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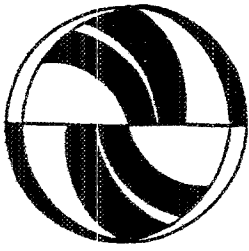https://escholarship.org/uc/item/9dd2t48q

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PREMIUM GASOLINE OVERBUYING IN THE U.S.:
CONSUMER-BASED CHOICE ANALYSIS

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ABSTRACT

High octane gasolines, including "premium" and midgrade, steadily gained market share in the United States during the 1980s, increasing from 12% of the total gasoline market in 1983 to 15% in 1985 and 30% in 1989. This 18% increase in market share represents an aggregate revenue transfer from U.S. consumers to industry of an additional $3 billion per year.

It is widely believed that many drivers do not gain any benefit from using premium gasoline. We review the substantial technical evidence underlying this presumption, and then analyze a survey of vehicle owners in New York and California to determine why people purchase premium gasoline, given that many of them receive no clear benefit.

We found that demand for premium gasoline is highly elastic, women and drivers in certain regions are more inclined to purchase premium gasoline, income plays a minor role, and the benefits are poorly understood. Many people buy premium gasoline for rather vague reasons, not on the basis of strong evidence or justification.

INTRODUCTION

The market for higher grade gasolines, including premium and midgrade gasoline, has been avidly pursued by the petroleum industry in recent years, and more closely monitored by government and consumer groups. In this paper we review the recent gasoline market, the technical basis for needing higher grade gasolines, and behavioral explanations for growing consumption of these fuels.

We examine three grades of gasolines most commonly consumed in the United States: regular (including leaded and unleaded), midgrade, and premium (leaded and unleaded). Premium and midgrade gasolines are distinguished from regular gasoline primarily by their higher octane rating and higher price. At fuel pumps, octane ratings are displayed as an average of two independent measurements: a research octane number (RON) and motor octane number (MON). In the U.S., premium gasoline has octane ratings of about 91 or more; midgrade gasoline, about 88-90; leaded regular gasoline, 87-90, and unleaded regular, 85-87.

Another distinguishing feature was the insertion of special additives in premium gasoline to keep the very narrow passages in modern fuel injectors clean. However, by 1989 when our survey was conducted, these detergent additives were widely used in regular gasoline as well (Consumer Reports, 1990). As indicated later, detergent additives were not an important reason for purchasing premium gasoline for respondents in our survey.

History of Premium Gasoline Sales and Prices

High octane gasolines dramatically increased market share in the United States during the 1980s, increasing from 12% of the total gasoline market in 1983 to 15% in 1985 and 30% in 1989 (Figure 1). The market growth of the 1980s followed by two price spikes in 1989 and 1990 suggest that this demand is highly elastic -- that high octane gasolines are widely treated as luxury goods. That is, through this seven year period, premium gasoline market shifts closely tracked average gasoline prices -- market share increasing through 1989 as prices dropped, and then market share dropping when prices rose

The two price spikes were responses to the Exxon Valdez oil spill and Iraqi invasion of Kuwait. These two episodes are particularly instructive. Immediately after the March 1989 Exxon Valdez oil spill, with price differentials between gasoline grades remaining constant,

gasoline prices jumped about 20 cents per gallon in two months (Figure 2), a response to the temporary shutdown of the Alaska oil pipeline, low inventories during the normal seasonal shift to low vapor gasolines (EIA, 1989), and industry efforts to capitalize on the opportunity (Borenstein, 1991).

Fig. 1 Gasoline Market Shares and Prices by Grade (1983-1991)

(a)

(b)
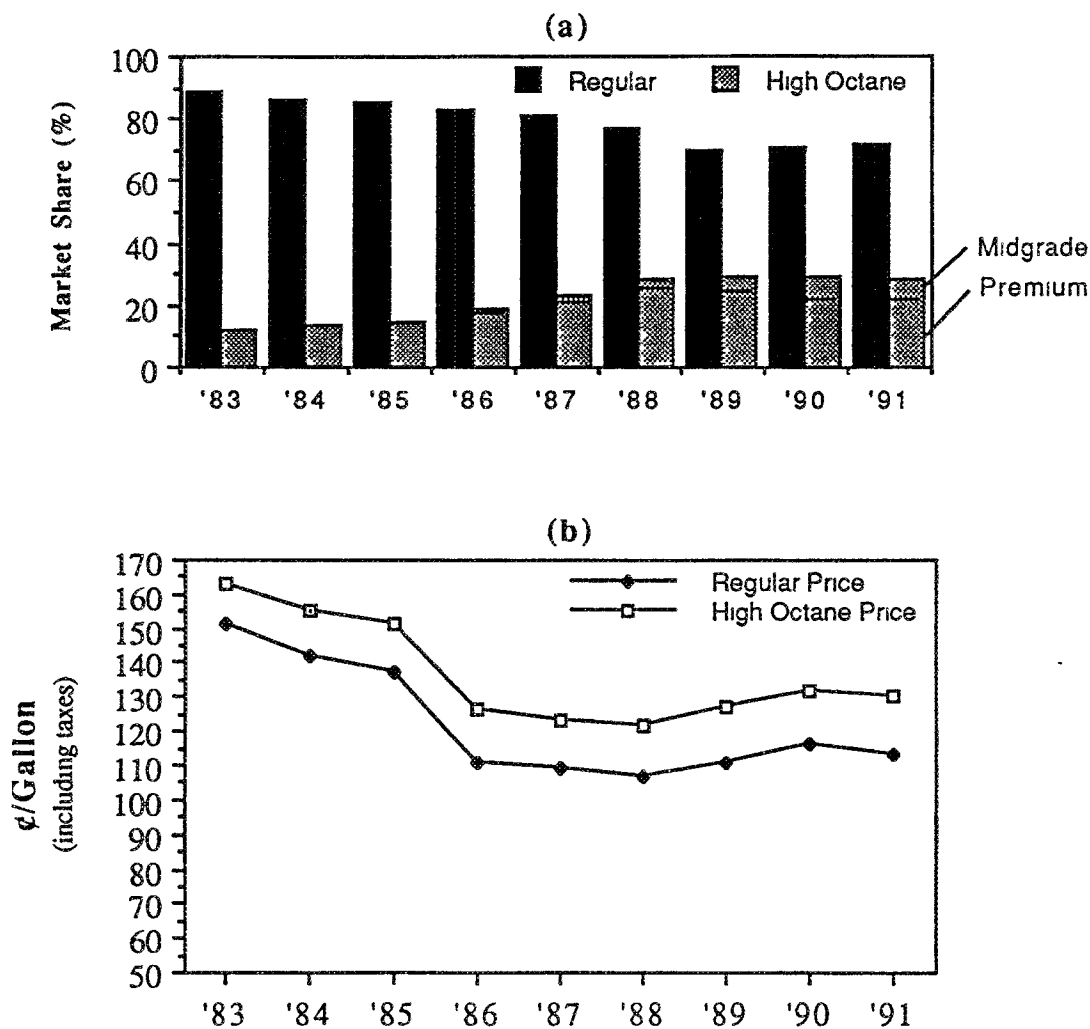
Note: Regular gasoline in Fig. 1 (a,b) includes both leaded and unleaded gasoline. High octane gasoline includes unleaded premium and unleaded midgrade (since 1986), unleaded midgrade market shares and prices from 1986-1988 are estimated by authors

