever been misfueled. Overall, the scope for short-run substitution between fuels was probably limited.

In the longer run, however, the relative price of fuels was one factor that would affect the decision to sell or abandon an older leaded gasoline car in favor of a newer car that took unleaded gasoline. While an *individual's* decision to sell or keep a car would be affected by the relative fuel prices, from the policy-maker's perspective what matters is the *aggregate* effect on abandonment or reduced use of autos that take leaded gasoline. Thus, the elasticity of aggregate leaded gasoline consumption with respect to relative fuel prices will be determined principally by the behavior of consumers at the "bottom" of the auto consumption chain – the people who drive cars that in the alternative would be sent to the junk yard. These people are obviously poorer than the population as a whole and are probably relatively more sensitive to short-run differences in operating costs. The greater sensitivity may be both because of liquidity constraints for poorer individuals and because fuel cost is probably a greater proportion of actual operating expenditures for such cars. The effect of price differences on fuel switching is likely to be most noticeable in the long run.

III. The Data and Estimation

Estimation of the rate at which consumption of leaded gasoline declines is done using annual observations of gasoline prices and volumes at the state level, taken in January of each year, 1980–1989. Data on volume sold of each type and grade of gasoline by state are 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 sur-

[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.

veyed 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 population-weighted averaged of the city prices were taken to represent the state.[3]

It is not possible to control directly for the many factors other than relative fuel prices that would affect the decision to switch autos or fuel, both in the short run and in the long run. Cars that took leaded gasoline systematically had poorer fuel efficiency, greater weight, higher performance engines, and larger body sizes than later model cars. The drastic design changes that followed gasoline price increases in the 1970s lagged by only one or two years the mandating of unleaded gasoline for new cars. Instead, I assume that the comparative attributes of cars that take leaded and unleaded gasoline is highly correlated with the share of total fuel consumption that is leaded. That is, if 60% of the gasoline sold in a given state in a given year is leaded, then the relative attractiveness of the leaded versus unleaded cars, on grounds other than fuel prices, is the same as when 60% of the gasoline sold in any other state in any other year is leaded. Thus, I am assuming that the share of leaded gasoline in a state at a given time reveals all relevant information about the features of leaded-fuel autos in comparison to unleaded-fuel autos. At time $t-1$, some function of $LEADSHR_{t-1}$ captures the influence of relative attributes on the decline in $LEADSHR$ between $t-1$ and t.

This is a sensible approximation because the most important omitted attributes are highly correlated with year of sale and, due to the nearly 100% switchover in 1975 from leaded to unleaded fuel in new cars, the percent of fuel that is leaded is probably a nearly

[3] I take the relative prices of leaded and unleaded regular self-serve gasoline as the principle price determinant of the share of leaded gasoline. Premium grade volumes are included in the leaded share calculation, but I assume that the marginal decisions to switch between leaded and unleaded gasoline are not affected by premium grade prices. Self-serve gasoline was a growing proportion of the market over the time period, from about 50% in 1980 to over 80% in 1989. Furthermore, those cars closest to being junked were likely to be more commonly fueled at a self-serve pump.

sufficient statistic for the relative age of autos that take leaded and unleaded gasoline.[4] The year of observation might contribute additional information. While the stock of leaded-fuel cars remains pre-1976, the average production year of unleaded-fuel cars increases 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

[4] This is not to say that the relationship is linear, and it is not restricted to be such in the estimation.

[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.

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 (1991) found that higher population density is significantly associated with higher auto junking rates, so the expected effect of $POPDEN$ is positive. $SNOW$ and $COLD$ indicate harsh climates where road salting and auto wear are greater, so leaded gasoline would be expected to decline more quickly, implying positive expected effects. HOT indicates a drier, milder climate in general, so is expected to have a negative effect on the rate of leaded gasoline decline.

As explained in the previous section, both short-run and long-run effects of price differences on the share of leaded gasoline are possible. Since the long-run effect is on automobile choices, the contemporaneous price difference would probably be less relevant than an earlier price. I use the previous year (January) price difference between leaded and unleaded gasoline $PDIF_{t-1}$ to capture this effect.[6] The short-run effect would be a response to contemporaneous price differences and is captured by $PDIF_t$.

