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PRICE DISCRIMINATION AND RETAIL CONFIGURATION

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June 1989

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ABSTRACT

The hypothesis that price discrimination exploiting the consumer's willingness to pay for quality can occur in multi-firm industries is confirmed using microdata on retail gasoline prices. A test based on the price differentials at stations providing only one service quality (full or self service) and stations providing both qualities is developed and implemented with controls for variations in outlet, brand and local market characteristics. The data suggest that price discrimination at the retail level adds at least ten cents per gallon on average to the price of full-service gasoline.

1. INTRODUCTION

Economists have long understood that monopoly firms will have an incentive to price discriminate when demand elasticities differ. It is well known that a monopolist can increase profits by charging customers different prices when consumers with different tastes are identifiable or by employing a self-selection scheme when the taste distribution is known but anonymous. While the formal literature has been limited largely to the behavior of monopoly firms selling a single product, there has long been informal discussion of price discrimination involving multi-firm industries and differentiated products. In recent years, the theoretical underpinnings for this wider understanding of price discrimination has begun to develop. A monopolist's ability to price discriminate by using a price-quality schedule for a vertically differentiated good has been analyzed by Mussa and Rosen (1979). The analysis has been extended to a duopoly setting by Shaked and Sutton (1982) and Gabszewicz and Thisse (1979). Borenstein (1985) has shown that when products are spatially differentiated and consumers have different tastes, price discrimination can occur in a free-entry equilibrium. Katz (1984) has modeled the pricing decisions of competing, multi-product firms, and demonstrates that firms may use a price-quality schedule to price discriminate when consumers have preferences over firms.[1] These analyses give support to the contention that the commonly observed pricing practices of non-monopoly firms may be motivated by price discrimination. Airlines selling seats on the same plane at different prices, student discounts at movie theaters, and larger mark-ups on luxury automobiles can be interpreted as examples of price discrimination.

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[1] In a closely related literature, price dispersion has been shown to be consistent with competition when consumers know only the price distribution and have different valuations of the good (Diamond, 1987) or different costs of search (Salop and Stiglitz, 1977 and 1982).

While both theory and casual observation suggest that price discrimination is commonplace, little empirical work on price discrimination has been done. This paper develops and applies an empirical test for price discrimination. In particular, the paper examines the pricing of full-service and self-service gasoline, and the test is motivated by the observation that gasoline is sold through single product dealers, who sell either full-service gasoline or self-service gasoline but not both, and through multi-product dealers, who sell both full-service and self-service gasoline. This mix of retailing configurations occurs within the same market, sometimes within the same city block, and provides a natural experiment for distinguishing price discrimination. A firm selling a single quality product and confined to a uniform, linear price cannot price discriminate even if it has market power. A firm with market power selling multiple products of different quality can price discriminate even when it is confined to charging a linear, uniform price for each quality. The opportunity for price discrimination will lead a multi-product retailer to set the price differential between full-service and self-service gasoline to maximize the joint profit from sales of both qualities. A single-product dealer is concerned only with maximizing profit from the sale of one quality and will not take into account the effect of his price on products he does not sell. As a result, the price differential at multi-product stations will differ from the differential observed across single-product stations offering different qualities. The essence of the test, then, is to compare these price differentials.

In section two, I develop a simple model of price and quality choice. If quality choice is embodied in physical capital or if a reputation for quality consistency increases demand, prices will change more rapidly than quality. In gasoline retailing, outlets change prices much more often than they change the quality of service. At any point in time, then, it is appropriate to think of the choice of price as conditional on the retail configuration. When retail configuration is fixed, the model predicts that the quality premium charged by multi-product retailers will be higher than that charged by dealers offering only full-service when the retail outlet has some market power and consumers care about service quality. In the longer run, the quality choice is endogenous and will reflect any differential in profitability created by price discrimination. Thus, the retail configuration in long-run equilibrium will be sensitive to local market power. If there is no price discrimination, multi-product stations are (weakly) dominated by single-product stations; if retail outlets have sufficient market power to price discriminate, multi-product stations may be the dominant configuration. The potential for price discrimination, then, may lead a manufacturer to establish multi-product outlets.

In section three, microdata on retail gasoline prices are used to test the price differentials predictions. The data on quality specific prices are consistent with the price discrimination hypothesis. In section four, aggregate data on changes in the retail configuration over time are examined and found to be only partially consistent with the model's predictions. Unsurprisingly, factors other than price discrimination possibilities--including the history of the distribution network--affect the observed choice of retail configuration. Section five offers some concluding comments.

2. A MODEL OF RETAIL PRICING AND OUTLET TYPE

Retail gasoline is differentiated both horizontally (by brand and location) and vertically (by service quality). In general, retail prices will reflect horizontal competition and vertical price discrimination; a complete model would take both types of differentiation into account. Since the focus of this paper is on the effects of retail configuration given some amount of market power, the analysis is simplified by looking only at two polar cases.

In the competitive case, there is no horizontal differentiation. In a model of spatial competition, this is equivalent to assuming that consumer transportation costs are zero. In the market power case, there is extreme horizontal differentiation so that each outlet is an effective monopoly. Again, in a spatial competition model, this is equivalent to assuming that transportation cost to the consumer's most preferred point is zero and to any other outlet is infinite. Alternatively, the market power case could be interpreted as retailers with exclusive territories. While neither the polar competitive nor market power case captures the nature of inter-firm competition in gasoline retailing, analyzing them isolates the effects of vertical differentiation on retail prices.

This approach disentangles the manufacturer's decision to differentiate vertically from her decision about the extent of intrabrand competition. The literature on quality choice frequently identifies quality differentiation with an increase in competition. In a vertically disintegrated context, the manufacturer is faced with a trade-off between the benefits of differentiation and the cost of increased intrabrand competition. In many cases, a manufacturer can offer multiple qualities through a single retailer; no increase in intrabrand competition need occur. The manufacturer can choose the number and location of outlets independently of the differentiation choice. Indeed, one way to think of the model developed here is as the choice of price and quality for a single outlet at a specific location with a given competitive environment.

The structure of the model is as follows. The competitive environment at the retail level is exogenous; retailers are either perfectly competitive or have exclusive territories. Conditional on the environment, the manufacturer chooses the retail configuration, the per unit wholesale price and the franchise fee. Conditional on his configuration and the wholesale price, the retailer chooses retail price(s). Reserving the choice of retail price for the downstream firm is consistent with the theoretical literature and with the legal constraints in this industry where resale price maintenance is clearly unlawful.[2] Allowing the manufacturer to choose quality is more controversial.[3] Since service quality is actually provided by the retailer, allowing costless quality choice by the manufacturer implies that quality is perfectly observable. In fact, it is easy to verify whether a station provides full-service or self-service.

To simplify the discussion, the following terminology has been adopted. Full-service gasoline is the high quality product and is denoted by *h*, and self-service is the low quality product, denoted by *l*. A multi-product (MP) retailer sells both qualities. A single-product (SP) retailer sells high or low quality only; a high (low) quality SP station offers only full-service (self-service) gasoline. A retail outlet described simply as "full-service" or "high quality" ("self-service" or "low quality") sells only full-service (self-service) gasoline.

2.1 Demand and Cost

Market demand is modeled following Gabszewicz and Thisse (1979) and Bolton and Bonano (1988). Each consumer has a utility function separable in income and consumption of gasoline and buys no more than one unit. Consumers

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[2]Simpson v. Union Oil Co., 377 U.S. 13 (1964). Retail price wars in the 1950s and 60s led to a concerted effort by refiners to control the retail price of gasoline. One strategy employed was to change the agency status of retailers from an independent sales force to consignment dealers. Gasoline ownership--and therefore the right to set retail price--was never transferred to the retailers under this system. In Simpson, the Supreme Court found the consignment system to have no purpose other than price fixing and declared refiner control of retail prices unlawful.

[3]If the retailer can choose quality, the control problem faced by the manufacturer is more complex; her optimization program includes incentive compatibility constraints with respect to quality choice as well as individual rationality constraints with respect to outside opportunities. These additional constraints can affect the manufacturer's product differentiation choice (Bolton and Bonano, 1988).

have identical preferences over quality but different incomes so that preferences can be represented by:

$$U = \begin{cases} V(s)(t-p_s) & \text{if she consumes one unit of quality } s \\ V(o)t & \text{if she does not purchase} \end{cases}$$

where s is high (h) or low (l) quality, $V(h) > V(l) > V(o) > 0$, and t is the consumer's type. Type (t) is assumed to be uniformly distributed on [0,1] with unit density.

