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Selling costs and switching costs: explaining retail gasoline margins

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Recent theoretical work has shown that price discrimination can take place in imperfectly competitive, as well as monopoly, markets. The persistence of higher retail margins on unleaded than on leaded gasoline during the 1980s suggests that discrimination may occur even in very competitive markets. This article studies a number of cost-based explanations for such gasoline pricing, as well as the possibility of price discrimination. The analysis indicates that gas stations discriminate against groups of customers who are less likely to switch to another station. The conclusions highlight the influence of shopping or search costs on pricing decisions, even in markets thought to be quite competitive.

1. Introduction

■ Throughout the 1980s, retail margins on unleaded regular gasoline exceeded margins on leaded regular gasoline. In 1987, for instance, wholesale prices of the fuels were nearly equal, but the retail price of unleaded gas averaged five cents greater than the retail price of leaded gasoline. The average difference in margins on self-service sales expanded from about one cent in 1980 to nearly six cents in 1986, and then declined back to about two cents by the end of the decade.[1] In some areas, the relationship has even reversed now, with the margin on leaded gasoline exceeding the margin on unleaded gasoline. In this article I analyze a number of possible explanations for the differences in retail margins between leaded and unleaded gasoline and for the changes in these differences over time.[2]

The difference in retail margins could indicate that the industry departs significantly from the perfectly competitive ideal. In markets where firms are heterogeneous, differing by location for instance, it is well understood that sellers can exercise market power without

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[1] During the decade, the chemical differences between the two fuels narrowed substantially. Due to changes in government regulation, the average lead content in leaded gasoline declined from 1.24 grams of lead per gallon in 1980 to 0.31 in 1986, and to just 0.09 in 1988.

[2] The term "margin" is used to mean $P_r - P_w$, retail minus wholesale price. Although margin is highly correlated with the retail markup, $(P_r - P_w)/P_r$, and standard microeconomic theory might suggest focusing on markups, I discuss the retailer behavior in terms of margins, for reasons explained below.

necessarily earning economic profits. Recent theoretical works by Katz (1984), Borenstein (1985), and Holmes (1989) demonstrate that price discrimination can persist in such markets.[3] Discrimination in these markets differs from monopoly price discrimination, because it can stem not only from variations in buyers' valuations of the product, but also from variations in the buyers' willingness to switch sellers, i.e., differences in cross elasticities of demand among sellers in the market. Since 1986, many stations have stopped carrying leaded gas. This has increased the average distance between sellers of leaded gasoline relative to the average distance between sellers of unleaded, and thus has raised the search costs of buyers of leaded gasoline relative to those of unleaded buyers. I use variation in the estimated proportion of stations that carry leaded gasoline to study the impact of heterogeneous switching costs on margin differences.

The margin differences could also be based upon differences in the costs of selling gasoline to these different types of buyers. I consider a number of cost-based explanations. Some of these relate directly to the marginal costs of serving different types of buyers, while others reflect possible differences in the average fixed costs of carrying each type of fuel. I also examine strategic explanations for the margin differences, particularly those that focus on the pricing of one type of gasoline to signal a retailer's prices on its other products.

Some of these hypotheses lend themselves to rigorous statistical tests; others must be evaluated by their consistency with the basic facts of the market and its evolution. I conclude that the most plausible explanation for the cross-sectional and time-series pattern of margin differences is that gasoline stations have some local market power and that they price discriminate against customers who are less likely to switch stations, i.e., those who have a low cross elasticity among sellers. The presence of price discrimination in such a competitive market suggests that the degree of market power necessary to support price discrimination is far less than that generally associated with monopoly.[4]

2. Explanations for margin differences in gasoline retailing

■ All of the explanations for the differences between unleaded and leaded gasoline margins are fairly straightforward, though some may be difficult to distinguish empirically. This section presents each theory and explains how it might lead to the pattern of margin differences that was observed in the 1980s. Section 3 discusses the data and presents some summary statistics about the buyers and prices of leaded and unleaded gasoline. In Section 4 I derive and implement a test of the price discrimination hypothesis.

□ **Price discrimination.** If a gasoline station faces different elasticities of demand from different groups, and if buyers cannot easily resell the product or switch between groups—as would be the case for most owners of cars that use unleaded fuel who do not wish to damage their catalytic converters—then margins are likely to differ across groups of purchasers. Borenstein (1985) presents such a model of price discrimination when buyers are heterogeneous and free entry drives profits in the industry to zero. The results are largely consistent with Holmes' (1989) work in which he solves for a noncooperative duopoly equilibrium with price discrimination. In both studies, price discrimination is not eliminated, or necessarily even retarded, by the presence of competitors.

A gasoline station may face different demand elasticities from unleaded than from leaded gasoline buyers, either because the groups differ in their elasticity of demand for the good or because they differ in their willingness to switch sellers of the good. Using a char-

[3] See Varian (1989) for a review of nonmonopoly price discrimination theories.

[4] Shepard (1991) reaches a similar conclusion in studying the retail gasoline industry, as do Borenstein and Rose (1991) in studying the domestic airline industry.

acteristic-space model of monopolistic competition, Borenstein (1985) distinguishes these two bases for discrimination as differences in reservation price for the good at the buyers' most preferred points and differences in the cost or utility loss from buying a product away from the buyers' most preferred points. Holmes generalizes these aspects of heterogeneity and puts them in more familiar terms, calling them differences in "industry elasticities" for the product and differences in "cross elasticities" among sellers.