The specification of the equation to be estimated is not dictated by theory. Because of the effect that $LEADSHR_{t-1}$ is supposed to capture, discussed earlier, $LEADDROP$ and $LEADDIF$ are modeled to be a linear functions of a fourth order polynomial of lagged $LEADSHR$ in order to allow maximum flexibility in the relationship between the level and change in $LEADSHR$. In fact, the results are altered little by inclusion of the higher

[6] Use of average of the previous 2 year prices leads to similar conclusions.

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

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

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

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: endogeneity and specification of the error term. The contemporaneous price difference is likely to be endogenous for reasons explored in Borenstein (1991). Leaded share of gasoline is associated with its relative availability which in turn affects the markup on leaded gasoline in comparison with unleaded gasoline. Because price differences are serially correlated for a given city, the lagged value of $PDIF$ might also be correlated with the error term. Berndt's (1990) implementation of a Hausman specification test to test for endogeneity indicates that $PDIF_{t-1}$ is clearly endogenous and $PDIF_t$ is borderline.

The excluded variables used as instruments to test for endogeneity and estimate the equation by two-stage least squares are the current and lagged wholesale price difference between leaded and unleaded gasoline ($WDIF_{it}$ and $WDIF_{it-1}$). Inclusion of wholesale prices as instruments is valid so long as the share of leaded gasoline is not a determinant of the relative wholesale prices. In fact, wholesale prices seem to be competitively determined and exhibit no industry scale economies. The wholesale price difference in the early part of the sample period is due primarily to the fact that lead was the least expensive way to boost octane levels in gasoline. The alternatives used in unleaded gasoline raised costs. In 1985-87, the federal government rapidly decreased the allowed lead content in gasoline by more than 90%, raising the cost of producing "leaded" gasoline with sufficient octane and equalizing the wholesale prices of the fuels. Even as the share of leaded gasoline declined to less than 13% in 1990, the wholesale prices of the two fuels remained equal.[7]

The two issues related to the distribution of the error term are its normality and possible correlation among observations. It may appear at first that the structure of the analysis calls for a limited dependent variable estimation approach. In fact, the residuals are bounded only by the [0,1] boundaries on $LEADSHR$, not by a constraint on the sign of $LEADDIF$ or $LEADDROP$. The dependent variable is negative, indicating an increase in the share of leaded gasoline, for at least one state in every year except 1981.

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[7] Borenstein and Gilbert, 1992, presents information supporting the assertion that wholesale prices are competitively determined.

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.

and $PDIF_{t-1}$, is negative and significantly different from zero at 5% in both regressions. As expected, the long-run effect of gasoline price differences on the change in the leaded share of gasoline is estimated to be larger than the short-run effect. The coefficients are significantly different at the 5% level in the regression with $LEADDROP$ as the dependent variable. They are not, however, statistically different in the regression of $LEADDIF$.

The estimated effects of $PDIF_{t-1}$ and $PDIF_t$ on $LEADDIF$ together that a one cent decrease in the price difference between leaded and unleaded gasoline would cause about a 0.8 percentage point increase in the annual decline of the leaded share of gasoline. The estimated combined price difference effects on $LEADDROP$ imply that a one cent decrease in the price difference between leaded and unleaded gasoline would directly cause about a 3% increase in the proportional decline of $LEADSHR$. If $LEADSHR$ were 50% at a point in time, for instance, every one cent increase in the price difference at that time would cause a one and a half percentage point greater decline in $LEADSHR$ over the following year. The estimated effects seem to be mostly the result of accelerated exit of leaded-gasoline cars from the fleet. The short-run effect, substitution among vehicles that use different types of fuel, is difficult to estimate with much precision and to distinguish from the long-run effect.

The macroeconomic variables $UNEMP$ and $INCGROW$ are highly correlated with one another, but they are jointly significant at the 1% level in both regressions. As predicted, higher unemployment slows the decline of leaded gasoline and higher growth in personal income accelerates it. These effects are most noticeable during the 1982 recession which caused $LEADSHR$ nationally to barely drop during that year.