Let $V(h) \equiv H$, $V(l) \equiv L$ and $V(o) \equiv O$. When there is only one quality available, all consumers who prefer consumption of the available quality to no purchase will buy. Demand for the single available quality is given by:

$$D(p_s) = 1 - \frac{V(s)p_s}{V(s)-O} \tag{1}$$

When both qualities are available, all consumers who prefer self-service to full-service and to no purchase at the prevailing prices will buy self-service. Consumers who prefer full-service to no purchase and to self-service at the prevailing prices will buy full-service. Demand for each quality is given by:

$$\begin{aligned} D_h(p_h,p_l) &= 1 - \frac{Hp_h}{(H - L)} + \frac{Lp_l}{(H - L)} \\ D_l(p_l,p_h) &= \frac{Hp_h}{(H - L)} - \frac{L(H - O)p_l}{(H - L)(L - O)} \end{aligned} \tag{2}$$

The demand functions in (1) and (2) define market demand. In the competitive case, prices are determined by marginal cost. In the market power case, each retailer is assumed to face the same uniform distribution of consumers with a density that may be a function of the number of firms. (1) and (2), then, also represent the demand function for the firm excluding a multiplicative density term. While density affects the quantities sold at any price, it does not affect the profit-maximizing prices. In characterizing retail prices, then, (1) and (2) can also represent the retailers' demand functions in the market power case.

Dealer individual rationality requires that the output of any quality offered be non-negative in equilibrium. That is, demand and cost conditions (including the wholesale price) must be such that retail profits will be maximized (and non-negative) at prices consistent with non-negative demand for the single quality offered by SP retailers and with non-negative demand for both qualities offered by MP retailers. Demand at SP firms will be strictly positive if:

$$p_s < \frac{V(s)-O}{V(s)} \tag{1a}$$

Strictly positive demand for both qualities at MP outlets requires:

$$\begin{aligned} p_l &< \frac{(L - O)Hp_h}{L(H - O)} \\ p_h &< \frac{(H - L)}{H} + \frac{Lp_l}{H} \end{aligned} \tag{2a}$$

Because quality is produced at the retail level, upstream production costs are quality invariant and can be set equal to zero without loss of generality. Downstream, high quality typically will involve an increase in fixed or marginal costs or both. Marginal cost is higher for full-service sales because they require more labor and may also require more highly skilled labor. For simplicity, marginal retailing costs are assumed to be constant, the cost of low quality is set equal to zero and the increment to marginal cost for producing high quality is $\alpha \geq 0$. Marginal cost is assumed to be invariant to station type. That is, the cost of high (low) quality is the same at SP and MP dealers. This assumption is essential to the empirical power of the model and is discussed at length in section three.

Fixed costs primarily reflect the value of the land, building, tanks, and pumps. The minimum scale requirements for MP stations are higher than those for SP stations: MP service usually involves at least two gasoline islands, but SP service does not. While a difference in fixed cost may affect the refiner's choice of station type, it will not affect the retailer's profit-maximizing choice of price conditional on station type. Fixed costs are discussed in the empirical work but are suppressed here.

In addition to the cost of quality, the retailer faces a per unit wholesale price of $w \geq 0$ imposed by the manufacturer. This price does not depend on the quality offered at retail; a refiner charges a single wholesale price for each grade of gasoline and cannot charge premiums specific to a particular station or to the station type. This assumption is consistent with observed industry practice[4].

It is well-known that imperfect competition at the retail level will result in a price above the simple monopoly price if the wholesale price is greater than upstream marginal cost. The manufacturer can avoid double marginalization by choosing a wholesale price equal to upstream marginal cost and extracting downstream profit through a franchise fee. There are, however, limitations on the use of franchise fees. At those stations where the land and major capital are owned by the manufacturer, the refiner-dealer contract includes an annual rental fee. Even at these stations, however, gasoline price and allocation controls in effect until 1981 distorted these contracts, and dealer activism in the 1970s and 1980s has resulted in protective state legislation that may prevent fully-efficient rent extraction. At other stations, there usually is no franchise fee. It is commonly believed that at least some of the downstream profit is extracted by setting the per gallon

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[4]Wholesale prices are posted at the terminal supplying the area. Discounts from the posted prices are sometimes offered, but not on a dealer-specific basis (DOE 1984).

wholesale price above the marginal cost of production (DOE, 1984)[5]. The model allows for any $w \geq 0$ that satisfies the retailer's individual rationality constraint.

2.2 Retail Prices and Price Differentials

With station type chosen by the manufacturer, the retailer's problem is simply to choose his profit-maximizing price(s) conditional on the quality or qualities he sells. If retailers are perfectly competitive and marginal cost does not vary by station type, price will equal marginal cost and the price differential between high- and low-quality gasoline will equal the cost differential (α). If retailers have market power, the price differential across qualities will depend on station type. The intuition is straightforward. If a dealer has market power, he will be able to raise price above marginal cost. If he offers only one quality, as the price rises an increasingly large share of consumers will prefer no purchase. The dealer earns zero profit from these consumers. At multi-product stations, as the dealer raises the price of one quality while holding the price of the other constant, some customers will switch to the other quality rather than forgoing any purchase. With the price of each quality above its marginal cost, the dealer makes a profit on the switching customers. The multi-product dealer, then, will set prices that take this switching effect into account.

For a SP station, profit is maximized by solving

$$\max_{p_h} \Pi_h^r = (p_h - w - \alpha)\, D(p_h) \tag{3}$$

if the station offers high quality, or

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[5]In a more general model, if retailers are risk averse, uncertainty about demand or cost could make a franchise fee below the expected value of the franchise and a wholesale price above the marginal cost of production an optimal contract (Rey and Tirole, 1986). Conversations with refiners confirm that at least some rent is extracted via the wholesale price.

$$\max_{p_l} \Pi^r_l = (p_l - w)\ D(p_l) \qquad (4)$$

if the station offers low quality. The profit-maximizing prices are, respectively:

$$p^*_h = \frac{(H - O)}{2H} + \frac{w + \alpha}{2}$$

$$p^*_l = \frac{(L - O)}{2L} + \frac{w}{2} \qquad (5)$$

The analogous problem for an MP retailer is:

$$\max_{p_h, p_l} \Pi^r = (p_h - \alpha - w)\ D_h(p_h, p_l) + (p_l - w)\ D_l(p_l, p_h) \qquad (6)$$

And profit-maximizing prices are:

$$p^{**}_l = \frac{(H+L)(L-O)}{\delta} + \frac{2wHL}{\delta} + \frac{\alpha H(L-O)}{\delta} \qquad (7a)$$

$$p^{**}_h = \frac{2L(H-O)}{\delta} + \frac{wL(H+L)}{\delta} + \frac{\alpha(2LH-LN+L^2)}{\delta} \qquad (7b)$$

where $\delta = 3HL + HO + L^2 - LO$.

If retail profits are to be non-negative for every station type, the prices defined by (5) and (7) must be greater than or equal to w and low enough to allow non-negative demand. Using the demand conditions from (1a) and (2a), non-negative profits at all station types require:

$$w \leq \frac{L-O}{L} \qquad (8a)$$

$$w \leq \frac{H-O}{H} - \alpha \qquad (8b)$$

$$w \leq \frac{(H-O)(L-O)}{H(L+O)} + \frac{\alpha(L-O)(L+H)}{(L+O)(H-L)} \qquad (9a)$$

$$w \leq \frac{L+O}{L} - \frac{2H\alpha}{H-L} \qquad (9b)$$

The conditions given in (8a) and (8b) ensure non-negative profits at self-service and full-service stations, respectively. Non-negative profits at MP stations are guaranteed by (9a) and (9b). If $w \geq 0$ is also imposed, then non-negative profit also implies an upper bound on α at full-service and MP outlets, respectively:

$$\alpha \leq \frac{H - O}{H} \tag{10a}$$

$$\alpha \leq \frac{(H - L)(O + L)}{2HL} \tag{10b}$$

Equations (8) - (10) can be thought of as the viability constraints.