All prices are weighted averages and inflation adjusted, these figures include federal and average state taxes, but exclude county and local taxes

Source: Energy Information Administration (1992), *Petroleum Marketing Monthly*, Tables 11 and 12, DOE, Washington, D C, (Apr)

Fig. 2 Gasoline Market Shares and Prices
(Jan. 1989 - Jan. 1992)

(a)

(b)
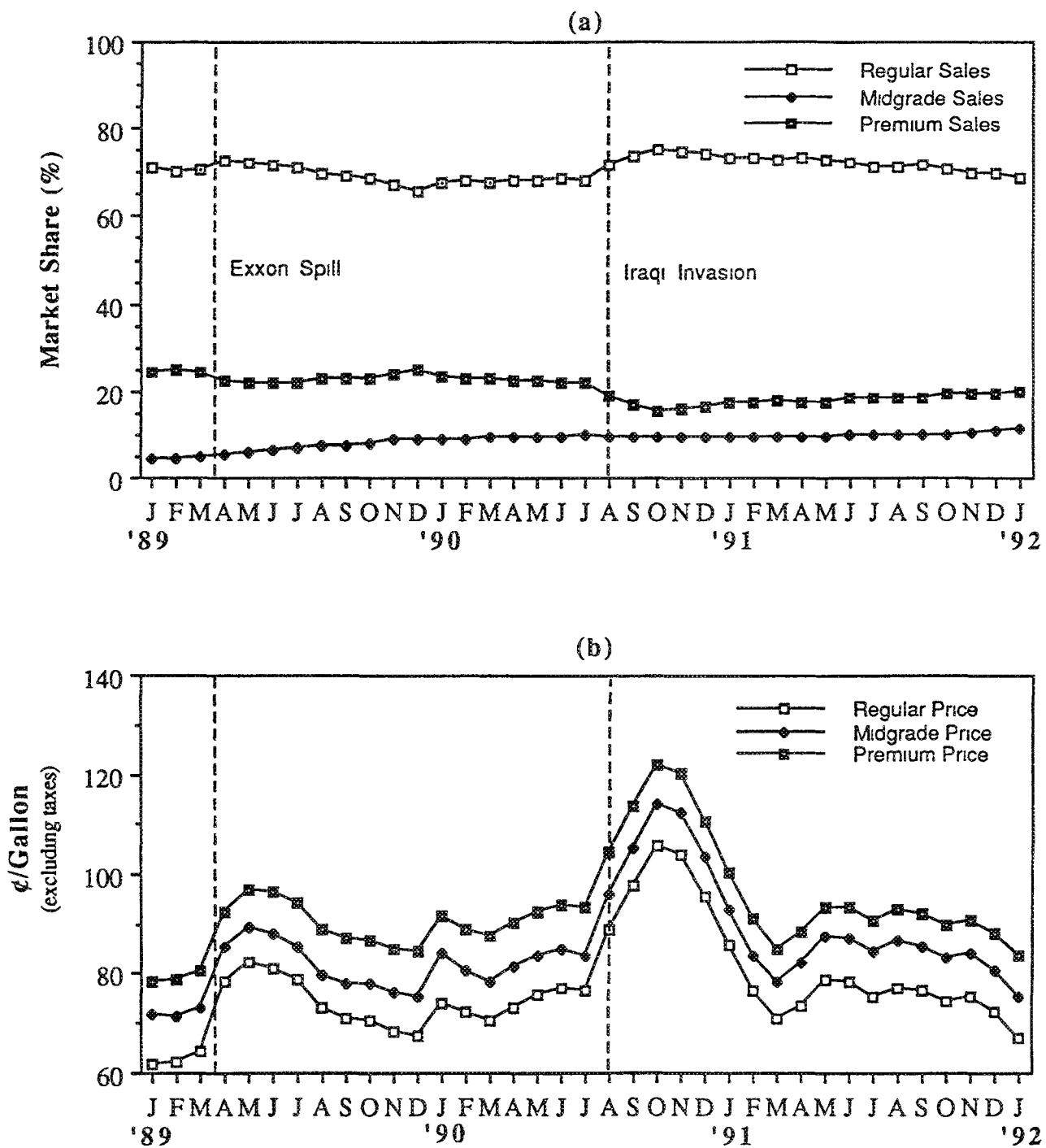
While total gasoline sales dropped 2% between March and May 1989, regular gasoline slightly increased its market share from 70.6% to 72.2% and midgrade from 4 8% to 6.0%. But premium sales dropped from 24.6% to 21.8% of the market.