None of the four variables included to capture cross-sectional differences in the rate of auto decay is estimated very precisely. All have the predicted signs except $COLD$, which indicates that after controlling for snowfall, leaded-fuel autos remained in use longer in areas with more below-freezing days. The four variables, however, are jointly significant at the 5% level in both regressions.

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 have occurred if there had been no price difference between the fuels. Figure 4 uses the estimates from the regression with $LEADDIF$ to present the actual and estimated decline in leaded gasoline under the actual price differences that occurred, as well as the estimated effect if there had been no retail price differences between the fuels. The estimates imply that leaded gasoline would have virtually disappeared by 1987 if there had been no price difference between the fuels. Estimates of this effect using the parameters from the regression with $LEADDROP$ give a slightly more rapid decline, with leaded gasoline vanishing in about 1986.

Figure 2 showed that the retail price difference between the fuels was in large part due to retail margin differences. Borenstein (1991) argues that the predominant cause of differential retail margins for leaded and unleaded gasoline during the 1980s was price discrimination. Buyers of unleaded gasoline were wealthier and less willing to search for a lower price, so individual sellers exercised greater market power and received higher margins in the unleaded gasoline market than in the leaded gasoline market. Figure 4 also presents a simulation, again from the $LEADDIF$ regression, of the decline of leaded gasoline that would have occurred had the retail margins on leaded and unleaded gasoline been the same.

The effect of fuel price differences overall and retail margin differences appears to be important. Taking the 1980 leaded gasoline share as given, the forecast decline with no price difference in the fuels would have been substantially faster than actually occurred. Even the retail price discrimination that occurred caused leaded gasoline to survive a couple of additional years.[9] The effects would have begun earlier and have been greater overall if the prices or margins had been equal starting in 1975 when unleaded gasoline was introduced. The data available, unfortunately, do not allow simulation of that full effect.

[9] This is, however, an upper bound on the effect of price discrimination, since the difference in margins is probably not wholly attributable to discrimination. Borenstein (1991) estimates that one-third to one-half of the margin difference is directly attributable to the proxies for discrimination that are used there. These are probably lower bound estimates of the proportion due to discrimination.

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 represented among buyers of the older fuel, causing retailers to charge higher margins on the new fuel, which is bought on average by wealthier people who are less willing to search for low prices. Discrimination against buyers of the new fuel will slow the fuel switch. Of course, the government could counter this effect by imposing lower taxes on the new fuel than the old fuel.

Differential Taxation Policies

The results in table 2 indicate that tax policies could have played an important role in altering the rate of leaded gasoline decline. One can simulate the impact that differential taxation of leaded and unleaded gasoline might have had on the decline of leaded gasoline, using the results of equation (1). Figure 5 presents three alternative scenarios, simulated from the parameters estimated in the $LEADDIF$ regression, in which the relative price of leaded gasoline is increased by five, ten, and fifteen cents through a tax targeted only at leaded gasoline. The actual tax necessary to achieve such changes in the relative prices could be larger due to less-than-complete passthrough of the tax, but Borenstein, Cameron, and Gilbert (1992) found that over 90% of wholesale cost increases are passed along in retail prices within 2 weeks. For purposes of this discussion, I assume 100% passthrough of such a tax.

Figure 5 indicates that if a 5¢ additional tax on leaded gasoline had been implemented in January 1980, the leaded share of gasoline would have dropped by about 7 percentage points more than it actually did by January 1981. That difference would have expanded in the following years, and leaded gasoline would have virtually disappeared by 1989. Ten and fifteen cent taxes on leaded gasoline would have had proportionally larger effects and lead to earlier leaded gasoline phaseout. Again, if the tax had been imposed in 1975, the period for which reliable price data are scarce, the large impact would have occurred earlier and the total leaded gasoline usage before its demise would have been smaller.

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.