Salop (1979) points out that the nature of competition will depend on what buyers perceive to be the alternatives to their most preferred actions in the market. If most consumers' next-best alternative to buying from a given seller is not to buy from any seller in the market, then most purchases are made under monopolistic conditions. In that case, Borenstein (1985) concludes that price discrimination in the market will be based on differences in buyers' values of the product, what Holmes terms differences in industry elasticities. On the other hand, if most purchases are made under competitive conditions—meaning that a company's marginal consumer is just indifferent between buying from it or a competing seller in the market—then the dominant source of price discrimination is likely to be heterogeneity in costs of switching sellers (heterogeneity in cross elasticities, using Holmes' terminology).

These two types of price discrimination can be difficult to distinguish empirically, because the variables that would be used to reveal a buyer's cost of switching among sellers or searching for low prices, e.g., income or employment status, would also be correlated with his reservation price. In recent years, however, the cost of switching sellers has increased for buyers of leaded gasoline as a result of a change that is not directly related to their demographic characteristics. Since 1985, when nearly all stations carried both types of regular gasoline, the proportion of stations that sell leaded gasoline has declined. The average distance between sellers of leaded gasoline has increased and, more important, has ceased to be equal to the average distance between sellers of unleaded gasoline.[5] If buyers' costs of switching retailers are important determinants of the margin on gasoline, then an increase in the distance between sellers of leaded gasoline, without a similar change in the distance between sellers of unleaded gas, would be expected to increase the margin on leaded gas relative to the margin on unleaded gas. In the empirical section, I use information on the share of gasoline in an area that is leaded, and some direct information on the share of stations carrying leaded gasoline, to diagnose price discrimination based on heterogeneity in switching costs.

□ **Cost-based margin differences.** The cost-based explanations for margin differences take two basic forms, only one of which presumes a perfectly competitive retail gasoline market, where prices will equal short-run marginal cost at all times. The explanation consistent with perfect competition is that, on a per-gallon basis, the marginal cost of serving a purchaser of leaded gasoline is lower than the marginal cost of serving a purchaser of unleaded gasoline. This could be the case if (1) some costs of serving a customer are not related to the size of purchase,[6] such as the cashier's time at a self-service station or the attendant's time to clean windshields, check oil, etc., (2) stations collect revenues for these indirect costs through their linear prices of gasoline, and (3) buyers of leaded gasoline buy larger quantities of gas per visit than buyers of unleaded gasoline.[7] The first proposition is likely to be true to some extent at least. Evidence of the second proposition comes from the fact that stations do not charge a fixed price for full service, but rather just increase their margin on the gasoline

[5] These average distances had been equal for the buyers of each type of fuel since stations were first required to carry unleaded gasoline in the mid-1970s.

[6] Or, some costs increase with size of purchase, but less than linearly.

[7] Lott (1991) suggests this as one possible cost-based explanation for the leaded/unleaded price difference, though he offers scant empirical support.

purchased.[8] The third proposition is an empirical question that I address in the next section. The per-gallon cost of serving buyers of unleaded gasoline could also be greater if they tend to pay by a method that is more costly for the station owner to process, namely credit card. I shall examine this explanation as well.

An alternative cost-based explanation focuses on differences in average fixed cost. If stations have similar fixed costs associated with carrying each type of fuel and if they sell more of one type of fuel than another, then the fully allocated or average cost of selling a fuel at lower volume will be greater per gallon than that of a more popular fuel. The explanation can be seen by considering the expected outcome if there were completely separate markets for leaded and unleaded fuel. As the demand for leaded fuel declines, some leaded-fuel firms leave the market. Without some imperfection in competition, however, the long-run equilibrium price still remains at minimum average cost, which is unchanged by a decrease in demand for the product. All adjustment occurs through changes in the number of firms. With monopolistic competition, it is possible that some firms will exit and others will slide up (reduced per-firm quantity) or down (increased per-firm quantity) their average cost curves, resulting in a higher or lower price in the new zero-profit equilibrium. The effect on price, or margin, will depend on the shape of each firm's average cost curve and the change in the elasticity of demand that each firm faces. Since the result will depend on the demand elasticity faced by each firm, this theory is difficult to fully separate from price discrimination. So long as all stations continue to carry leaded gasoline, the average-cost explanation is consistent with increases in the relative margin on leaded gasoline as its use declines, but the result of the argument is ambiguous if some stations drop the fuel, because the volume sold by the remaining stations could increase or decrease. When all stations do carry both fuels, the average cost explanation implies a precise relationship between margins and the relative volume of each grade of gasoline sold, as discussed in the following section.

Some of the trade publications in the service station industry have stated that the low margin on leaded gasoline reflects its use as a "loss leader" or "fighting brand." These two terms seem to have nearly the same meaning in reference to the gasoline market, though neither is used to mean exactly the same thing as it has in the past.[9] The argument is that gas stations post low prices for regular leaded gasoline to signal, accurately or not, that they offer low prices on all grades and types of gasoline that they sell. Thus, the theory goes, buyers of unleaded and premium gasolines will infer the relative prices of their types and grades of gasoline from the stations' prices for leaded regular gasoline. If competition among stations can occur only, or most easily, on leaded regular gasoline, then this explanation may be credible, but one must ask why stations with lower prices on unleaded gasoline don't post those prices as well or instead. In fact, most stations now do post their prices for unleaded regular gasoline and have for many years.[10]

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[8] The full-serve/self-serve differential cannot explain the margin differences between leaded and unleaded gasoline, however, because the differential exists separately for full-serve and self-serve purchases of each product.

[9] The reference to loss leaders in gasoline retailing does not usually mean that the price is intended to induce buyers to enter the station so that they will buy other products as well as the one advertised at a low price. This traditional use of the term does have some application to stations that sell other products as well, i.e., those with convenience stores or service bays. The latter is unlikely to explain margin differences at self-service stations, most of which do not perform maintenance. The former is unlikely to be an explanation, because the latest data available (1988) indicate that convenience store/gas stations still account for less than 7% of volume nationwide. In either case, even if these were significant incentives, it is not clear why drivers of "leaded" cars would be better prospects to attract. Similarly, fighting brand may not have the same implication as it did in the cigarette industry at the turn of the century, when the American Tobacco Company used a discount brand to appeal to the most price-sensitive buyers who would otherwise switch to other companies that produced only lower-quality brands.