The same phenomena occurred immediately preceeding and following the August 2 1990 Iraqi invasion of Kuwait, but in a more extreme fashion. Again, price differentials held constant, as gasoline prices increased by about 30 cents per gallon from July to October 1990. Regular gasoline increased its market share by 10%, while midgrade dropped 4% and upper-end premium market share dropped by 30%, from 22.2% to 15.5% of the market (Figure 2). In both cases premium gasoline market share dropped sharply and instantly when overall prices rose.

After October 1990, with prices receding from their highs of October 1990, premium and midgrade gasoline slowly increased market share -- premium reaching 19.8% by early 1992, and midgrade increasing to 10.3% -- further evidence of high elasticity of demand for premium gasoline.

As suggested by the shifts in market share, the high octane market is now very different from what it was in the 1980s. Beginning in 1986, mostly in the eastern part of the country, the petroleum industry began marketing unleaded midgrade gasoline -- with octane ratings of 88-90 -- as a response to the apparent willingness of consumers to pay for extra octane. The introduction of midgrade gasolines was an attempt to expand revenue by moving regular gasoline users upscale without losing premium buyers. Where midgrade gasoline is sold, retailers generally raise the price of premium relative to regular gasoline, and insert midgrade as a more moderately priced high octane fuel. The national price differential between regular and premium was 14 cents in 1986; in January 1992 it was up to 17 cents. Nationally, midgrade gasoline accounted for about 2% of sales in 1986 (accurate data are not available because midgrade was counted as part of regular at that time), gradually increasing to 10.3% in January 1992 (Figure 2).

An important underlying phenomena contributing to the popularity of more expensive grades of gasoline is that gasoline costs have been decreasing for consumers even as prices increased. Between 1983 and 1989, gasoline costs per mile dropped by 27% (EIA, 1990; MVMA, 1990), the result of lower real world oil prices (all prices adjusted using consumer price index) and increasing automotive fuel economy. Thus, even with increasing gasoline prices and an increasing price differential between premium and regular gasoline (3 cents

per gallon increase during this 6 year period), premium gasoline still cost less in 1989 than regular gasoline had cost a few years before.

It is not the objective of this paper to document the price elasticity of demand for premium gasoline, but simply to demonstrate that the elasticity is high -- market share doubled in six years when gasoline costs (per mile) dropped 27%, and then market share dropped 30% when premium prices increased 25% between July and October 1991.

The objective here is to understand consumer behavior and the extent to which premium gasoline is viewed as a luxury good, determine whether premium sales are irrationally high, and explore implications for future gasoline demand.

OCTANE RATINGS AND OCTANE REQUIREMENTS

The primary distinguishing attribute of premium gasoline is its high octane rating. From the early 1920s until recently, high octane was achieved principally by using tetraethyl lead additives (Hancock, 1985). Octane rating is a widely used index to measure gasoline resistance to knocks in spark ignition engines. Knocks occur when the compressed fuel-air mixture explodes prematurely in engine cylinders. Under normal conditions, the mixture is compressed in the cylinder until a timed spark ignites it. Gasoline with a higher octane rating has a greater resistance to knocking and is more expensive to produce.

Different cars have different octane needs. Engines with higher compression ratios require higher octane gasoline. To some extent, weather, terrain and engine age are also known to affect octane requirements· at low altitude, high ambient temperature, and low humidity, and on steep uphill gradients, engines require higher octane gasoline (Bigley *et al.*, 1971; Keller *et al.*, 1978). And as engines age, they tend to require higher octane. The octane requirement increase (ORI) is a result of carbon deposits building up inside the combustion chamber. These deposits increase engine compression ratios and also absorb heat, igniting fuel-air mixture prematurely (Callison *et al.*, 1989).

Previous Studies

Oil and auto industry analysts agree that people are buying premium gasoline beyond what their vehicles need (GAO, 1991). That is, consumer perceptions of the benefits of premium gasoline are not always accurate.

The major auto manufacturers insist that virtually all their vehicles will run well on regular gasoline (GAO, 1991). Indeed, a study by Colucci (1989) at General Motors found that only 3% of the automobile fleet (including cars, vans and light-duty trucks) needed premium gasoline in 1989. These results are lower than others because untrained "raters" are used as drivers. All the other tests reported below used trained raters who are more sensitive to knocking and pinging (GAO, 1991). The Energy Information Administration (EIA) of the US Department of Energy arrived at a somewhat higher estimate, determining that 15% of all passenger cars required premium gasoline in 1988 (EIA, 1990), and a study sponsored by the American Petroleum Institute (API), using the same class of vehicles analyzed by EIA, concluded that 21% of the vehicles required high octane gasoline (Dougher *et al.*, 1990).

The only systematic test of motor vehicle octane needs is conducted by the Coordinating Research Council (CRC), a non-profit organization funded principally by the auto and oil industry. CRC found that 20% of new cars required 88 octane or more in 1988; and 19% in 1989 (CRC, 1989-1990). But these CRC tests tend to overstate octane requirements (and premium gasoline needs). As noted above, the tests are conducted by trained raters who are sensitive to knocking and pinging. CRC categorizes vehicles as needing higher octane if any knocking is detected in a vehicle, even though automotive engineers note that small amounts of knocking and pinging do not hurt the engine. In fact, an engine is operating most efficiently when it knocks on hills and during hard acceleration. In follow-up studies, CRC found that only about half as many normal (i.e., untrained) drivers detect knocking as trained raters (CRC, 1989).