Because there is a nearby substitute for each quality at MP stations not present at SP stations, the viability constraints are tighter at MP stations. Thus, it can be shown that (9a) implies (8a), (9b) implies (8b), and (10b) implies (10a). Further, $\alpha \leq \hat{\alpha} \equiv \frac{O(H - L)}{HL}$ implies the low quality constraints will bind first because consumers prefer high quality to low when prices are equal. However, as α gets larger, the relative price of the high quality good must increase to cover the cost. For sufficiently high α, the high quality constraint will bind first.

The differential between high and low quality prices at the same w will vary by station type. At MP stations, the differential is:

$$\Delta_{MP} \equiv p_h^{**} - p_l^{**} = \frac{(H - L)(L + O)}{\delta} - \frac{wL(H - L)}{\delta} + \frac{\alpha(LH + HO - LO + L^2)}{\delta} \tag{11}$$

Δ_{MP} is increasing in the cost differential as expected. It is also decreasing in the wholesale price because the optimal low quality price increases in w more rapidly than the optimal high quality price. A change in w causes an upward adjustment in both prices, but as the high price rises, former high quality consumers defect to low quality. For the marginal revenue from low quality consumers to increase in response to the increase in w, the low quality price must rise by more than the high quality price.

The differential for SP stations comes from comparing prices across stations. From (5), this differential is:

$$\Delta_{SP} \equiv p_h^* - p_l^* = \frac{O(H - L)}{2LH} + \frac{\alpha}{2} \quad (12)$$

Since changes in w lead to the same mark-up changes in high and low quality prices, Δ_{SP} is invariant to w. For low α, Δ_{SP} is greater than the cost differential, but is less than the cost differential for high α. Both Δ_{SP} and Δ_{MP} increase in α, but the differential at MP stations increases more slowly. At MP stations, when the high quality price rises in response to an increase in α, the low quality price also increases to control defections from high to low quality. At SP stations, the additional cost of high quality has no effect on the low quality price.

Let $\Delta \equiv \Delta_{MP} - \Delta_{SP}$, the difference in differentials. It is easy to show that when $w = 0$, $\Delta > 0$. The intuition is that at MP stations prices are set to exploit the variation in demand through price discrimination. At SP stations, price discrimination is not possible, and the single quality price is set to be in the middle of the demand distribution. Thus, as long as both MP and SP stations are viable, the price differential will be larger at MP stations. Since relative price differentials have empirical content only when all station types are observed, I assume that all necessary viability constraints are met. With $w = 0$, the only outstanding constraint (10b) is that α not be so large that there is no demand for high quality when low quality is available at p_l^{**}.

It is clear from equations (11) and (12) that Δ declines as w increases. It can be shown, however, that when MP (and, therefore, SP) outlets are viable--that is when equations (9) and (10b) are satisfied--Δ is non-negative. Δ is strictly positive for all w satisfying (9) except when $\alpha = \hat{\alpha}$. This point defines the boundary for which constraint in (9) is binding. If the cost differential is exactly $\hat{\alpha}$ and w is as high as possible for that α, Δ can be zero. For all other values of α and w, Δ will be strictly positive.

A larger differential at MP stations can be the result of a higher price for full-service, a lower price for self-service or both. Without information about α and w, it is not possible to predict which margins will contribute to the larger differential. Using the constraints in (9), however, it is possible to show

$$\Delta_h \equiv p_h^{**} - p_h^{*} \geq 0$$
$$\Delta_l \equiv p_l^{**} - p_l^{*} \leq 0. \tag{13}$$

Further, these differentials will be zero only when the constraint on w binds. The high prices will be close to equal when the constraint on w imposed by the low quality price is close to binding. The low quality prices will be close to equal when the constraint imposed by the high quality price is close to binding.

In summary, when marginal costs do not differ by station type, the competitive case implies that $\Delta = 0$. The market power case, however, implies that $\Delta > 0$ except at a single point in (α, w) space. The competitive case implies that the price for a given service quality will be equal across stations ($\Delta_h = \Delta_l = 0$); in the market power case, the high quality price may be higher and the low quality price lower at MP stations ($\Delta_h \geq 0$, $\Delta_l \leq 0$).

The assumption of equal costs across station types is obviously important in generating these predictions. There will be a higher price differential at MP stations in the competitive case only if the difference in cost between low and high quality is larger at these stations. I argue in the empirical section that the economics of gasoline retailing suggest that moving to MP retailing either has no strong effect on marginal costs or reduces the cost differential. If the cost differential is lower at MP stations, Δ will be smaller and could be negative.

2.3 Quality Choice

The refiner chooses w, the franchise fee and station type that maximizes her profit given the retailer optimization problem. Since only the quality choice is observed, the analysis in this section focuses on characterizing the choice of quality when the downstream firms are competitive and when they have market power. Conditional on parameter values, the model yields clear predictions about the choice of station type; predictions that are at variance with the observed mix of station types. Within the simple framework of the model it is never optimal, for example, to have both full-service outlets and self-service outlets. These predictions, however, are based on a model that abstracts from the history of the distribution network. Gasoline retailing has changed substantially over the last twenty years and the distribution networks are slowly changing to reflect current demand and supply conditions. The observed mix of station types is clearly not an equilibrium. The predictions regarding quality choice, then, should be interpreted as suggesting the direction of change. Section four discusses the evolution of the distribution system and the extent to which this change appears to be consistent with the model's predictions.

If the downstream market is competitive, prices will equal marginal cost. Let $p_l^c = w$ and $p_h^c = \alpha + w$. For SP stations, the refiner's choice of w is defined by:

$$\max_w \Pi_{s,c} = w\, D(p_s^c) \tag{14}$$

where D(.) is defined by (1). Maximized profit is given by:

$$\Pi^*_{l,c} = \frac{L - O}{4L}$$

$$\Pi^*_{h,c} = \frac{(H - O - \alpha H)^2}{4H(H - O)} \tag{15}$$

When $\alpha = 0$, $\Pi^*_{l,c} < \Pi^*_{h,c}$ because consumers prefer high quality to low at the same price. As α gets larger, the profitability of high quality sales declines while the profitability of low quality sales is unchanged. Thus, there is some $\alpha' > 0$ at which low quality becomes more profitable than high.

At MP stations, the refiner earns w on each gallon sold and, therefore, cares only about the total sales volume, not what quality is purchased. Sales volume is determined only by the self-service price because it determines the share of consumers who prefer no purchase at the prevailing prices. Thus, the objective function at MP stations reduces to:

$$\max_{w} \Pi_c = w\, D_h(p^c_h, p^c_l) + w\, D_l(p^c_l, p^c_h) = w\, D(p^c_l) \qquad (16)$$

where $D_s(.)$ is defined by (2). It follows immediately that when high quality stations dominate low quality stations, MP stations are also dominated. It is also clear that MP stations can, at best, be as profitable as low-quality stations. It also can be shown that when $\alpha = \alpha'$, MP stations are viable, but that there exists some larger $\tilde{\alpha} > \alpha'$ at which MP stations are not viable because the price of high quality is too high given that low quality is available at the w defined by (16).

For low α, then, the refiner strictly prefers full-service stations; for intermediate α the refiner is indifferent between low-quality stations and MP stations. In the latter case, the refiner gains nothing from the provision of full-service. For still higher α, MP stations are not viable and the refiner will strictly prefer low quality outlets. So when the downstream market is competitive, SP stations will weakly dominate MP stations, and only one type of SP station will be observed.

When there is market power downstream, the results might be affected by the extent to which profit can be extracted by franchise fees. It is well-known that if the upstream firm can set w = 0 and charge a franchise fee to extract downstream profit, a retailer with an exclusive territory will make choices that maximize the profit of the vertical structure. Thus, when there is no constraint on the use of franchise fees, refiner profits will be given by the maximization problem defined in equations (3), (4) and (6). Simple algebraic manipulation demonstrates that when $\alpha = 0$, MP profits are higher than profits at SP stations of either quality. This is simply the familiar result that an integrated monopolist can maximize profit by differentiating the product when quality is costless. As α increases above zero, profits at MP stations decline, but it can be shown that as long as α satisfies the viability constraint given by equation (10b), MP profits will be higher than SP profits. That is, as long as alpha is not so large that an MP station is unable to make a non-negative return on high quality sales, MP stations will be the optimal choice. When MP stations are not viable, the optimal choice is low quality stations. High quality stations are never optimal.