[10] Nalebuff (1987) notes the higher average margin on unleaded than on leaded regular gasoline and suggests two possible explanations: the "loss leader" theory and the possibility that stations discriminate based on differences in search costs.

3. Some facts about gasoline consumers and prices

■ In this section, I present aggregate demographic data about the buyers of leaded and unleaded gasoline and data on U.S. average prices and margins for each type and grade of gasoline. These data cast doubt on the likelihood that the cost-based theories discussed in the previous section could substantially explain the pattern of margin differences over time. They also give preliminary support to the view that price discrimination explains at least part of the differences in margins.

The data on buyers is from NPD, Inc.'s panel study of the gasoline-purchasing behavior of 5000 families from 1980 to 1984. This panel study includes data on characteristics of the families, the cars they own, and the gasoline purchases they make, including size of purchase, grade and type of gasoline, and method of payment. Table 1 presents averages for segments of the purchasing population during two time periods.[11]

The most notable contrasts are that buyers of leaded gasoline are poorer than unleaded buyers and are somewhat less likely to use a credit card.[12] The income differences seem to widen substantially between 1980 and 1984. Buyers of leaded gasoline do not seem to make consistently smaller or larger purchases than unleaded buyers, and in no case do average

TABLE 1 Characteristics of Regular-Grade Gasoline Purchasers, 1980 and 1984

	Sample Size	Average Gallons Purchased	Average Age of Buyer	Average Age of Auto	Average Family Income	Percent Using Credit Card
1980						
Lead, self-serve	98978	10.2	45.2	7.2	$33,017	25.6%
Unlead, self-serve	50512	10.5	46.6	2.7	$37,347	29.9%
Lead, self-serve, premium	6129	10.2	45.4	9.6	$34,375	37.0%
Unlead, self-serve, premium	7068	10.4	46.7	3.3	$35,983	40.0%
Lead, full-serve	60477	10.1	44.8	7.6	$30,411	30.2%
Unlead, full-serve	42228	10.8	48.0	3.0	$38,027	38.9%
Lead, full-serve, premium	5559	10.7	45.0	9.0	$36,506	38.6%
Unlead, full-serve, premium	8989	11.0	45.9	3.6	$36,853	44.1%
1984						
Lead, self-serve	61580	11.0	46.9	9.9	$29,379	21.9%
Unlead, self-serve	95652	10.4	47.9	4.1	$36,584	27.7%
Lead, self-serve, premium	1516	11.0	49.5	11.2	$32,965	22.4%
Unlead, self-serve, premium	23267	11.0	47.4	4.6	$36,176	35.4%
Lead, full-serve	19230	10.1	46.2	10.4	$27,538	22.6%
Unlead, full-serve	34653	10.1	47.9	4.6	$35,454	29.6%
Lead, full-serve, premium	637	12.3	54.0	11.6	$29,299	42.1%
Unlead, full-serve, premium	12798	10.6	46.9	4.9	$35,916	38.4%

All figures except gallons purchased are weighted by gallons purchased.
Average family income figures are in January 1989 dollars.
Standard errors of all averages or percentages are less than 0.5% of the estimates.

[11] Data from the first half of 1980 could be distorted by residual effects from the gasoline shortages and rationing that began in the summer of 1979. For this reason, Table 1 is constructed only using data from the second half of each year.

[12] The family income figures could be distorted by differences in family size, but these differences are quite small. For the second half of 1984, the (gallon-weighted) average family size of a self-service buyer of regular leaded gasoline was 3.41, while the average for a self-service buyer of regular unleaded gasoline was 3.30. For the second half of 1980, these figures were 3.49 and 3.40. Not shown in the table, but consistent with the income and credit card differences, buyers of unleaded gasoline are better educated and are less likely to be unemployed or employed only part time than buyers of leaded gasoline.

purchase sizes appear to differ by more than 10%. The average age of buyers does not seem to differ substantially.[13]

The idea that retailers charge a higher per-gallon margin on unleaded gasoline to compensate for the smaller average purchases made by buyers of this product is given little support.[14] Although it does appear to be the case in 1984 that the average self-serve purchase of regular unleaded gasoline was about 5% smaller than the average self-serve purchase of regular leaded gasoline, this cannot explain a substantial difference in retail margins. If the fixed cost per purchase is the same for the two types of buyers, then only a 5% higher margin on unleaded gasoline can be justified by this cost argument. In 1984, the average margin on unleaded gasoline was more than two times the average margin on leaded gasoline. Furthermore, in 1980 the average self-serve purchase of leaded gasoline was smaller than for unleaded gas. In all of the other grade/service categories, the average purchase size of unleaded is as high or higher than leaded, with the exception of the very small sample of leaded, premium, full-serve purchases in 1984.

The credit-card cost explanation of margin differences is also given little support in Table 1. The NPD data indicate that buyers of unleaded gasoline did in 1984 make greater use of credit cards, but the difference cannot justify even a half-cent difference in average margins. If 6% more of the regular unleaded buyers used credit cards (as was the case in 1984 for self-serve purchases), and if such use added five cents per gallon to the retailer's cost of selling, then this difference in credit card use could explain just a 0.3-cent higher average margin on unleaded gasoline than on leaded gasoline. In fact, retailers' additional costs of credit card purchases is less than 5 cents per gallon, as indicated by the 3- or 4-cent cash discount that some stations now offer.[15] In addition, more than three-quarters of the credit card purchases in every category are made with the station's own credit card, rather than a bank card. Presumably, the internal cost of processing these charges is lower than the fee paid on receipts from bank cards. Lastly, the credit-card cost explanation provides no apparent explanation for the pattern of increasing and then decreasing margin differences during the 1980s.