In conclusion, arriving at a precise and accurate measurement of premium gasoline overbuying is impossible. We can, however, say with great confidence that consideable premium ovebuying did occur. Even using the most conservative results, we find that premium gasoline sales exceed actual vehicles needs by a large margin.

Revealed Preference Survey

To understand why so many drivers overbuy premium gasoline, we conducted a survey of drivers in the household market. The questionnaire was mailed in late February 1989 to 5000 households, split equally between New York state and California Follow-up postcard reminders and questionnaires were mailed through March. The names were randomly selected from a population of registered owners of cars (light duty trucks were

excluded), the list was purchased from R.L. Polk, Inc. Each respondent was asked to respond to the car specified in the cover letter or to the car that had replaced it. The questionnaire elicited information on car attributes, fuel purchase behavior, attitudes and beliefs regarding premium fuels, and socio-economic and demographic characteristics of respondents and their households. (For more detail and other survey findings, see Sperling et al., 1993).

A total of 1859 usable surveys were received; an additional 505 were undeliverable, 78 were returned by owners of leaded-fuel car or unleaded car owners who regularly engaged in misfueling, 11 were returned by diesel car owners, and 6 were returned blank, giving a final response rate of 42%. The mix of vehicle make and model years in the returned questionnaires were not significantly different from those not returned (at the 5% level), suggesting that the sample does not contain self-selection bias.

Test Results vs Actual Usage

When respondents were asked to state the gasoline grade they used in the identified vehicle, 29% (534/1859) stated they always used premium gasoline; 14% used premium gasoline more than half the time (264/1859); and 34% (636/1859) used premium gasoline less than half the time. This self-reported usage of premium gasoline is more than, but close to actual sales recorded during the time the survey was conducted: 33% of total unleaded gasoline sales in California, and 44% in New York (EIA, 1989).

This usage of high octane fuels was considerably higher than CRC studies suggest is necessary. As shown in Table 1, drivers of every model year vehicle consume more high octane gasoline than deemed necessary by CRC.

Octane Requirement Increase (ORI)

Octane requirement increase is especially prevalent in newer engines. CRC tests vehicles at zero, 5,000, 10,000 and 15,000 miles. CRC finds that octane requirements typically increase about 4-5 points in modern engines over the first 15,000 miles, and then stabilize (Callison et al., 1989).

This large amount of octane requirement increase (ORI) in newer vehicles is deceptive, however, because these newer model year vehicles also have lower octane needs when new than did older model years, as indicated in Figure 3.

Table 1   CRC-Measured Premium Gasoline Needs vs. Reported Premium Gasoline Usage in Survey, 1989 Mix of Vehicles

Model Year	% of Vehicles Needing Premium Gasoline (>90 octane), CRC[a]	% of Vehicles Using Premium Gasoline 100% of Time, Survey[b]	Difference
1975	25	33	+ 8
1976	24	26	+ 2
1977	26	31	+ 5
1978	25	26	+ 1
1979	29	36	+ 7
1980	25	30	+ 5
1981	23	23	0
1982	22	32	+10
1983	24	30	+ 6
1984	22	28	+ 6
1985	18	27	+ 9
1986	17	31	+14
1987	17	24	+ 7
1988	16	30	+14
1989	15	35	+20

a Coordinating Research Council, *Octane Requirement Increase* (CRC, 1978-1980; 1982, 1983a-b, 1984-86; 1991a), and Callison *et al* (1989)

The CRC percentage was based on *average sensitivity* full-boiling range unleaded (FBRU) reference fuels which have similar sensitivities to those of commercial gasoline

The CRC percentages were estimated from the unweighted distribution of 15,000-mile best-fit octane number requirements, (RON+MON)/2, for the corresponding model year   We constructed the distributions from the test results of individual vehicles provided by the CRC in Appendix D of their reports on octane requirement increases   The data are expressed in the research octane number (RON) index, so we converted them to an (RON+MON)/2 basis using conversion factors in their Appendix C.

Octane ratings of greater than 90 are used here for premium gasoline, rather than the 91+ used by EIA, so as to account for gasoline otherwise falling between midgrade (88-90) and premium (91+)

b Includes only exclusive users of premium gasoline (n=534)

Fig. 3 Octane Number Requirement Trends, New Vehicles, 1975-89
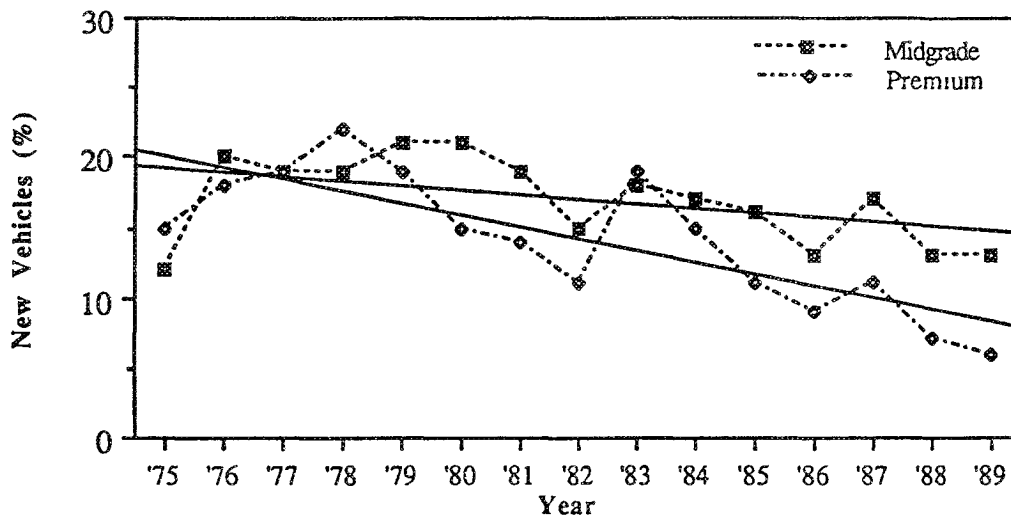
Source: Estimated from the CRC, *Octane Number Requirement Survey*, (various issues)