If the refiner must use the per unit price to extract some of the rent, the analysis is less straightforward. Consider the worst case for MP stations: all rent must be extracted with w. Double marginalization will reduce the refiner's profit at all stations. The analogous expression to (14) is:

$$\max_{w} \Pi_{s} = w\left(1 - \frac{V(s)p_{s}^{*}}{V(s) - O}\right) \qquad (17)$$

where p_{s}^{*} are defined by (5). Profits at SP stations are:

$$\Pi_{h}^{*} = \frac{(H - O - \alpha H)^{2}}{8H(H - O)}$$

$$\Pi_{l}^{*} = \frac{L - O}{8L}$$

As in the competitive case, full-service stations will be preferred to self-service stations for small α and vice versa for large α.

With w as the only instrument, the refiner again cares only about total sales at MP stations, so the refiner's problem reduces to maximizing:

$$\max_{w} \Pi = wD(p_{l}^{**}) \qquad (18)$$

where p_1^{**} is defined by (7a). At first glance, it looks as if the refiner has nothing to gain from MP stations relative to self-service stations since the mark-up for high quality cannot be extracted. When there is downstream market power, however, double marginalization is attenuated at MP stations through the dealer's effort to price discriminate. To see that this is so, remember that $p_1^{**} \leq p_1^{*}$ for any common w. As a result, MP stations will dominate self-service-only over some values of α. Comparing the results from (17) and (18), MP stations will dominate self-service stations for small α. As α increases, the profit from MP stations declines, eventually falling below the profit earned at low quality stations. The profit earned from low quality stations may be greater even when MP stations are viable. Compared to the case where rent is extracted with a franchise fee, low quality stations are attractive over a wider range of α. At low α, high-quality stations dominate low-quality stations as usual. As α increases, high quality becomes relatively less profitable, and is dominated by low quality for $\alpha > \alpha'$. Whether full-service stations are ever the optimal choice depends on the value of L relative to O. For L close to O, high quality stations are more profitable than MP stations at $\alpha = 0$. For L much higher than O, MP stations are always more profitable. In either case, there is always some range of α for which MP stations dominate both types of SP stations.

In summary, when retailers have market power, MP stations will be the profit-maximizing choice when a franchise fee is available unless the cost of quality is very high. When rent must be extracted with the wholesale price, MP stations will still be the profit-maximizing choice for some values of α. However, MP stations will be dominated by self-service stations for smaller values of α than in the franchise fee scenario. In addition, for very small α and if the taste for low quality is quite low, full-service stations may be the profit-maximizing choice. Only one type of station will be observed in equilibrium.

3. EVIDENCE FROM RETAIL GASOLINE PRICES

3.1 The Data

The data base is a cross section of retail prices and stations characteristics for all stations in a four county area[1] in Eastern Massachusetts. The data set has observations on 1528 stations and includes information on station location (street addresses and cross streets) and on some station characteristics, including the brand of gasoline sold and whether full or self service or both were available. Although constructed as a cross-section, data collection occurred over a twelve week period in early 1987. The wholesale prices of refined petroleum products were rising slowly over this period. To adjust for wholesale price increases, the retail prices have been indexed using weekly wholesale price data for the Boston area.[2] Retail prices observed in any given week are indexed by the wholesale price reported at the end of the preceding week.

Prices are reported separately for full-service and self-service for each gasoline grade. The most commonly sold gasoline grade is regular, unleaded gasoline,[3] and all prices reported here are for regular, unleaded. The data also report cash discounts where they were offered. The price used in the analysis is the minimum price for regular, unleaded gasoline available at each station by service quality. The analysis focuses on branded gasoline. Branded product sold in the Boston area included Shell, Exxon, Amoco, Gulf, Mobil, Citgo, Texaco, Sunoco, and Chevron gasoline. Unbranded gasoline is

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[1]The full data set covers Norfolk, Suffolk, Middlesex and Essex counties and includes the cities of Boston and Cambridge as well as outlying suburban areas, extending north to New Hampshire, south to Rhode Island, and approximately twenty-five miles west of Boston harbor.

[2]The station-level data were collected by Lundberg Surveys, Inc. The wholesale price data are from Oil Price Information Service.

[3]Less than one percent of the stations did not carry regular, unleaded gasoline. But twenty percent did not sell regular, leaded and six percent did not sell premium, unleaded.

gasoline not associated with a major refiner (e.g. Merit, Global, Angelo's, Stop-N-Go). Unbranded gasoline sells at a retail discount from branded prices[4]. Some of the analysis exploits the information on station location. Street addresses were converted to cartesian coordinates for an arbitrarily defined subset of the total geographic area. This portion of the four country area contained 1011 stations.[5]

Approximately two thirds of the outlets in the data base are full-service stations with the remaining stations split fairly evenly between MP and self-service. Approximately three-quarters of the stations carry branded gasoline. Compared to branded stations, unbranded stations are more likely to be self-service outlets, and much less likely to be MP outlets. Historically, unbranded gasoline has gained market share by offering low service and low price; self-service gasoline was introduced by unbranded retailers. In contrast, the branded networks were built to emphasize full-service gasoline sales. While self-service has become the dominant mode for gasoline sales nationwide, the character of the branded and unbranded networks reflects their distinct histories. The station type distributions of the full sample and the subsample with location data are similar. Data on the distribution of stations by brand status and service quality appear in Table 1.

3.2 Cost and Product Differences

Interpreting variations in price as evidence of price discrimination requires that the prices be for the same product produced at the same cost.

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[4]The average indexed price for regular, unleaded, full-service gas was 83.9 cents per gallon at unbranded stations and 90.5 cents at branded stations. The analogous self-services prices were 76.5 and 81.0.

[5]Locating stations using street addresses and cross streets required detailed maps. Consistent assignment of coordinates is facilitated by maps of the same scale. Combining these requirements reduced the geographic area covered.

TABLE 1: STATION TYPE

		BRANDED	UNBRANDED	TOTAL
ALL STATIONS	FULL-SERVICE	791	215	1006
	SELF-SERVICE	136	147	283
	MP	232	7	239
	TOTAL	1159	369	1528
MAPPED STATIONS	FULL-SERVICE	553	136	689
	SELF-SERVICE	84	77	161
	MP	156	5	161
	TOTAL	793	218	1011

In many ways, gasoline retailing at stations of different type constitute a natural experiment that holds constant critical cost and product elements. Location and brand preference aside, unleaded gasoline with an octane rating of 87 sold at branded stations would seem to be a homogeneous product. Because the data are for stations in the same geographic area, the wholesale price of gasoline and the price of labor will be invariant to station type. Nonetheless, it is in principle possible that cost or product variation across stations might induce price variation unrelated to price discrimination. The data contain no direct cost information, but do contain information about product mix and scale of operation (presented in Table 2) that might be related to cost. The product mix data might also be used to test for product differences. In this section, I argue these data suggest that any cost differences would bias the results against a finding of price discrimination. The analysis presented in Section 3.3 supports the claim that these variables cannot explain the observed price differentials.

One of the critical assumptions underlying the model's price predictions is that the marginal cost of quality (α) is not higher at MP stations than across SP stations. In principle, a higher price differential at MP stations might reflect only cost differences if the cost of full-service is higher and/or the cost of self-service is lower at MP stations. If the average MP station simply replicates the average specialized stations on a common site, there is little reason to believe that marginal costs will differ by station type. Costs could be type-specific, however, if the stations types differ in important ways.