Aggregate data on gasoline prices and quantities are presented in Table 2. The price data, from Lundberg Survey, Inc., include average wholesale and retail prices for full-service and self-service sales of leaded regular, unleaded regular, and unleaded premium gasoline in up to 63 Standard Metropolitan Statistical Areas (SMSAs) for January of the years 1981–1989. The data for leaded premium gasoline run from 1981 to 1986, but most SMSAs show no leaded premium sales after 1983. I focus on self-service sales, which have made up more than half of regular-grade gasoline sales since 1980.[16] Data on volume sold of each type and grade of gasoline by state are from the Department of Energy's (DOE's) *Petroleum Marketing Monthly* and a study by Ethyl Corporation.[17]

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[13] The high average age of all buyers in the survey is explained in part by the fact that the survey included only households of two or more people and seems to have a somewhat larger proportion of retired people than is representative of the population. See Gilbert (1986) for a thorough discussion of the NPD survey data.

[14] I examine this argument in terms of retail margins, rather than markups, because if the pricing is intended to cover the retailers' costs of the transaction, the net revenue per transaction, not the proportional revenue, is the correct indicator.

[15] That the 5 cents per gallon figure is too high is also supported by the fact that gas stations generally pay credit card companies 3% or less of their credit card revenues.

[16] Cities in Oregon and New Jersey, where self-service gasoline stations are not permitted, were excluded from the analysis. In all other states, self-service accounted for at least half of all retail gasoline sales in 1988. The Lundberg data do not explicitly record discounts for cash purchases, but the argument for higher average margins when a higher proportion of customers use credit cards holds whether the discount for cash is given explicitly or just factored into the retailer's pricing decision.

[17] The DOE source exists for 1983–1989. Volume data for earlier years are from the Ethyl Corporation study. The two series overlap in 1983 and are highly correlated in that year.

TABLE 2 Descriptive Statistics of Self-Service Gasoline Pricing

	January 1981	January 1982	January 1983	January 1984	January 1985	January 1986	January 1987	January 1988	January 1989
Average leaded regular price	$1.67	$1.60	$1.37	$1.29	$1.18	$1.19	$0.84	$0.91	$0.86
Average leaded regular margin (cents)	7.98	6.08	5.51	3.75	5.56	5.79	0.28	6.08	4.47
Average unleaded regular price	$1.76	$1.69	$1.46	$1.38	$1.27	$1.28	$0.89	$0.95	$0.89
Average unleaded regular margin (cents)	11.20	9.97	10.21	8.40	10.28	11.61	5.23	9.50	7.03
Average leaded premium price	$1.81	$1.81	$1.66	—	—	—	—	—	—
Average leaded premium margin (cents)	14.88	16.72	21.96	—	—	—	—	—	—
Average unleaded premium price	$1.89	$1.83	$1.63	$1.55	$1.44	$1.43	$1.04	$1.10	$1.05
Average unleaded premium margin (cents)	15.06	16.64	19.52	17.15	19.24	18.75	11.15	14.66	11.42
Average leaded regular–unleaded regular margin	−3.22	−3.89	−4.70	−4.65	−4.72	−5.82	−4.95	−3.42	−2.56
Average leaded premium–unleaded regular margin	3.68	6.76	11.75	10.14	10.42	7.66	—	—	—
Average unleaded prem–unleaded regular margin	3.86	6.67	9.31	8.75	8.96	7.14	5.92	5.16	4.39
Leaded regular market share	51.7%	49.9%	47.7%	43.9%	38.9%	34.4%	28.3%	23.2%	16.1%
Unleaded regular market share	37.5%	38.5%	40.5%	43.6%	46.2%	50.9%	57.0%	58.1%	61.5%
Leaded premium market share	2.9%	1.5%	1.2%	—	—	—	—	—	—
Unleaded premium market share	7.9%	10.0%	11.3%	12.5%	14.9%	14.7%	18.7%	18.7%	22.4%
INCRATIO	0.782	0.783	0.782	0.781	0.779	0.775	0.773	0.779	0.788

All prices and margins are in January 1989 dollars.
All prices, margin and markup data are unweighted averages of SMSAs for which data were available (>20 SMSA's in all cases).
Market share data include self-serve and full-serve sales.
Standard errors of average difference in margins are all between 0.22 and 0.32 cents.

There is a pattern of increasing differences between the regular unleaded and leaded margins until 1986, and a clear decrease in the differences since then. Leaded gasoline was already much less than half of the market in 1986, but it wasn't until about this time that many stations began phasing out its sale.[18]

The average-cost explanation for margin differences appears to be consistent with the data after 1986, when the margin differences narrowed as the regular leaded share of sales in the market fell. From 1986 to 1989, however, the proportion of stations carrying leaded gasoline declined and the volume per station that carried the fuel may have increased or decreased. The data prior to 1986, when all stations carried leaded gasoline and volume per station was clearly declining, are not consistent with this explanation. Furthermore, in its simple form, this average cost explanation would dictate that the margin on the lower-volume type of fuel would exceed the margin on the more popular fuel when all stations carry both fuel. Yet even as the leaded share of gasoline sales fell to 34% in the beginning of 1986, its average margin was still below that of unleaded regular, with a market share of 51%.