THE CORE GROUP OF PREMIUM BUYERS IS SMALL

As a first step toward understanding the motives and buying stability of premium fuel buyers, we asked respondents to select from a list their three most important reasons for buying "higher-grade" gasoline. Their responses support the hypothesis that a relatively small number of premium gasoline (91+ octane) buyers truly need premium gasoline.

Listed in Table 2 are the reasons given by habitual users (those who used 91+ octane premium gasoline at least half the time) for purchasing premium gasoline. We identify the core group as including the 22% of habitual premium users who gave the following first reason for buying premium gasoline:

Car knocks or pings without higher grade unleaded (HGU) (16.6%)
Car runs so poorly on regular that I have to use HGU (5.0%)
Car "diesels" or "runs-on" when not using HGU (0.7%).

We note that the 22% of users identified above owned a disproportionate number of older cars (66% of the vehicles were 6 years or older compared to 40% for the sample population), and that older vehicles are susceptible to ORI.

TABLE 2 Reasons for Buying Premium Gasoline

No.	Responses	Reasons (%)*		
		First	Second	Third
1.	My Owner's manual recommends a Higher Grade Unleaded (HGU)	14 3	9.7	7.0
2.	I try to buy gasoline which has a high octane number	7.2	14.6	12 9
3.	I try to buy gasoline which has a detergent additive	2.9	5.9	10 9
4.	A mechanic (dealer) recommended I use a HGU	4.1	9.8	7.5
5.	A friends (acquaintance) recommended I use a HGU	0.9	2.8	4.5
6.	Based on my own experience, my car runs better on a HGU	42.3	21 5	13.8
7.	My car "knocks" or "pings" when I do not use a HGU	16.6	16 2	8.6
8.	My car "diesels" or "runs-on" after I turn off the ignition when I do not use a HGU	0 7	3 6	6.1
9.	I could use unleaded regular, but I prefer a HGU	6.0	10 4	18.9
10.	My car runs so poorly on unleaded regular that I have to use a HGU	5.0	5.5	9.8

Note: *Calculated based on exclusive users of premium gasoline of 685, 642, and 603 for First, Second and Third respectively; figures in columns may not sum to 100 due to rounding

Other reasons -- listed in Table 2 -- for purchasing premium gasoline are not as compelling as the three listed above. For instance, even though 14.3% said they purchased premium because it was recommended by their owner's manual, we know that very few owner manuals recommend the use of high octane gasoline; in this case, a partial explanation may be that the manuals of some older cars recommended gasoline octane in the RON index (RON is higher than (RON+MON)/2). Other reasons, such as searching for a high octane number, or that premium was recommended by others, suggest that the purchase is not based on any direct functional need.

The response that "based on my own experience, my car runs better on a HGU" is more difficult to discern; clearly this response may include some cars that have excessive pinging or knocking with regular gasoline, but it probably includes a large proportion of drivers who are reacting to minor pinging and knocking.

Indeed, of those premium users who checked the response that the most important reason for buying premium gasoline was that their car runs better, 80% agreed or strongly agreed with the statement "I could use unleaded regular, but I prefer a higher grade unleaded," and 60% disagreed or strongly disagreed with the statement, "My car runs so poorly on unleaded regular that I have to use a higher grade unleaded."

We conclude that the core group is about 22-40% of habitual premium users -- the 22% identified above, plus about 2/5 of the 42% who ticked the response "Based on my own experience, my car runs better on a HGU."

Perceived Non-Octane Benefits of Premium Gasoline

These responses reaffirm the observation that many drivers are buying premium gasoline on vague premises. Although octane rating is technically the single most important distinguishing attribute of premium gasoline, many consumers do not purchase premium gasoline for its higher octane. Many people are absolutely convinced that high octane gasoline gives them better fuel economy and power.

One claim is that low octane fuels in high compression engines causes so much knocking that performance and fuel economy are impaired. Few vehicles fall in this group.

Another argument is that cars with knock sensors will have better performance and fuel economy with premium gasoline. Knock sensors are becoming increasingly common; they were found on about 14% of 1983 model year vehicles, increasing to 40% in 1989 (CRC, 1989-1990). A trade journal, Octane Week, suggests that such vehicles will gain 10-15% power at high speeds (around 60 mph) with premium, and a 1% improvement in fuel economy for each octane number (Douthit, 1992) One CRC study found that some vehicles equipped with knock sensors do indeed have improved acceleration when tested on higher octane fuels than normally used (CRC, 1991b).

The fuel economy claim is especially suspect. Another study sponsored by CRC, with participation by both auto and oil companies, found "...no significant improvement in fuel economy for any of the vehicles when using premium relative to regular octane quality fuel. In fact, several vehicles showed an unexplained decrease in fuel economy when using premium compared to regular octane quality fuel" (McNally et al., 1989). This finding is not definitive, since only 14 vehicles were included in the test.