One potential source of cost differences might be interactions with goods and services other than gasoline sold at the station. There may, for example, be economies of scope in retailing convenience store products and gasoline or

TABLE 2: BRANDED STATION CHARACTERISTICS

	Full	Self	MP
Service Bays	0.93	0.42	0.98
C-store	0.04	0.42	0.05
Remodeled in last Three Years	0.44	0.73	0.74
Lot Size (sq ft x 1000)	12.57 (6.43)	16.77 (21.35)	14.95 (5.60)
Number of Gas Islands	1.29 (0.49)	2.25 (1.81)	2.11 (0.49)
Number Fueling Places	3.60 (1.64)	5.83 (2.09)	5.51 (1.89)
Full	--	--	2.63 (1.02)
Self	--	--	2.88 (1.16)
Monthly Sales (gals x 1000)	48.90 (29.92)	96.91 (42.49)	90.18 (40.33)

Standard deviations in parentheses.

automotive service and gasoline.[6] In terms of product mix, MP stations appear to be more similar to full-service than to self-service stations. Nearly all the full-service (93%) and MP (98%) stations are conventional outlets with automotive repair bays; very few of these stations--less than five percent--have the newer, convenience store configuration found at forty-two percent of the self-service stations. To the extent that product mix affects the cost of gasoline sales, these data suggest that the cost of full-service gasoline should differ less across station type than the cost of self-service gasoline. In particular, since full-service gasoline at both MP and SP stations is sold in a similar environment, the data suggest that the cost of full-service should be type invariant. Making the reasonable assumption that specialized self-service outlets have an output mix that is well-suited to efficient self-service sales, the data suggest that the cost of self-service gasoline might be higher at MP stations. If so, α will be lower at MP stations.

A higher proportion of MP and self-service stations have been remodeled or built within the three years preceding data collection,[7] so that full-service stations are significantly older on average than the other stations (see footnote 8). Remodeling might make the stations more efficient (e.g. through installation of electronic control equipment or faster pumps). If so, full-service stations will have higher marginal costs on average suggesting a higher α at SP stations.

Differences in capacity also might influence marginal cost if capacity utilization rates are constant across stations and marginal costs are declining in output. The available capacity measures (station square footage,

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[6] The interaction of automotive service and gasoline sales has changed over time and is discussed in section four.

[7] The data record whether the station has been remodeled, but not what has been done. Remodeling can mean complete rebuilding, adding a canopy, putting in new pumps or tanks or any combination.

average number of islands, and room for automobiles at the pumps) indicate that full-service stations have a smaller total capacity than self-service and MP stations. The average full-service station has a smaller lot, fewer gasoline islands and can serve fewer cars at the same time than can be served at either MP or self-service stations. The differences in means are statistically significant (at the 0.01 level) for all three measures of capacity[8] and are relatively large. MP stations are twenty to sixty percent larger than full-service stations; specialized, self-service stations are thirty to seventy percent larger. In contrast, average capacity is very similar at MP and self-service stations. If there are important scale economies, then, costs at full-service stations should be higher, increasing α at SP stations.

If, on the other hand, there are scale economies that are specific to service quality, the capacity data suggest a possible loss of scale economies at MP stations. Typically, MP stations dispense full and self service gasoline at separate islands. Thus, although MP stations have a total capacity similar to self-service stations, capacity per service type is much closer to that at the typical full-service station. If one island is reserved for full-service, the average MP station has about half as much self-service

[8]The differences and standard errors are:

	(self)-(full)	(MP)-(full)	(self)-(MP)
Lot Size	4.25	2.42	1.83
	(0.94)	(0.47)	(1.48)
Islands	0.96	0.82	0.14
	(0.08)	(0.04)	(0.13)
Fuel Places	2.23	1.91	0.32
	(0.16)	(0.13)	(0.21)
Sales	48.01	41.27	6.73
	(2.98)	(2.43)	(4.44)
Remodeled	0.29	0.30	-0.01
	(0.05)	(0.04)	(0.05)

capacity as a self-service-only station, but only slightly less capacity for full service than a full-service-only station. Similarly, the number of automobiles that can be served simultaneously (fueling places) at full-service pumps differs more across self-service and MP stations than across full-service and MP stations. The capacity data, then, suggest that any loss of service-specific scale economies will be more severe for self-service gasoline. If there are service-specific scale economies, the cost of self-service gasoline at MP stations should be higher and α lower than at SP stations.

Another possible source of cost differences is the larger sales volume at self-service and MP stations. Higher volume can independently reduce the marginal cost of gasoline if refiners give volume discounts. Some non-linear wholesale pricing apparently occurs (Slade, 1986, DOE, 1984). Quantity discounts would suggest that, on average, marginal cost will be higher at full-service outlets, but approximately equal at MP and self-service stations. Thus, the cost of full-service gasoline at SP stations should be higher than the cost of full-service gasoline at MP stations.

Taken together, these factors suggest that any variation in marginal costs across station type should lead to higher, not lower, cost differentials at SP stations. Volume discounts suggest that self-service and MP stations should face similar wholesale prices, but the cost of gasoline at full-service stations will be higher on average. Capacity differences suggest that if economies of scale exist, the cost of self-service gasoline will be higher and the cost of full-service gasoline lower at MP stations. If remodeling reduces marginal cost, the cost of full-service gas at SP stations will be higher than at MP stations. Product mix variations imply that the cost of self-service will be higher at MP stations.

If prices are cost driven only, then, the price differential for SP stations will be equal to or larger than the differential at MP stations. If costs are type invariant and price discrimination occurs at MP stations, the price differential will be smaller at SP stations. If the cost-differential is larger at SP stations, and MP stations price discriminate, the price differential could be smaller (if the price discrimination effect dominates) or larger (if the cost effect dominates) at SP stations. Cost variation could disguise price discrimination, but cannot reasonably be expected to mimic price discrimination. Testing for price discrimination based on the sign of Δ can lead to false negatives, but not false positives.

Prices may differ by station type without price discrimination based on gasoline service if there are important dimensions of product quality other than full or self-service that differ by type.[9] As noted above, product mix tends to differ by station type: automotive service is more common at stations with full-service gasoline, and convenience stores are almost always associated with self-service stations. If the bundling of station type and non-gasoline services has been optimized, consumers who highly value full-service (self-service) also tend to value highly automotive (convenience store) service. Automotive service bays, then, should increase full-service prices at both SP and MP stations leaving Δ unaffected. Convenience stores should increase self-service prices, and, since nearly all convenience stores are at self-service-only stations, should increase the average price of self-service gasoline at SP stations, thereby reducing Δ.

Finally, if consumers value newer stations, the fact that full-service stations tend to have older plant and equipment suggests that prices will be lower at these stations. If stations exploit a preference for newness by raising prices, a positive Δ could be observed without price discrimination based on service quality.

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[9] Notice that unless these factors also affect cost, price discrimination is still going on, but may not be based only on differing valuations of gasoline service.

3.3 Stochastic Specification and Price Differential Results

The data set is a complete population census of gasoline stations in the Boston area in early 1987. While there is no sampling error in the usual sense, the observed prices can be interpreted as a single realization of a stochastic process. Prices at station i of type t for gasoline supplied with service quality *s*, in market j can be represented by:

$$P_{ijts} = \eta + \beta_0 S_i + \beta_1 S_i T_i + \beta_2 T_i + \gamma_{1j} m_j + \gamma_{2j} m_j S_i + \phi X_{ijts} + \mu_{ijts} \qquad (19)$$

where S and T are dummy variables for full-service gasoline and MP stations respectively, m is a market dummy, X is a vector of other station characteristics and the error term, μ, is assumed to have mean zero. The market effects are included in the specification to account for local, unobserved variations in supply or demand conditions that may have service-specific effects.

By construction, η is the mean price for self-service gasoline at SP stations, β_0 is the average differential between full and self-service prices at SP stations ($\bar{\Delta}_{SP}$), β_2 is the average increment to the self-service price associated with MP stations ($\bar{\Delta}_l$), and β_1 is an estimate of the mean difference in price differentials ($\bar{\Delta}$). The average difference between full-service prices across station types ($\bar{\Delta}_h$) is $\beta_2 - \beta_1$, and the price differential at multi-product stations ($\bar{\Delta}_{MP}$) is $\beta_2 - \beta_0$. Absent type-specific cost differences, the competitive model predicts that $\bar{\Delta}$, $\bar{\Delta}_h$, and $\bar{\Delta}_l$ will be zero, but price discrimination at multi-product stations predicts that $\bar{\Delta}$ and $\bar{\Delta}_h$ will be greater than or equal to zero and $\bar{\Delta}_l$ will be less than or equal to zero.