The argument that regular leaded gasoline has been used as a device for stations to signal low prices or as a "fighting brand" is taken quite seriously in the gasoline retailing trade press. The signalling argument is made despite the fact that many states do not allow stations to post their leaded regular prices without their unleaded regular prices. The fighting brand argument seems to differ slightly because there is a common implication that retailers are attempting to limit competition to leaded gasoline. These explanations have drawn enough attention and concern that there is probably some substance to them. Yet, some of the facts in Table 2 are difficult to explain with this theory. One would think that the cost of signalling or fighting with leaded prices would decline as the leaded share of the market declined, making this a more common technique. In fact, as leaded fuel has become the clear minority product, the margin difference has narrowed since 1986. Perhaps it is the case that leaded gasoline has become a rare enough product that most consumers have ceased to pay attention to its prices, so that the usefulness of fighting or signalling with leaded prices has declined in recent years. Though this may be true, the argument is ad hoc, and there is no clear way to test for the rise and fall of the effectiveness of signalling with leaded gasoline.

In fact, the fighting brand concept may not differ substantially from a theory of price discrimination. Service stations may "fight" with their leaded regular gasoline prices not because they choose to battle on that turf, but because the buyers of leaded regular gasoline force them to. Just as the fighting cigarette brands at the turn of the century were aimed at the least brand-loyal customers, lower brand loyalty among leaded gasoline purchasers may induce retailers to compete more strongly for their business.

The Lundberg price and margin data also give some indication of the source of price discrimination, if it exists. If most of a station's marginal buyers are deciding between buying from that station or reducing total purchases of gasoline, then the seller is a monopolist for most of its buyers and faces a demand elasticity close to or equal to the buyers' elasticity of demand for the good. Alternatively, if most of a station's marginal customers are deciding between buying from one station or switching to another, then the seller is competing with other stations for its marginal customers and faces a demand elasticity that reflects the buyers' cross elasticity of demand among sellers. The fact that gas stations charge markups that are no greater than 5% to 10%[19] implies that they face demand elasticities of no less

[18] Shepard (1991) reports that in January of 1987, about 20% of Boston-area stations did not sell leaded gasoline. At that time the leaded share of the gasoline market in Massachusetts was 15.4%. Also see *National Petroleum News*, November 1986.

[19] The markups are actually probably smaller because some of the retail/wholesale price difference is attributable to direct marginal costs.

than 10 to 20. These are far greater than the common estimates of the price elasticity of demand for gasoline, which are virtually always less than 2.[20] Thus, the demand elasticities that individual stations face seem to be determined primarily by the buyers' cross elasticities among sellers, not their overall demand elasticities for the product. This indicates that price discrimination would more likely be based on differences in cross elasticities—costs of switching sellers—than differences in elasticities of demand for the product.

4. Testing for price discrimination

■ The higher income and somewhat greater use of credit cards among buyers of unleaded gasoline may in fact indicate that these consumers are more loyal to an individual station or brand, or are less willing to take the time to shop around for a lower gasoline price. When the distance between sellers was the same for unleaded and leaded buyers, this may have been the cause of greater margins on unleaded than on leaded gasolines. As some retailers have discontinued sales of leaded gasoline, the distance between sellers of this product has increased, and the remaining retailers of leaded gasoline may now face nearly as low as elasticity of demand from leaded buyers as from unleaded buyers. This would imply nearly equal margins on the two products.

To test the effects of income and product availability on retail gasoline margins, I estimate margin differences between leaded and unleaded regular self-service gasoline, as a function of these variables for a panel of 63 SMSAs over January of nine consecutive years. Unfortunately, data on the actual proportion of stations in each SMSA selling leaded fuel are not available. Data on each product's share of total gasoline volume, however, allow construction of an availability measure that relates the volume share of leaded fuel to the proportion of stations that offer it.

$$AVAIL = \begin{cases} 1, & \text{if} \quad 0.22 < s_{rl} \leq 1; \\ (s_{rl}/0.22) & \text{if} \quad 0 \leq s_{rl} \leq 0.22, \end{cases} \tag{1}$$

where s_{rl} is the volume of regular-grade leaded gasoline sold in the state in which the SMSA is located divided by the total volume of gasoline sold in the state. This formulation implies that all stations carry any fuel that constitutes more than 22% of the market, and that the proportion of stations carrying a fuel declines linearly as the fuel's share drops below 22%. The 22% cutoff and the linear relationship were chosen based on the data presented in Table 3. The proportion of California stations selling each type of premium gasoline is from Lundberg Survey, Inc. The Boston data point is from Shepard (1991). Using these data, a regression of the percentage of stations selling a grade/type of fuel on that fuel's share of total gasoline volume resulted in estimates that suggest all stations carry a fuel that is 22% of the market. The linear relationship when a fuel is less than 22% of the market is indicated by the fact that higher-order terms were insignificant and lowered the adjusted R^2 of this regression.[21]

According to Table 1, the ratio of the income of leaded gasoline buyers to the income of unleaded gasoline buyers fell between 1980 and 1984. Such a widening disparity in income would be consistent with the increases in margin differences between leaded and unleaded gasoline that seem to have taken place during this time. Unfortunately, the NPD data do not allow such a comparison for later years or for individual states or SMSAs. Instead, I use the 1984 NPD data to construct an age-of-auto/income-of-driver profile,

[20] See Archibald and Gillingham (1980), Dahl (1982), and Gallini (1983).

[21] The regression estimated is $PCTSTN = 0.04 + 4.38 \cdot PCTGAS$. The estimate on the constant has a t-statistic below one, and the estimate on the $PCTGAS$ parameter has a t-statistic of 11. The estimates of the equations in Tables 4 and 5 are stable in sign and vary little in magnitude if the 22% figure is set anywhere from 20% to 50%.