In summary, this first part of the paper found the following: driving tests have shown that many cars do not actually need high octane gasoline, the purported performance and fuel economy benefits of premium gasoline have not been substantiated, aggregate market analyses show that premium demand is highly elastic, and our survey shows that many drivers have only a vague (and oftentimes mistaken) perception of the benefits of premium gasoline.

In the next section of this paper, we analyze the willingness of consumers to pay for premium fuel, and explore differences across the population.

WILLINGNESS TO PAY FOR PREMIUM GASOLINE

The willingness of consumers to pay for premium gasoline was estimated using the contingent valuation method (CVM). The basic premise of CVM is that a good, market, and payment technique are described to a respondent who then bids how much he/she is willing to pay for that good under those conditions (Cummings and Brookshire, 1986). In dichotomous choice CVM, each respondent is asked to accept or reject one particular good at a specified price (bid): "Yes, I would pay that amount" or "No, I would not pay that amount" (Hanemann, 1984; Loomis, 1988). In this study, eight different bid amounts were specified. Individual respondents were randomly assigned to one bid. There are three questions in the survey which deal with consumers' willingness to pay.

The Logit Model and Variable Specification

We use a logit model, and create design variables using the "partial method". This partial method has been widely utilized in epidemiology research, whereby one group in the sample is treated as the reference group and the other as the exposed group(s). The ease of interpreting the results make it a more popular technique than its counterpart, the "marginal method." (see Dixon, 1983).

To analyze demand for premium grade fuel, willingness-to-pay for octane is treated as a dependent variable Responses were coded as zero if the respondents were not willing to pay at a given price (bid amount) and one if they were. In the survey design, we identified 7 independent explanatory variables that might influence the premium fuel purchase decision; in Table 3 they are organized into two subgroups.

Table 3 Variables Used in The Model

No.	Variable	Definition	Values[c]
A.	_Dependent Var._		
1.	Premium (PRM)[a]	willingness to pay for unleaded premium gasoline	0=no 1=yes
B.	_Independent Var._		
2.	[b]Log of bid (LBID)	log of bid amount (in dollars)	log (0.02) log (0 05) log (0.10) log (0.15) log (0 20) log (0.25) log (0.35) log (0.45)
	Sosioeconomic & Demographic Attributes		
3	Income (INC)	annual household income before tax	1=$0-$24,999 2=$25,000-59,999 3=>$59,999
4.	Gender (SEX)	sex of respondent	0=female 1=male
5.	State (STA)	respondent's domicile state	1=New York 2=California
	Car Attributes		
6.	# Cylinders (NCYL)	number of cylinders	1=3 or 4 cylinders 2=5 or 6 cylinders 3=8 cylinders
7.	Fuel injection (FINJ)	fuel-injection equipped cars	0=no 1=yes
8.	Domestic (USA)	cars sold under GM, Ford or Chrysler nameplates	0=no 1=yes

Note:[a] Abbreviation used in estimated logit function
[b] A continuous variable.
[c] The lower or lowest value in each discrete independent variable is treated as _reference group_

The first subgroup includes three socioeconomic and demographic variables Income was measured as household income before taxes in 12 intervals, but was collapsed into three categories here: $24,999 or less, $25,000 to $59,999, and more than $59,999 The other two variables -- gender and state of residence -- are binary variables.

The second subgroup of independent variables are car characteristics which may affect a driver's choice of fuels. The three variables are engine size, measured as number of cylinders (3-4, 5-6, and 7 or more cylinders); fuel injection; and vehicle manufacturer,

measured as domestic versus foreign, where domestic includes all vehicles sold with General Motors, Ford and Chrysler nameplates.

Response rates (see Appendix) were not significantly different for the eight bids, ranging from 11.5% to 13.6% of the total sample for each bid amount; nor were differences in the basic demographic variables (income, gender and state of residency) statistically significant.

Some questions in our survey were not answered, which threatens to reduce the usable sample size considerably and thereby lead to less efficient estimates, and to create possible biases (Little and Rubin, 1987). The sample size would be reduced to 85% if questionnaires that contained missing values were deleted. An attempt has been made to impute those missing values. Four out of the seven independent variables have at least one missing value.

We used single imputation -- the assignment of values to missing observations -- to replace missing values. It is the easiest and most commonly used technique for handling non-response, but has the drawback of leading to underestimation of variance and therefore a tendency to accept a hypothesis when it should be rejected. In general, though, single imputation is adequate and has been widely utilized (Rubin, 1987). Several techniques were used to impute values, including logistic regression, and mean value method.

MODEL ESTIMATION

The model was estimated twice: for the entire population sample, and for all drivers who stated that they use premium gasoline at least half the time (habitual users).

To measure willingness to pay for premium gasoline, we asked "Would you use unleaded premium if it was priced [bid amount] higher than unleaded regular?"

Expected Willingness-to-Pay for Premium Gasoline

We used a logit model to estimate the willingness of consumers to pay for premium gasoline, and included, first, the entire population sample in the analysis and then habitual users only. The parameters were estimated with only bid amount as an independent variable, since we are interested in how the predicted probabilities would vary with price

(bid amounts). The area under the predicted probability curve is the expected value of the maximum WTP for premium.

Mathematically, the expected value is the integral (or sum) of the cumulative distribution function (figures shown are for those who used premium at least half the time).

$$\hat{f}(x) = 2.815 - 7.234 \, x \tag{1}$$

$$WTP = \int_0^\infty [1 - F_\varepsilon(x)] \, dx = \$ \, 0.39 \tag{2}$$

where: $\hat{f}(x) =$ the estimated logit function

$x =$ bid amount (in dollars)

$WTP =$ maximum willingness to pay (the expected value)

$F_e(x) =$ cumulative distribution function of the error term

The calculated expected value is 20 cents for the entire population and twice that much, close to 40 cents, for habitual users. Given that premium gasoline is usually 4-5 octane points higher than regular gasoline, this analysis suggests that on average consumers are willing to pay 4-8 cents more per octane number.