Based on the estimates of the effect of price differences, this paper simulates the impacts that differential taxation of leaded and unleaded gasoline would have had in the 1980s. A five to fifteen cent additional tax on leaded gasoline would have substantially increased the speed with which leaded gasoline declined as a share of the total gasoline market. The estimates are also used to quantify the impact that retail price differences and price discrimination in favor of leaded gasoline buyers had on the decline of leaded gasoline. Discrimination against buyers of unleaded gasoline – which is likely to occur with the introduction of any new fuel – appears to have had a significant slowing effect on the decline in leaded gasoline use. Overall price differences due both to discrimination and differential production costs are estimated to have slowed the phaseout out of leaded gasoline by about 4 years.

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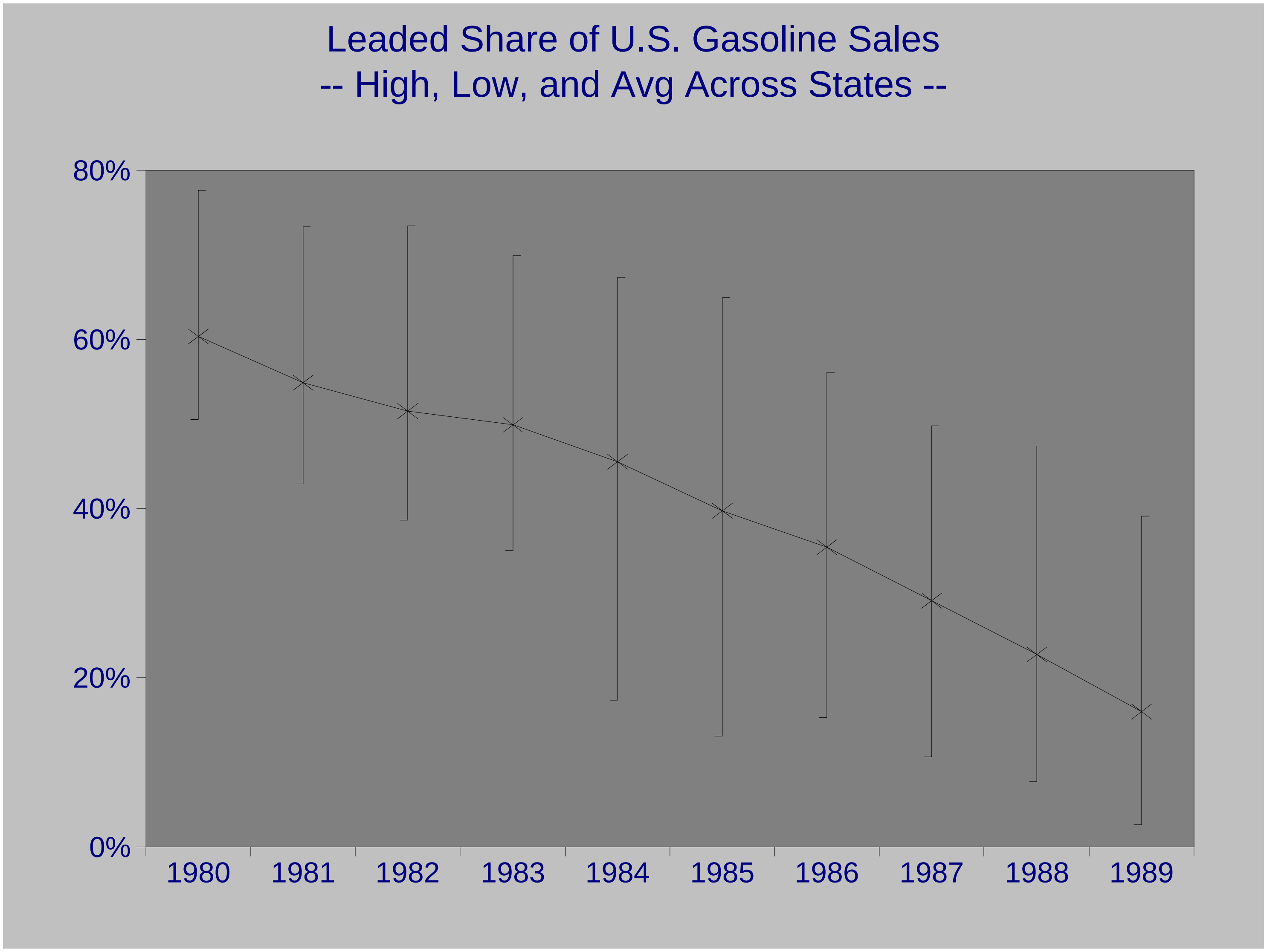
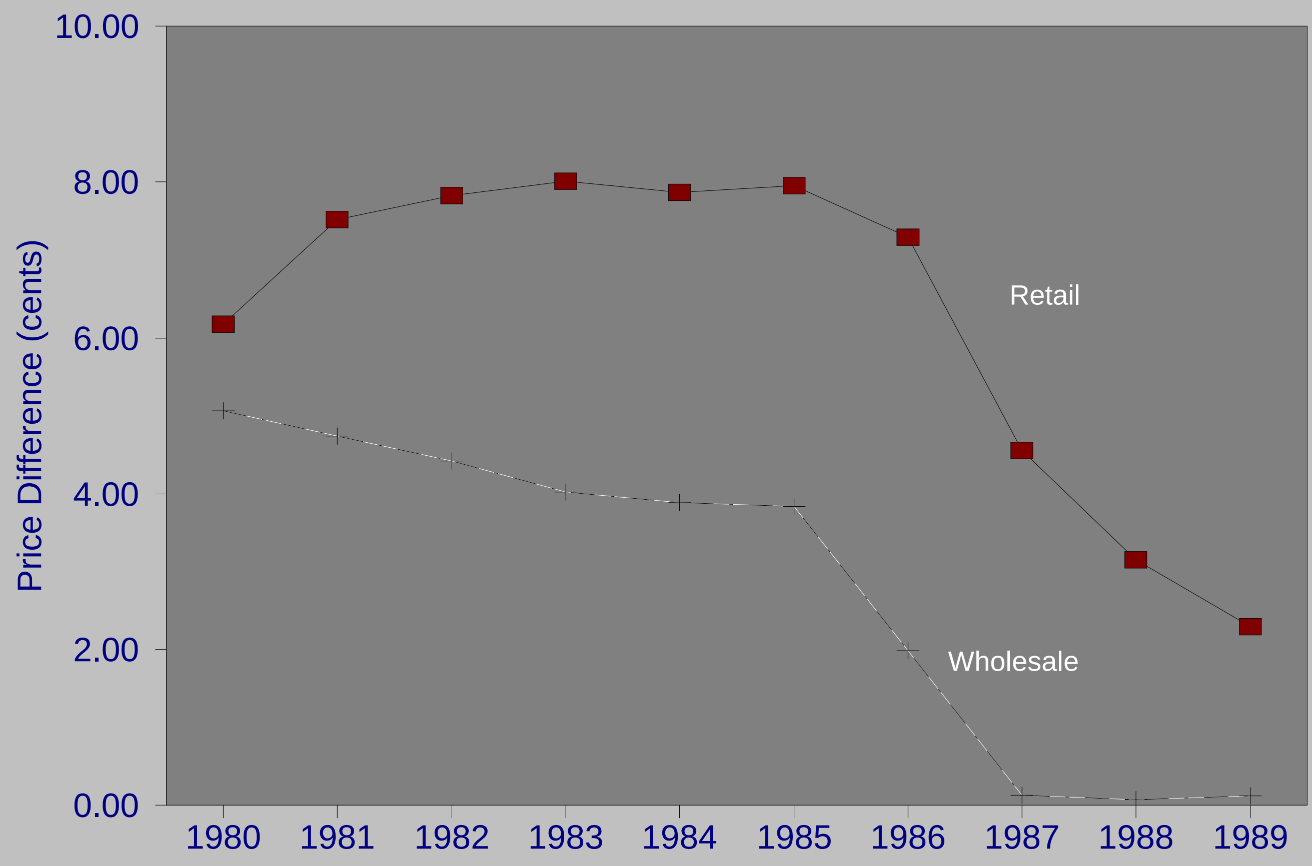
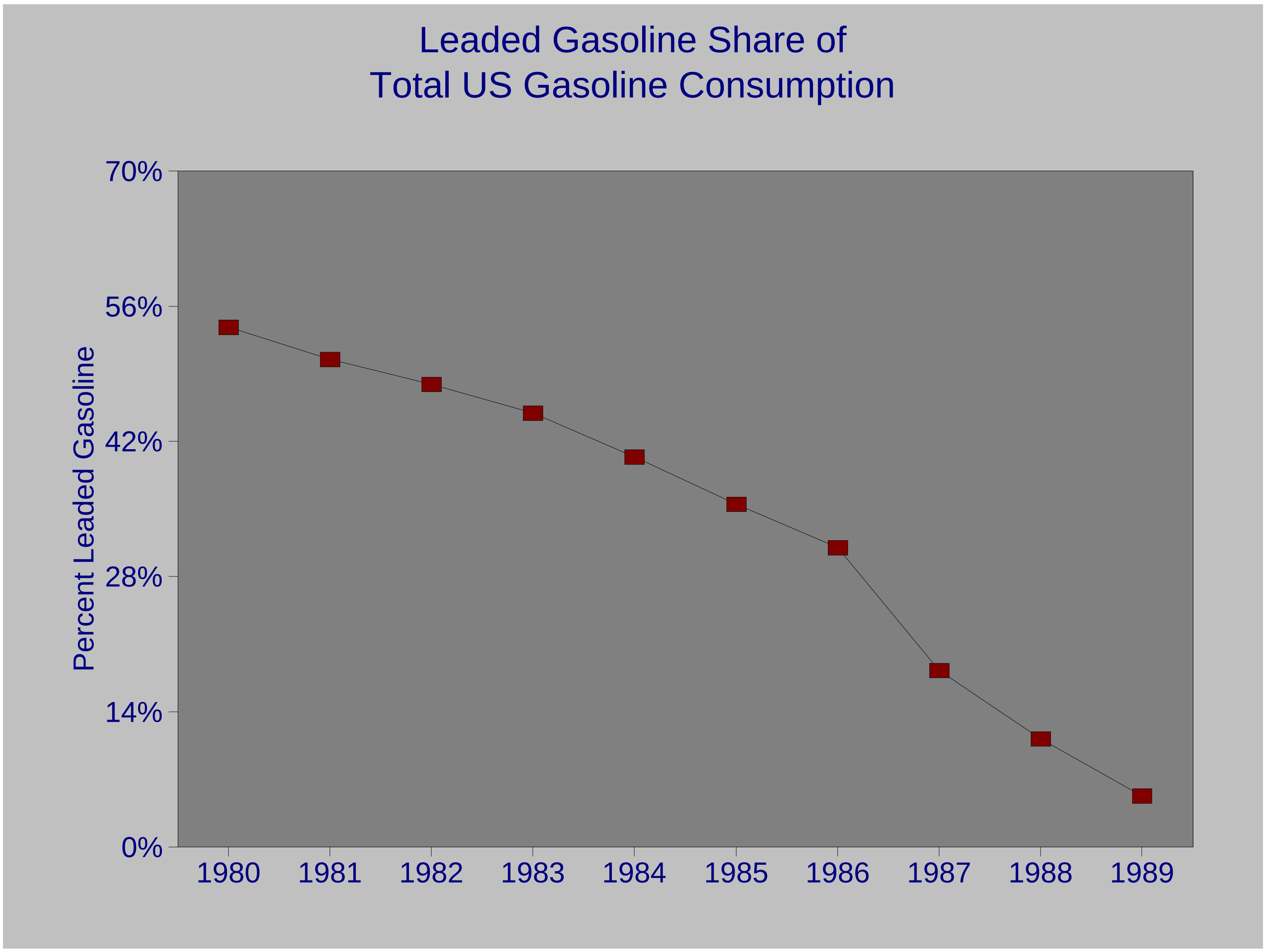
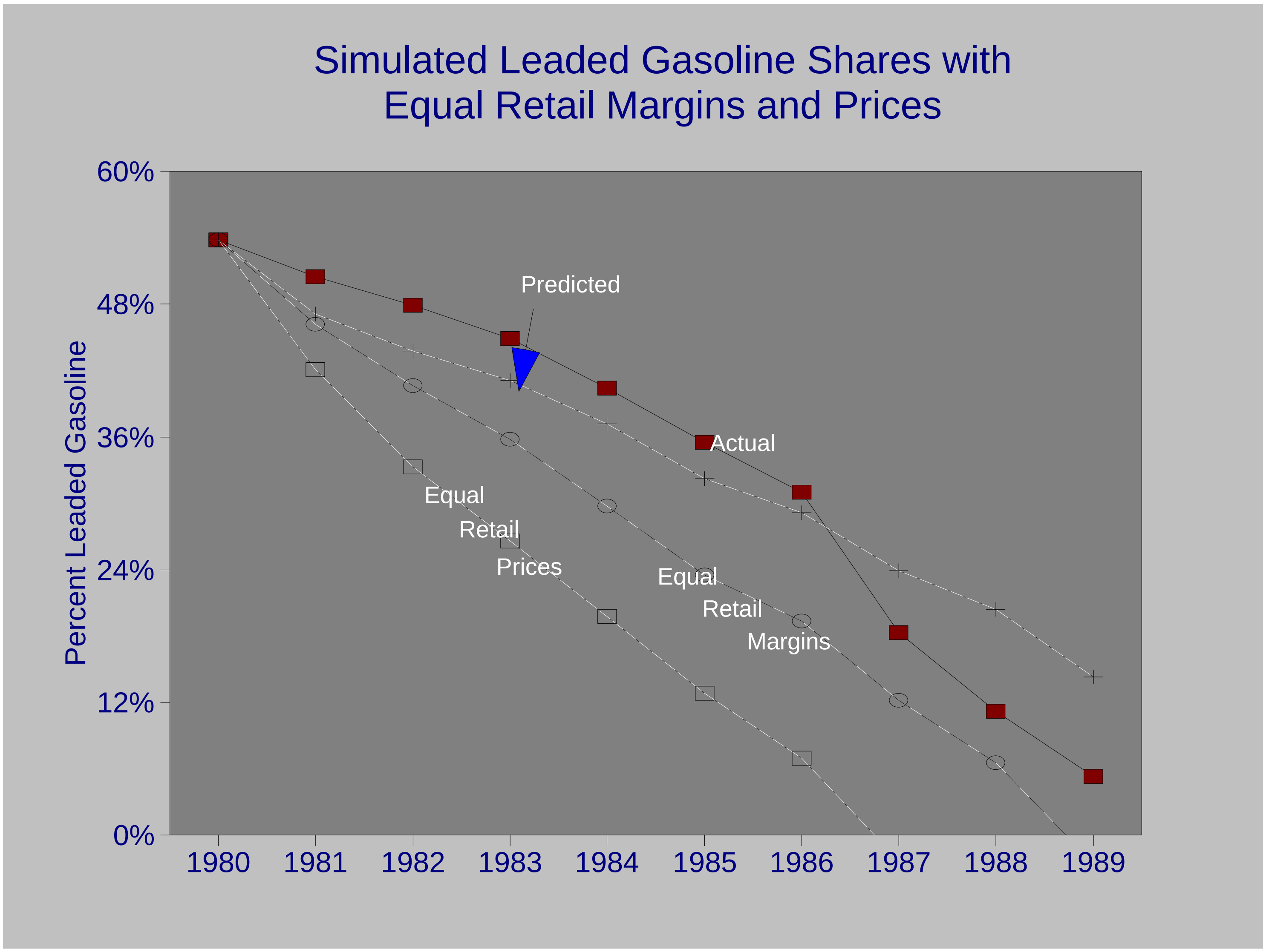