The vector of station characteristics (X) includes variables that might be related to cost or demand. Consistent with the discussion of potential cost differences, presence of a convenience store (CSTORE) and automotive repair bays (BAY) are included along with a measure of gasoline sales capacity. Of the capacity measures presented in Table 2, fueling places (CAPACITY) is probably the most meaningful. The relationship of capacity to lot size depends both on what structures exist at the station and on design efficiency. A station with a major convenience store will have a larger lot, on average, than a station with a small store or no store. Because an island can contain from one to eight pumps, the number of islands is also an ambiguous capacity measure. Fueling places, however, is a relatively standard metric and reflects only gasoline sales capacity. The number of fueling places is defined as the number of cars that can easily fit at the available pumps for the relevant service level.

Some of the prices recorded as "self-service" are actually mini-service prices. Mini-service means that a station employee pumps the gasoline but will not perform any of the other services associated with full-service (cleaning windows, checking fluid levels, etc). Because mini-service is more labor intensive than self-service, it may be more costly. Six percent of the branded stations classified as self-service and twenty-three percent of the stations classified as MP offered mini-service rather than self-service. MINI is a dummy variable for mini-service at "self-service" pumps. The final station characteristics are dummy variables for stations that carry unbranded gasoline (UNBRANDED) and stations that have been remodeled in the three years prior to observation (NEW).

If the unobserved market effects are zero or uncorrelated with the other explanatory variables, an unbiased estimate of the remaining parameters can be obtained by estimating

$$P_{ijts} = \eta + \beta_0 S_i + \beta_1 S_i T_i + \beta_2 T_i + \phi X_{ijts} + \epsilon_{ijts} \qquad (19')$$

The ordinary least squares estimates of (19') using all the stations in appear in Table 3.[15]

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[15] The number of observations for this regression is 1749; there are 1277 SP stations and two observations for each of the 236 MP stations.

TABLE 3: REGRESSION ANALYSIS OF ALL STATIONS

	INDEXED PRICES				CURRENT PRICES			
	(1)	(2)	(3)[2]	(4)[2]	(5)	(6)	(7)[2]	(8)[2]
CONSTANT[1]	78.57 (0.46)	80.88 (0.51)	84.28 (1.06)	---[3]	82.36 (0.48)	84.92 (0.53)	87.95 (1.10)	---[3]
$\bar{\Delta}_{SP}$	8.36 (0.52)	7.00 (0.53)	5.77 (0.75)	5.41 (0.89)	8.74 (0.54)	7.22 (0.55)	5.93 (0.78)	5.53 (0.76)
$\bar{\Delta}_1$	2.53 (0.68)	0.34 (0.70)	-0.99 (0.92)	-1.53 (0.89)	2.62 (0.71)	0.20 (0.73)	-1.42 (0.96)	-2.00 (0.92)
$\bar{\Delta}$	9.98 (0.87)	11.35 (0.87)	12.90 (1.02)	13.04 (0.99)	10.45 (0.91)	11.97 (0.90)	13.67 (1.06)	13.81 (1.02)
UNBRANDED		-4.43 (0.47)	-4.68 (0.53)	-4.36 (0.74)		-4.90 (0.49)	-4.94 (0.55)	-4.96 (0.77)
MINI			2.71 (1.01)	1.73 (0.98)			3.12 (1.05)	2.13 (1.01)
CAPACITY			-0.44 (0.12)	-0.46 (0.11)			-0.52 (0.12)	-0.56 (0.12)
BAY			-0.08 (0.68)	-0.01 (0.66)			0.04 (0.76)	0.10 (0.68)
CSTORE			0.30 (0.73)	0.01 (0.71)			0.16 (0.76)	-0.03 (0.73)
NEW			-1.68 (0.41)	-1.74 (0.40)			-0.84 (0.43)	-0.93 (0.41)
ADJ. R^2	0.386	0.415	0.440	0.48	0.385	0.418	0.445	0.490

[1]The omitted service and type is self-service at specialized stations.

[2]Number of observations reduced to 1520.

[3]Brand fixed effects

Standard errors in parentheses.

The coefficient estimates are consistent with the price discrimination predictions and inconsistent with cost-driven differentials. On average, the price differential at MP stations is eleven to fourteen cents per gallon higher than the differential across SP stations. The higher differential comes from higher full-service prices rather than lower self-service prices; when controlling for branded versus unbranded prices, the mean self-service differential ($\bar{\Delta}_I$) can not be distinguished from zero in most specifications. Starting with essentially equal self-service prices, multi-product stations charge approximately an eighteen cent mark-up ($\bar{\Delta} + \bar{\Delta}_{SP}$) for full-service while full-service stations charge only about a seven cent mark-up. These results are robust to using the observed prices (columns five through eight) or the observed prices indexed by the relevant wholesale price (columns one through four). The results also are robust to the inclusion of other station characteristics that might affect cost or price formation.

As expected, unbranded gasoline is sold at a significantly lower price than branded products: the mark-up for branding is four to five cents a gallon. Mini-service increases the price of self-service gasoline by two to three cents per gallon, although this increment is estimated with only moderate precision. Recently remodeled stations appear to have somewhat lower prices suggesting that newer stations may be more cost efficient. Capacity has a very small effect on price, adding another fueling place reduces price by less than 0.5 cents per gallon. There is no distinguishable effect from the presence of service bays or a convenience store.

Some of the differences in prices may reflect different wholesale pricing strategies by upstream firms. Firms also have differing distribution networks that could conceivably bias the results. For example, sixty percent of Shell's 182 stations in the sample are MP stations while only 16 percent of

Texaco's 171 stations are MP stations. To test for brand-specific effects, (19′) was run with brand fixed-effects, and the results appear in columns 4 and 8 in Table 3. Some of the (unreported) fixed effects are significant, but their presence does not substantively change the sign or magnitude of Δ. Allowing the intercept to vary by firm does, however, lead to a significantly negative estimate of Δ_l.

Although prices have been indexed to account for changes in the wholesale price over time, the retail prices may still display substantial temporal variation. Conversations with gasoline retailers suggest that the period was not one of substantial retail price instability, but the retail response to slowly rising petroleum prices may be less smooth than is implicit in the indexing procedure. If so, it is possible that the results in Table 3 are an artifact of idiosyncratic price movements over time. To test for potentially confounding time effects, equation (19′) was estimated for prices recorded within each week. The results appear in Table 4. The central results on relative prices are confirmed; $\bar{\Delta}$ and $\bar{\Delta}_h$ are clearly positive, and $\bar{\Delta}_l$ cannot be bounded away from zero. Unbranded gasoline shows a significant price discount. The coefficient estimates of the other station characteristics are imprecise and unstable. The CSTORE variable has been omitted from this analysis because it is colinear with self-service in several weeks.

The error term in the regressions reported in Tables 3 and 4 include the market effects. These market variables reflect unobserved, local differences in supply or demand facing the stations. The volume of traffic and the income and taste distribution of potential customers may vary widely across the surveyed area. Similarly, the competitive environment facing a station with many other stations nearby may be substantially different from that facing an isolated station. To the extent that the type distribution of stations is not