Can this be true? First we consider the validity of the method, then the accuracy of the interpretation.

The weakness of contingent valuation methods is the bias associated with hypothetical choice questions. Bias is the result of respondents not being familiar with the good or service and, because they know that they will not be bound by an expression to pay, overstating their willingness to pay.

Unfamiliarity was not a problem; consumers have been exposed to extensive advertising for premium gasoline, and routinely face the purchase choice.

We tried to reduce the bias of overstated willingness to pay by using dichotomous choice bidding, creating a more market-like setting for the respondent. Even so, as indicated below, the expressed willingness to pay was somewhat greater than actual behavior witnessed in the marketplace.

Fluctuations in gasoline prices that took place shortly after the survey was administered provides a range of values to test our findings. In Figure 4, monthly premium gasoline sales as a function of average gasoline price is plotted for July 1990 to February 1991 during the time of the Iraqi invasion and occupation of Kuwait when prices rose and then declined. Average gasoline price is an appropriate measure for the independent variable in this case since the price differential between gasoline grades did not vary much during this period.

As shown in Figure 4, the estimated willingness to pay calculated from our survey data is similar to actual sales data.

Fig. 4 Premium Gasoline Demand, Survey Results vs. Market Data (July 1990 to February 1991)

Retail Gasoline Price (including taxes, $/Gallon)
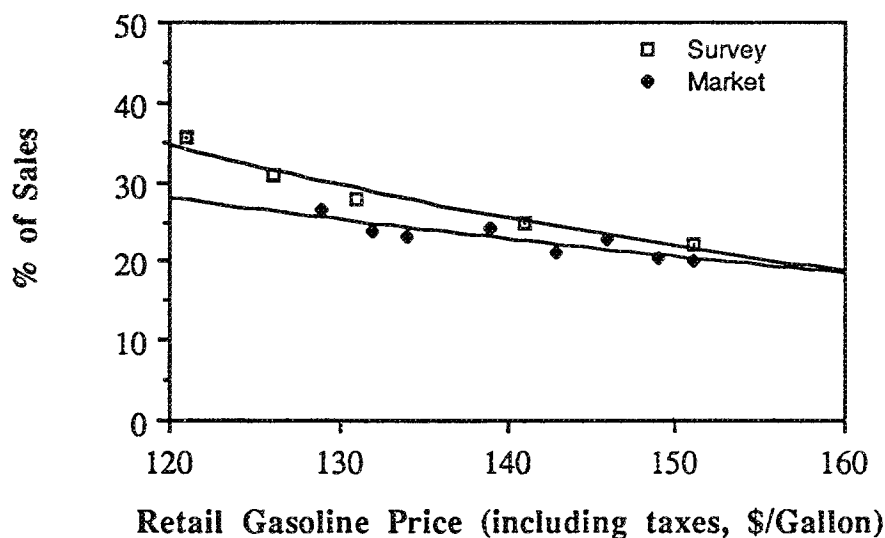
Note: Market data were estimated from EIA, *Petroleum Marketing Monthly*, Tables 34 and 43, DOE, Washington, D C , (Aug '90-May '91)

The lowest price was recorded in July 1990, and the highest in October 1990 Sales percentages for market data are a ratio of premium sales—both in NY and CA—and total unleaded gasoline, while survey figure represents a ratio of habitual premium users and total users

Prices for market data points are weighted averages and inflation adjusted (1989 $)

Other Findings

The logit model was reestimated for habitual users of premium gasoline, with seven independent variables (Table 4). The likelihood ratio test leads us to reject the null hypothesis that all variables have zero slopes with 5% level of significance This is shown in Table 4, where the calculated likelihood ratio equals 249.84 asymptotically distributed as chi-square, with df = 9, which is significantly larger than 16.92.

As expected, the log of the bid amount was strongly correlated with willingness to pay (Table 4). The minus sign in this variable shows that as bid amount increases, the willingness to pay decreases. This lends further support to our hypothesis that premium prices have been a major factor in consumer purchase decision. The last column in the same table is the odds ratio, which can be interpreted as the likelihood of a consumer to buy premium for a unit change in the log bid variable.

Income was associated with willingness to pay, although not as strongly as we expected. The highest income group, with a higher odds ratio, is more willing to pay for premium than the lower group, which has a lower odds ratio. This finding is consistent with data from a national survey of residential transportation energy consumption, in which only a weak relationship was found between income and the type of gasoline purchased (DOE, 1991).

We found that gender is strongly related to willingness to pay. Everything else equal, males are willing to pay only about 63% as much as females for premium gasoline (see the corresponding odds ratio) (Table 4). This behavioral difference is not explained by responses to the question regarding the reason for buying premium gasoline, nor by vehicle attributes (new versus used, model year). The only explanatory variable with significant differences between men and women was "mechanical inclination." On a scale of zero (not at all) to 10 (very inclined), only 11% of female drivers considered themselves as highly mechanically inclined (7-10 on our scale), versus 49% for men.

This analysis suggests that lesser mechanical knowledge (and/or confidence) by female drivers may be the motivating factor in their decision to spend a little more for fuel. Perhaps female drivers consider the extra cost to be an inexpensive form of insurance against mechanical failures.