TABLE 3 Relationship Between Fuel Share and Station Availability

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
				Premium unleaded in California						
% of gasoline		13.6	15.4	13.1	17.0	18.0	18.8	21.4	21.4	22.7
% of stations		41.7	74.0	79.7	80.9	81.9	84.0	98.2	92.8	99.1
				Premium leaded in California						
% of gasoline	20.6	10.6	6.7	5.1	4.4					
% of stations	97.8	55.8	27.8	27.3	20.0					
				Leaded regular share in Boston						
% of gasoline								15.4		
% of stations								80.0		

which allows production of a variable that is a proxy for the ratio of the average income of buyers of leaded gas to the average income of buyers of unleaded gasoline.

The 1984 NPD data permit calculation of the gallon-weighted proportion of regular-grade gasoline purchased for each model year of vehicles in use during 1984 and the gallon-weighted average family income of the purchasers. For instance, the resulting data indicate that nine-year-old cars in 1984 accounted for 7.6% of the (regular-grade) gasoline used and that the average income of persons buying (regular-grade) gasoline for nine-year-old cars was $25,749 (1984 dollars). From the volume data discussed above, one knows the proportion of regular gasoline that is leaded. With the fairly accurate assumption that the purchasers of leaded gasoline owned the oldest autos on the road, one can then calculate the ratio of the income of leaded buyers to the income of unleaded buyers.[22] Thus, if 40% of gasoline purchased in an area in a given year was leaded, I calculate the average income of the zero to 40th percentile buyers of gasoline, where the percentiles are based on age of auto, weighted by gallons purchased. I then do the same calculation for the remaining 60% of the population. The variable *INCRATIO* is the ratio of these two figures, a proxy for the average income of leaded-gasoline buyers divided by the average income of unleaded-gasoline buyers. This approach requires the unfortunate assumption that the age-of-auto/income-of-buyer profile is stable over time and location.

The equation that I estimate is then

$$DMARGIN_{it} = \beta_0 + \beta_1 \ln AVAIL_{it} + \beta_2 INCRATIO_{it} + \epsilon_{it}, \qquad (2)$$

where *DMARGIN* is the difference between the average margin on unleaded and leaded regular gasoline in SMSA i during January of year t, *AVAIL* and *INCRATIO* are as described above, and the errors are assumed to have identical normal distributions with mean zero. I use the natural log of *AVAIL* because the impact of additional outlets on the distance between competitors is smaller if there are already many stations carrying the product.[23]

[22] The assumption that leaded gas is used in the oldest cars could be challenged if many cars that are built to use unleaded gas are "misfueled" with leaded gas. Though this does occur, EPA figures show that even at its highest point, the early 1980s, less than 7% of the randomly checked autos that were built to use unleaded fuel exhibited signs that they had been misfueled at any time. By 1987, the rate was less than 3%. Furthermore, it is likely that misfueling is more common among older "unleaded" cars.

[23] Consider N stations randomly distributed over a two-dimensional area with m ($<N$) of them carrying leaded gasoline. If δ is the average distance from one station carrying leaded fuel to the closest station that also sells leaded fuel, then $\partial\delta/\partial m$ declines in absolute value as m increases.

□ **Econometric issues.** The first difficulty with estimation of this equation is that the errors are possibly correlated across observations of the same SMSA over time and across observations of different SMSAs at the same time. Though ordinary least squares estimation is still unbiased with such correlations,[24] it is inefficient, and the estimated standard errors of the OLS estimates are incorrect. Tests indicated that the assumption of no correlation among residuals of the same SMSA over time cannot be rejected, but that there is strong correlation of the residuals within the same year. Estimation with fixed-effect and random-effect models yielded very similar results, so I present the fixed-effects results.

The second difficulty with estimating this equation is that AVAIL might be jointly determined with *DMARGIN*. *DMARGIN* could affect availability in two ways. The first involves the standard problem of identifying demand and supply. A high margin on leaded gasoline relative to unleaded might cause more stations to choose to carry leaded gasoline. This problem is lessened to a great extent by the proxy used for availability, the ratio of leaded to all gasoline sales. So long as the proportion of stations that carry leaded gasoline does not have a substantial effect on the total quantity of leaded gasoline consumed, this bias will not be substantial.

The same use of this proxy, however, creates a different endogeneity that is more likely to cause bias. A high margin difference might affect consumer choices of unleaded versus leaded gasoline both in the short run, as some consumers illegally put leaded gasoline in autos meant to use unleaded fuel, and in the long run, as a higher margin difference induces more people to hold on to their older "leaded" cars.

To address this possible bias, equation (2) is also estimated by two-stage least squares. Five SMSA characteristics are used as instruments for *AVAIL*: population density, per capita income, annual snowfall, annual number of 90+ degree days, and annual number of subfreezing days. Each of these is interacted with the number of years since 1975, the last year in which the majority of new cars were built to use leaded fuel.

Since the variable *INCRATIO* is based in part upon the proportion of an SMSA's regular fuel sold that is leaded, and since that factor may be endogenous, *INCRATIO* could also be endogenous. To address this problem, an identifying instrument for *INCRATIO* was calculated just as the construction of *INCRATIO* described above, but using the predicted share of leaded gasoline from a regression of the actual leaded share on the instruments described above. This modification had virtually no effect on the results.

The final modelling issue is the choice of the appropriate dependent variable. Though standard economic theory indicates that the percentage markup over marginal cost is the correct measure of market power, the industry literature and analysis focuses on the retail/wholesale margin measured in cents. In fact, if the source of a seller's market power is the buyer's cost of switching dealers, then there is little reason to believe that a retailer's ability to raise price will be related to the wholesale price of gasoline.[25] If market power is determined by the cost of switching sellers and that cost is not closely related to the wholesale prices of gasoline, then the margin is a better indicator of market power. I present results using *DMARGIN*, but the basic empirical findings are robust to the choice of dependent variable.