TABLE 4: REGRESSIONS FOR EACH WEEK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Constant[1]	85.77	86.37	84.23	83.88	90.17	82.59	85.85	78.02	81.39	75.55
	(2.26)	(3.65)	(1.71)	(2.55)	(3.36)	(2.89)	(3.26)	(8.58)	(2.35)	(5.56)
$\overline{\Delta}$	8.42	6.18	4.22	5.08	5.78	5.32	3.47	9.88	4.54	5.32
	(1.70)	(2.44)	(1.65)	(1.73)	(2.25)	(2.17)	(2.56)	(6.82)	(1.70)	(3.84)
$\overline{\Delta}_1$	0.15	-1.16	-5.15	-2.36	-0.48	-0.34	-5.67	4.59	-2.86	-2.30
	(2.30)	(3.24)	(2.05)	(2.14)	(2.66)	(2.78)	(3.46)	(8.80)	(2.05)	(4.16)
$\overline{\Delta}_{SP}$	12.63	15.83	15.00	13.47	11.37	8.68	18.60	5.51	13.96	13.65
	(2.53)	(3.34)	(2.32)	(2.31)	(3.18)	(3.07)	(3.91)	(9.03)	(2.34)	(4.53)
Unbranded	-4.81	-3.40	-5.41	-5.85	-3.61	-5.38	-8.23	-3.73	-4.52	-5.88
	(1.19)	(2.36)	(1.07)	(1.15)	(1.47)	(1.46)	(1.71)	(4.91)	(1.37)	(2.70)
Mini	3.29	-3.31	4.84	0.17	3.63	-0.06	3.72	-3.72	3.20	-4.18
	(2.80)	(6.74)	(1.94)	(2.97)	(4.14)	(2.98)	(3.30)	(9.48)	(1.84)	(6.62)
Capacity	-0.79	-1.00	-0.39	-0.35	-0.75	0.13	-0.10	0.41	-0.76	-0.38
	(0.26)	(0.46)	(0.19)	(0.28)	(0.44)	(0.39)	(4.30)	(1.22)	(0.26)	(0.62)
Bay	-0.69	-4.14	0.85	1.17	-4.28	2.73	4.00	1.27	0.50	3.79
	(1.51)	(2.23)	(1.40)	(1.61)	(1.90)	(2.06)	(2.36)	(5.86)	(1.71)	(2.32)
NEW	-1.90	-1.20	1.13	-9.08	-3.74	-0.41	-2.06	-2.42	0.75	2.83
	(0.96)	(1.57)	(0.95)	(1.06)	(1.30)	(1.10)	(1.32)	(4.09)	(1.02)	(2.63)
R^2	0.510	0.610	0.479	0.492	0.461	0.333	0.684	0.296	0.396	0.543
Number Observations	290	101	289	255	116	187	94	53	285	79

the same in every market environment, unobserved local characteristics may bias the results from estimating (19').

These unobserved effects can be removed by differencing equation (19) by service quality for each market. This leads to two equations for each market of the form:

$$\bar{\Delta}_{s_j} = \bar{p}_{j1s} - \bar{p}_{j0s} = \theta + \phi\,(\bar{X}_{j1s} - \bar{X}_{j0s}) + \bar{\mu}_{j1s} - \bar{\mu}_{j0s} \qquad (20)$$

where $\bar{p}_{j1s}$ ($\bar{p}_{j0s}$) is the average price for gasoline of quality *s* by MP (SP) stations in area j. This approach eliminates the local effects common to the stations in market j, assuming that it is possible to categorize the observations by market. It does not resolve the issue of how a "market" is to be defined.

The objective of market definition in this context is to identify a group of stations that can reasonably be expected to face common demand and supply conditions. Note that this has nothing to do with defining a "market" in the usual industrial organization sense. It does not matter, for example, whether there are stations not included in the identified group that compete with the stations included in the group. In this limited sense, markets can be defined by proximity; stations within a specified cartesian distance are said to be in the same market. Since there is no a priori rule for how large these areas can be before demand or supply heterogeneity becomes an important factor, the analysis uses several different levels of proximity.

Finally, there is an issue about whether proximity alone implies common demand and supply conditions. Consider a town with one major street. All stations within x miles of a station on the main street may include stations on side streets--where the traffic volume and land values may be very different--as well as other stations on the main street. In this case, it might be preferable to limit the market definition to stations within x miles and on the main street. In contrast, if a town has two major, intersecting streets, an algorithm that picks up stations on both streets might be appropriate. The analysis below uses both definitions. To implement the second definition, the analysis is limited to stations on numbered routes.[16]

Under the first definition, the analysis begins with the 1011 mapped stations, of which 793 are branded stations and 156 are MP stations. Each of these multi-product stations becomes the center for a local area j. For each j, all branded stations within a radius of x miles are identified, the average price for each type and service ($\bar{p}_{jts}$) is calculated, and these averages are used to construct $\bar{\Delta}_{s_j}$. For $\bar{\Delta}_{s_j}$ to be non-missing, at least one branded, SP station selling gasoline of quality *s* must be in the prescribed geographic area. As a result, the number of markets is often less than the number of MP stations. This is particularly true for the self-service differential, because there are relatively few self-service stations. The number of market (MARKETS) and the number of stations (STATIONS) used to estimate the coefficients in equation (20) appear in Table 5. For example, when a market is defined to be all stations within a half mile radius of the MP station, there are 84 markets containing a full-service station, and these 84 markets include 209 MP or full-service stations (column one, Table 5). The procedure changes in an obvious way when the analysis is restricted to stations on the same numbered route. There are 412 mapped stations on numbered routes, of which 342 are branded stations and 84 are MP stations.

The analysis is limited to prices at branded stations; the presence of unbranded stations in a market is treated as part of the common supply environment removed by differencing. Because MINI is relevant only for self-

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[16] In principle, it would be possible to include all stations and define an algorithm that searches for changes in street name. In New England, however, street names change in a pattern unrelated to any observable phenomenon. Limiting the analysis to stations on numbered routes increases the probability that the stations will actually be on what could reasonably be considered the same street.

TABLE 5: LOCAL AREA REGRESSIONS

ALL BRANDED STATIONS

RADIUS	0.5		1.0		1.5		2.0	
DEPENDENT VARIABLE	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$
CONSTANT	12.61 (1.84)	-1.80 (2.58)	11.59 (1.57)	-1.71 (2.53)	11.27 (0.91)	-0.10 (1.99)	9.38 (0.86)	0.43 (2.16)
MINI	--	3.09 (2.62)	--	3.42 (3.13)	--	2.24 (2.71)	--	3.16 (2.87)
CAPACITY	0.33 (1.08)	-0.47 (0.50)	-0.36 (0.94)	-0.64 (0.53)	0.19 (0.60)	-0.33 (0.41)	0.41 (0.57)	-0.12 (0.47)
BAY	1.75 (6.21)	0.14 (2.53)	7.05 (5.83)	1.46 (2.35)	5.40 (3.61)	0.35 (1.90)	7.03 (3.86)	0.57 (1.86)
CSTORE	6.33 (15.87)	-0.93 (2.39)	16.15 (10.30)	0.78 (2.49)	11.84 (6.90)	0.14 (2.03)	-6.30 (6.41)	0.18 (2.07)
NEW	-2.46 (2.46)	0.76 (2.13)	-3.89 (2.68)	0.55 (1.90)	-2.74 (1.81)	0.46 (1.65)	6.58 (1.80)	-0.55 (1.79)
MARKETS	84	34	112	61	131	88	128	106
STATIONS	209	65	375	120	521	161	564	194

Standard errors in parentheses.

service, it appears only in the regressions for self-service prices. When the analysis is limited to stations on the same numbered route, only three markets have full-service or MP stations with convenience stores. CSTORE, then, appears only in the regressions for self-service prices in Table 6. Differencing market averages transforms the dummy variables in equation (19) to differences in proportions. Thus, for example, the MINI variable in equation (20) is the proportion of multi-product stations providing mini-service minus the proportion of self-service stations providing mini-service.

Tables 5 and 6 present the coefficient estimates from weighted least squares regressions based on equation (20). These are regressions of market averages weighted to reflect the underlying number of observations for each mean. The resulting error covariance matrix is homoskedastic. When a station is in more than one market[17], the errors will not be independent. Because these duplications are identifiable, the exact covariance matrix can be constructed and is used to correct the estimated standard errors. Results are reported only for indexed prices, but are essentially unchanged when the analysis uses unindexed prices.

When markets are defined to include all stations within a specified radius, the earlier results are confirmed. Even for very tightly defined markets, the average MP price for full-service is at least ten cents per gallon higher than the SP full-service price. This differential is precisely estimated and changes very little as the market radius changes from 0.5 miles to 2.0 miles. The coefficients on CSTORE, CAPACITY, NEW, and BAY are unstable and estimated with low precision in the full-service equations. As before, the mean self-service differential cannot be distinguished from

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[17]For example, if two MP stations are within half a mile of each other, each station will contribute to the mean MP prices calculated for the two markets. The errors for these two markets will not be independent.