Table 4 Estimation Results for Premium Gasoline WTP Model

No	Variable	Estimated Coefficient	Standard Error	t-statistic	Odds ratio
1.	Constant	-2.6408	0.3907	-6.759	0.071
2.	Log of bid[a]	-1.6766	0.1478	-11.344	0.187
A.	*Socioeconomic & Demograpic Attributes*				
3.	Income (1)[b]	0 1791	0.0812	2.206	1.196
	(2)	0 2144	0.0824	2.602	1.239
4.	Gender	-0.4657	0.1261	-3.693	0.628
5.	State	-0.5612	0.1314	-4.271	0.571
B.	*Vehicle Attributes*				
6.	# Cylinders (1)	0.3798	0.1215	3.126	1.462
	(2)	0.5093	0.1786	2.852	1.664
7.	Fuel injection	0.4723	0.1442	3.275	1.604
8.	Domestic	0.1256	0.0938	1.339	1.133

Summary statistics:

Number of observations =798
Number of cases = 781
$L(0) = -779.13$

$L(\beta) = -654.210$

The Estimated Logit Function:

$$\hat{f}(x) = -2.641 - 1.677 \text{ LBID}^c + 0.179 \text{ V}_{21} + 0.214 \text{ V}_{22} - 0.466 \text{ SEX} - 0.561 \text{ STA}$$
$$+ 0.380 \text{ V}_{61} + 0.509 \text{ V}_{62} + 0.472 \text{ FINJ} + 0.126 \text{ USA}$$

Note: [a] In dollars

[b] Figures in parentheses correspond to design variables

[c] See Table 3 for definition

An analysis of premium gasoline demand by location indicates that New Yorkers are more willing to pay for higher grade fuel than Californians (Figure 5). This difference is explained in part by the fact that New Yorkers drove cars that were larger (measured here by number of cylinders) and older, hence requiring higher octane, and drove less, thus

being less sensitive to the higher per-gallon prices of premium Another explanation is the adverse weather in New York· New Yorkers responded more strongly to a question relating adverse weather to premium gasoline use. Still another explanation may be that historically higher gasoline prices in New York may have conditioned drivers there to a greater willingness to pay higher prices. In any case, actual sales data reported earlier support this analytical finding that New Yorkers are more inclined to purchase pricier premium gasoline than are Californians.

Fig. 5   WTP for Premium Gasoline
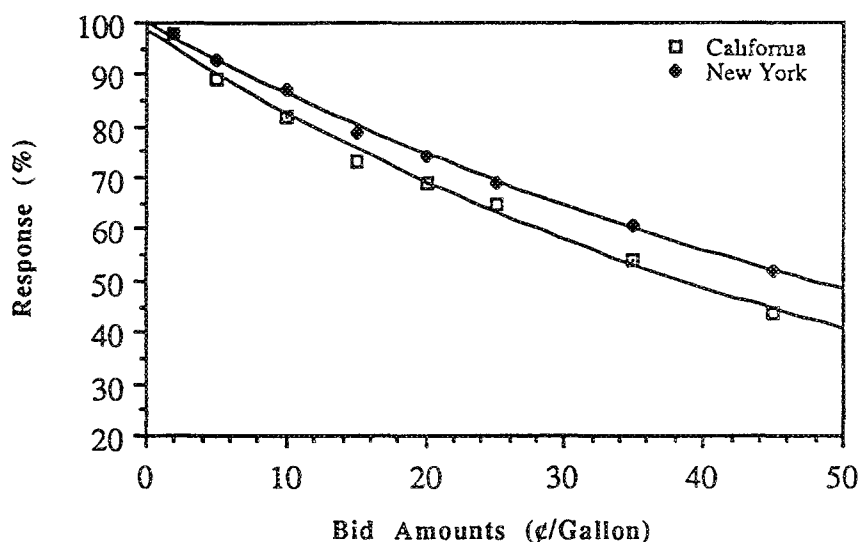
Another finding from this analysis is that drivers of fuel-injected cars are more likely to purchase premium gasoline than those without fuel injection, all else being equal. This preference is partly explained by the historically greater use of detergent additives in premium gasoline to keep the very narrow passages in modern fuel injectors clean (Consumer reports, 1990). Greene (1990) also observed this same relationship.

We did not find a statistical difference between owners of domestic and foreign nameplate cars in willingness to pay for premium fuel, possibly because this differentiation is becoming increasingly irrelevant as U.S., Japanese and European auto manufacturers

continue to integrate and homogenize their products, producing more similar cars, jointly producing vehicles, and participating in marketing alliances.

CONCLUSION

The evidence is overwhelming that overbuying of premium gasoline did occur (and continues to occur). Although the exact magnitude is difficult to specify, it is clear that premium gasoline is seen as offering more benefits than in fact it does provide -- for many if not most buyers. For many, payment of 10-20 cents per gallon is a minor cost, especially given the small and shrinking cost of gasoline in vehicle ownership. Premium gasoline is seen as improving performance and fuel economy, improving reliability, and just taking good care of a very large household investment.

These perceptions and valuations of benefits vary relatively little across the population. Demand for premium is greater with more affluent individuals, but cuts across all income groups, and is greater with women and in some regions than others. As a luxury good, demand is elastic, sensitive to modest gasoline price shifts.

The primary lesson is that if a fuel can be positioned as a premium fuel, then consumers will pay substantially more for that fuel. In the case of high octane fuel, many people buy it for rather vague reasons; clearly, they do not need strong evidence or justification -- as long as the extra cost is not perceived to be substantial, which apparently it has not been in recent times.

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APPENDIX:

Response Rate by Bid Amounts

Bid Amount ($)	Response Frequency	Relative Frequency (%)	Cumulative Frequency (%)
0.02	99	13.4	13.4
0.05	84	11.3	24.7
0.10	90	12.1	36.8
0.15	88	11.9	48.7
0.20	101	13.6	62.3
0.25	101	13.6	75.9
0.35	85	11.5	87.4
0.45	93	12.6	100.0