□ **Results of econometric analysis.** Table 4 presents the results of OLS estimation and 2SLS with fixed effects. The signs of the estimates are consistent with the price discrimination hypothesis and are robust to changes in estimation technique. The differences between these estimates result primarily from including fixed effects, as the 2SLS results without fixed

[24] This is true so long as the factors that cause correlation in the errors are orthogonal to the included right-hand-side variables.

[25] To the extent that the retail price of gasoline is part of search or switching costs, e.g., fuel burned while looking for the best place to buy gasoline, then there will be some relation. I assume that fuel costs are a small part of search or switching costs.

TABLE 4 Results of Econometric Estimation

Dependent Variable: Leaded Regular Margin–Unleaded Regular Margin			
	OLS	2SLS with Fixed Year Effects	2SLS with Fixed Year Effects
Intercept	−39.92*	—	—
	(10.17)		
ln *AVAIL*	−1.24*	−1.54	−2.73*
	(0.36)	(1.23)	(0.99)
INCRATIO	45.55*	8.62	
	(13.06)	(24.87)	
Observations	520	520	520
F-statistic	25.58*	11.51*	12.11*

* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.

effects closely reflected the OLS results.[26] The statistical significance of the individual parameter estimates varies due to colinearity between *INCRATIO* and the natural log of *AVAIL*, which have a correlation of −0.53 in the sample, but in the 2SLS estimation with fixed effects the parameters are still jointly significant at the 1% level.

The availability of leaded gasoline appears to affect the difference in margins substantially. The parameter estimate of −1.54 implies that the drop in the average value of the log of *AVAIL* between 1986 and 1989 explains a decline in the difference in leaded and unleaded margins of about 0.87 cents. This is more than one-quarter of the 3.26-cent drop in the difference in average margins during this time. With the OLS estimate, *AVAIL* explains slightly less than one-quarter of the decline. If the *INCRATIO* variable is excluded, the parameter on *AVAIL* nearly doubles and is highly significant.

These estimates for the effect of *AVAIL* may be biased due to a selection bias in the sampling done to create average prices by SMSA. Branded stations, such as Exxon or Mobil, often have higher margins than unbranded independent stations, and branded stations were probably the first to drop leaded regular gasoline. This is supported by press accounts and by disaggregated data for California that indicate branded stations were the first to drop leaded premium gasoline and the first to adopt unleaded premium. If branded stations dropped regular leaded fuel before unbranded stations, and if branded stations had higher margins than unbranded, then the estimated effect of declining availability would be biased downward. Unfortunately, the Lundberg nationwide data do not distinguish branded from unbranded prices.

The results also indicate that the ratio of the income of leaded buyers to the income of unleaded buyers is a significant determinant of the difference in margins. As the average income of leaded buyers increases relative to the income of unleaded buyers, the margin on leaded gasoline increases relative to the margin on unleaded gasoline. The average values of *INCRATIO* by year are shown in Table 2. From 1986 to 1989, the average value of *INCRATIO* increased by 0.013. With the parameter estimate of 8.62, this implies a decrease in the difference in margins between leaded and unleaded regular gasoline of 0.11 cents. With the effect of *INCRATIO* estimated in the OLS regression, the impact of the change in relative incomes would explain about one-sixth of the decline in margin differences between 1986 and 1989. If *AVAIL* is excluded from the 2SLS estimation with fixed effects, the parameter on *INCRATIO* jumps back to about 40 and is significant at the 1% level.

[26] In fact, a Hausman test on *AVAIL* could reject the null hypothesis of exogeneity at only the 20% level.

□ **Evidence from changes in premium gasoline margins.** Premium gasoline has traditionally been a very profitable product for refiners and retailers. Over 20% of gasoline now sold is premium, though less than 5% of U.S. autos need the higher octane that premium gas contains. Surprisingly, Table 1 indicates that among buyers of leaded gasoline, premium buyers are only slightly wealthier than regular buyers, while among buyers of unleaded gasoline, premium buyers are actually slightly poorer than regular buyers. Yet throughout the sample period, margins on premium gasoline are substantially higher than on regular gasoline.

During the sample period, availability of leaded and unleaded premium gasoline changed. The share of leaded premium gasoline declined in the early 1980s, and the product had virtually disappeared by 1986. At many stations it was replaced by unleaded premium, so the availability of the new high-octane fuel grew as the old high-octane fuel become scarce. Since unleaded regular fuel was widely available throughout the sample period, Table 2 uses margins on that fuel as the baseline in examining relative margins on the premium products as their availability changed.

If the competitive price discrimination theory suggested for regular leaded gasoline also applies to premium gasoline, one would expect to see relative margins on leaded premium gasoline increase as it became less available and relative margins on unleaded premium fall as it gained widespread acceptance. Table 2 suggests that the first conjecture is probably true, but the second conjecture does not appear to have much support.

The regressions in Table 5 bear out these conclusions. The *INCRATIO* variable has been dropped now, because there is little systematic difference in the distribution of incomes for buyers of the premium fuels and buyers of unleaded regular. Inclusion of an *INCRATIO*

TABLE 5 Estimation for Premium Gasolines

Dependent Variable: Premium Leaded Margin–Regular Unleaded Margin Time Period: 1981–1983		
	OLS	2SLS with Fixed Year Effect
Intercept	3.95**	—
	(1.58)	
ln *AVAIL*	−0.92***	−0.55
	(0.53)	(0.81)
Observations	83	83
F-statistic	2.99***	8.09*

Dependent Variable: Premium Unleaded Margin–Regular Unleaded Margin Time Period: 1981–1989		
	OLS	2SLS with Fixed Year Effects
Intercept	7.54*	—
	(0.24)	
ln *AVAIL*	1.15*	1.88*
	(0.23)	(0.38)
Observations	509	509
F-statistic	24.15*	17.79*

Standard errors in parentheses.
* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.

variable, calculated analogously to the variable for the leaded/unleaded regular margin regressions, showed no explanatory power and had little effect on the estimated effect of *AVAIL*, but it did raise the standard error of this estimate. As in the earlier regressions, the margin difference examined is between the observed fuel and unleaded regular gasoline.