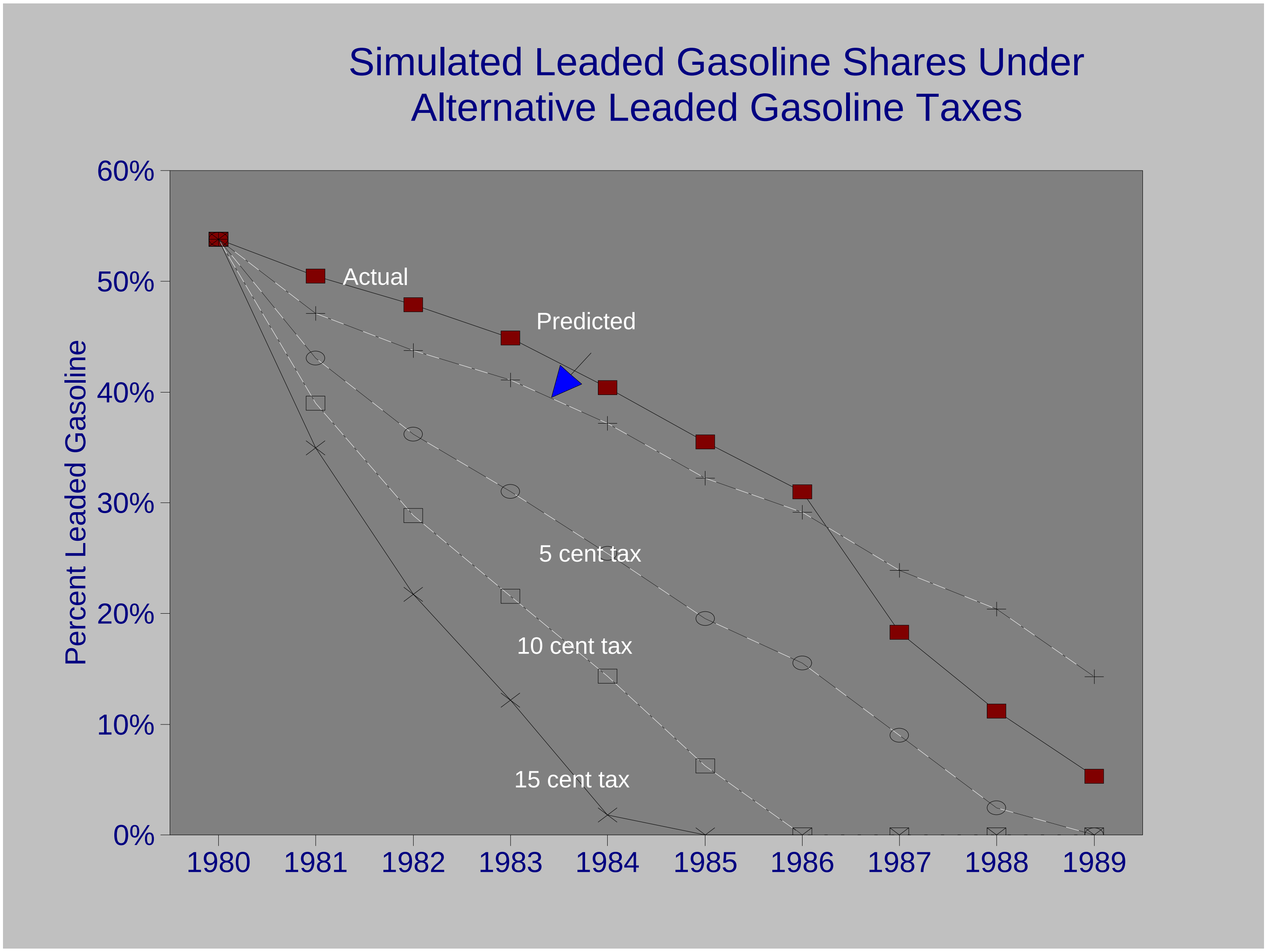
Leaded Share of U.S. Gasoline Sales
-- High, Low, and Avg Across States --
80%
60%
40%
20%
0%
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989

Average US Unleaded-Leaded Gasoline
Price Differences at Retail & Wholesale




Leaded Gasoline Share of
Total US Gasoline Consumption
Percent Leaded Gasoline
70%
56%
42%
28%
14%
0%
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989


Simulated Leaded Gasoline Shares with
Equal Retail Margins and Prices
Percent Leaded Gasoline
60%
48%
36%
24%
12%
0%
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
Predicted
Actual
Equal
Retail
Prices
Equal
Retail
Margins


Simulated Leaded Gasoline Shares Under
Alternative Leaded Gasoline Taxes
Percent Leaded Gasoline
60%
50%
40%
30%
20%
10%
0%
Actual
Predicted
5 cent tax
10 cent tax
15 cent tax
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989