The results using leaded premium support the idea that a decline in the availability of the fuel led to increased margins on it. The estimates are somewhat smaller than for leaded regular. The estimates are not as significant as in Table 4, but this may be due to the smaller sample size. In contrast, the result from the introduction of unleaded regular gasoline conflicts with the competitive price discrimination theory. As the availability of unleaded premium increased, its margin also increased. One possible explanation for this surprising and significant result is that unleaded premium was a new product, without an established consumer base, that manufacturers were hoping to sell to buyers of unleaded regular gasoline. As acceptance of the new product grew, so did its margin.

Finally, Table 6 presents results that are based on a much smaller sample, but one for which there are actual availability data. The data are from the same source as in Table 3. The data cover seven California cities for nine years, 1981–1989, but are available only through 1986 for leaded premium. *PCTSELL* is the proportion of stations selling the premium fuel. These data also support the inverse relationship between availability of leaded premium and its margin. The estimates are much larger than in Table 5 or the estimated effect of leaded regular availability in Table 4. The estimated premium unleaded results for a somewhat longer time series in these California cities reinforce the results in Table 5, though they are quite unstable.

TABLE 6 Estimation for Premium Gasoline Using Actual Station Counts in California

Dependent Variable: Premium Leaded Margin–Regular Unleaded Margin Time Period: 1981–1986

	OLS	2SLS with Fixed Year Effects	OLS	2SLS with Fixed Year Effects
Intercept	−6.05*	—	−3.57*	—
	(1.31)		(1.26)	
ln *PCTSELL*	−4.66*	−5.33**	−6.23*	−3.91***
	(0.83)	(2.50)	(0.80)	(2.16)
PCTBRAND			−7.07*	−6.25***
			(1.71)	(3.46)
Observations	42	42	42	42
F-statistic	31.38*	13.98*	30.52*	15.80*

Dependent Variable: Premium Unleaded Margin–Regular Unleaded Margin Time Period: 1981–1989

	OLS	2SLS with Fixed Year Effects	OLS	2SLS with Fixed Year Effects
Intercept	7.77*	—	−3.72	4.43
	(0.59)		(5.35)	(7.92)
ln *PCTSELL*	2.06	8.82	1.84	−4.00
	(1.31)	(5.78)	(2.66)	(11.77)
PCTBRAND			−0.57	−0.19
			(5.97)	(15.15)
Observations	63	63	63	63
F-statistic	2.48	11.86*	1.22	20.84*

Standard errors in parentheses.
* Signifiant at 1% level.
** Signifiant at 5% level.
*** Signifiant at 10% level.

The third and fourth columns of Table 6 include the variable *PCTBRAND*, which is the proportion of the stations selling the premium fuel that are branded divided by the proportion of the stations selling the regular unleaded fuel that are branded. Inclusion of this correction for the effect of branded versus unbranded stations appears to have no systematic effect on the conclusions. Furthermore, the negative sign indicates that the margin difference actually widened as the branded stations stopped selling the premium gasoline. It appears that unbranded stations in the California dataset had lower prices on premium gasoline due only to the lower wholesale prices they paid; their retail margins are about the same or somewhat larger than branded stations.

5. Conclusion

■ This article has reviewed a variety of possible explanations for the difference between leaded and unleaded gasoline retail margins and the way in which those differences have changed over time. The most common cost-based arguments for the differences appear to explain little of the margin differences and are not useful in explaining the changes in the margin difference over time. Larger average purchases by buyers of leaded gasoline are unlikely to explain more than a few percent of the average difference in margins. The fact that buyers of leaded gasoline use credit cards somewhat less frequently also explains very little of the difference.

The argument that posted leaded gasoline prices have been used to inform or misinform consumers of a station's prices on other types of fuel is much more difficult to analyze. The extensive attention that this technique has received by the industry publications and by consumer protection organizations gives some credence to this theory. Still, the pattern of margin or markup differences evident in the data is not easy to explain as resulting from variations over time and across cities in the use of leaded gasoline as a "loss leader" or "fighting brand." Though these marketing techniques are probably part of the explanation, they are surely not the whole story.

Furthermore, it is hard to see why the use or effectiveness of these marketing techniques would be highly correlated with the variables used to describe the availability of leaded gasoline or the difference in average income between buyers of leaded and unleaded gasoline. The effect of availability on the difference in margins appears to be significant both statistically and quantitatively. Estimates of the effect of income differences are also consistent in sign, though smaller in estimated impact. Both results are consistent with a model of spatial competition in which differences in the willingness of buyers to switch stations results in price discrimination. The declining availability of leaded gasoline from 1986 to 1989 may explain nearly 1 cent of the 3.1-cent decline in the margin differences during this time.[27] Evidence from analyzing markets for leaded premium gasoline at the time it declined and disappeared in the first half of the 1980s also supports the theory of competitive price discrimination. Evidence from the introduction of unleaded premium gasoline, however, is clearly inconsistent with the theory. This may be due to the marketing efforts to attract new users of unleaded premium.

The theoretical finding that price discrimination can persist in imperfectly competitive market leaves open the question of the degree of competition that can still support discrimination. Price discrimination in gasoline retailing accompanied by low markups on all grades of gas suggests that even markets "very close" to perfect competition are still quite a bit different from the ideal.

[27] One might at first wonder why the upstream firms would fail to take advantage of higher markups on one fuel by raising its wholesale price. If, however, free entry forces the retailers to earn zero profits (operating profits just covering fixed costs), then an increase in the wholesale price will simply decrease the number of retail sellers.

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