TABLE 6: LOCAL AREA REGRESSIONS

BRANDED STATIONS ON NUMBERED ROUTES

RADIUS	1.0		1.5		2.0		2.5	
DEPENDENT VARIABLE	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$	$\bar{\Delta}_{h_j}$	$\bar{\Delta}_{l_j}$
CONSTANT	14.24 (2.27)	7.75 (3.17)	12.07 (2.11)	6.50 (5.18)	11.61 (1.85)	1.99 (3.51)	10.96 (1.64)	1.17 (2.68)
MINI	--	2.54 (3.10)	--	2.76 (5.91)	--	4.40 (5.17)	--	4.08 (3.92)
CAPACITY	0.47 (1.24)	0.38 (0.63)	-0.42 (1.15)	0.55 (0.95)	-0.19 (0.96)	-0.07 (0.67)	0.50 (0.94)	-0.19 (0.55)
BAY	12.90 (6.30)	3.21 (2.79)	11.53 (6.33)	1.69 (5.43)	14.46 (5.31)	3.56 (5.19)	7.89 (5.97)	2.29 (3.69)
CSTORE	--	9.14 (3.85)	--	6.87 (5.55)	--	5.27 (4.05)	--	3.71 (3.12)
NEW	-4.73 (3.32)	4.34 (2.26)	-2.81 (3.20)	3.61 (3.76)	2.19 (3.15)	0.68 (2.85)	2.51 (2.98)	0.45 (2.40)
MARKETS	46	12	53	22	55	24	58	29
STATIONS	113	26	151	37	170	48	191	58

Standard errors in parentheses

zero. Except for the coefficient for mini-service, all the coefficients in the self-service equations are very small and not precisely estimated. The mini-service effect is larger--suggesting that mini-service at MP stations increases the price differential by two cents per gallon over the price at stations providing unadorned self-service--but imprecisely estimated.

The results are similar when only stations on the same route are included in the analysis. Table 6 reports these results for radii from one to 2.5 miles. The larger radii are necessary to get a reasonable number of markets with specialized, self-service stations. Given that only stations along the same street are considered, the larger radii may be appropriate since the demand and supply conditions may change more slowly along a main street than when moving off a main street. Even with this restrictive definition of local markets--a definition that restricts the analysis to densely stationed streets--the mean MP full-service price is eleven to fourteen cents higher than the SP full-service price. In these equations there is also the suggestion that prices at stations with service bays may be higher, but the coefficient is estimated with only weak precision. As before, the mean self-service differential cannot be distinguished from zero, and the mini-service coefficients have the expected sign but are imprecisely estimated.

Except for the firm fixed effects specification, the estimates of Δ_1 suggest the average price for self-service gasoline is the same at SP and MP stations. If costs are type invariant, (nearly) equal self-service prices will occur only when the wholesale price, given α, is high enough to make the viability constraint on full-service at MP stations (close to) binding. But in this case, the price of full-service gasoline at MP stations is so high that demand for it is (close to) zero. It seems unlikely that refiners would choose to invest in full-service capacity and then set a wholesale price that implies the capacity will not be used. This explanation also is inconsistent with the observed volume of sales as reported in Table 2. Very low full-service sales at MP stations would imply that MP stations are selling almost twice as much self-service gasoline per self-service fueling place as are self-service stations. This difference in capacity utilization rates also seems unlikely.

An alternative and more plausible explanation is that the marginal cost of self-service is higher at MP stations than at self-service stations. A cost disadvantage of this type will increase the MP retail price for self-service (in response to the higher cost) and decrease the MP retail price for full-service (self-service sales are less valuable). As a result, Δ_1 can be positive and Δ will be smaller. Self-service at MP stations will be more costly if there are service specific scale economies. It seems reasonable that this type of scale economy might be present; the most labor-efficient method for retailing self-service is to use automatic metering devices and a single cashier for many self-service pumps. These labor savings would be particularly important in the tight labor market of the Boston area. The data are inconclusive regarding scale economies: prices decrease in capacity in equation (19′), but are indistinguishable from zero in equation (20). Note that if the scale of self-service is low enough at all MP stations that the most efficient large scale technology is dominated by a more labor intensive technology, costs could be higher even if the true capacity coefficient were zero over the relevant range. Labor costs for self-service also could be higher at MP stations if the same worker provides both service qualities and high quality requires more highly paid labor.

Note that a third explanation--that self-service customers have a very elastic demand for gasoline while full-service customers have less elastic demand--is not consistent with the data. Suppose self-service customers have an infinitely elastic demand so that the retail price of self-service is equated to its marginal cost (w). Then the self-service price will be invariant to station type, but the full-service price will not. The problem facing the full-service retailer is unaffected by the demand elasticity for self-service. But the problem facing the MP dealer is affected by marginal cost pricing for self-service. His ability to exploit the less elastic demand for full-service is constrained by the availability of self-service at marginal cost. The consumer's incentive compatibility constraint will result in a price differential that is lower than the price differential across SP stations. In this model, if $p_1^{**} = p_1^{*} = w$, Δ will be negative.

4. Retail Configuration

The model's predictions with respect to the choice of station configuration suggests that the mix of station types observed in the sample is not optimal. If stations have no market power, full-service or self-service will be optimal, but only one type will be observed. If stations have market power, MP stations might be optimal, but, again, only one station type should be observed. The divergence between the model's predictions and the observed mix of station types is not surprising given the relatively slow adjustment process for distribution systems and the variety of factors that affect the choice of station type. While prices can reach their equilibrium values relatively quickly, distribution networks change only very slowly. Equilibrium predictions with respect to prices are more likely to be verified in the data than equilibrium predictions with respect to the nature of the distribution network.

The branded distribution system has changed dramatically over the last twenty years, and there is no reason to believe that the current system is an equilibrium. A major change has been the growth of self-service sales. In 1974, twenty-percent of the gasoline sold in the U.S. were self-service sales; by 1982 the proportion had grown to seventy percent (Fenili, 1985). Coincident with this change has been a sharp decline in the number of service stations: the station population declined by 35 percent from 1972 to 1982 according to the U.S. Census. The decline appears to have accelerated since the end of price and allocation controls in 1981: between 1983 and 1985 the major refiners reported a reduction of 28 percent in the number of their retail outlets (Energy Information Administration, 1986). Over the same period, gasoline output per station has grown: the major refiner outlets show an increase of thirty-five percent in average monthly volume. The ongoing change is toward fewer stations with larger capacity and providing self-service.

Underlying these demands is a change in technology.[18] The conventional service station of the 1950s and 60s sold gasoline, other refined petroleum products (lubricants and other automotive fluids), standard automobile parts (batteries, tires, belts, etc.) and automotive service. Automotive service included basic maintenance provided in service bays--engine tune-ups, brake pad replacement, lubrication, etc.--and "driveway" service provided at the pumps--checking fluid levels, tire pressure and wear, window washing, etc. Over the 1970s, technological change in the automobile industry has reduced the need for driveway service and some types of basic maintenance. In addition, the skill required for many remaining maintenance tasks has increased, shifting demand toward specialty auto repair shops. As a result, the demand for automotive service at gasoline stations has declined. Service bays were valuable to refiners when they lead to sales of their non-gasoline products; the decline in demand has reduced the usefulness of stations as an outlet for these products. Because full-service is associated with driveway services, the decline in demand for driveway service has also made full-service less important for promoting the sale of non-gasoline products. These technological changes have reduced the value of full-service to the refiner, making self-service relatively more attractive. At the same time, advances in electronic control equipment have reinforced the dominance of self-service by reducing its cost. In terms of the model in section 2, the change in demand

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[18] The discussion in this section is based on Temple, Barker and Sloan, 1988, and Nordhaus, Russell and Sturdivant, 1983.

suggests that $H - L$ has declined over time; the increased efficiency of self-service implies that α has increased. Both of these changes lead to a decline in the profitability of full-service relative to self-service.

The effect has been that full-service stations have borne a disproportionate share of the decline in the number of stations and that new stations should tend to offer self-service. The intertemporal substitution of self-service for full-service is apparent in the data on station type presented in Table 7. These data--drawn from trade press publications--have a large measurement error[19], but are useful for showing the long-term trend. The first three columns include data on any upstream firm reporting in a given year with more than 1000 retail outlets. The last three columns include data on a subset of firms reporting in most years. The data in Table 2 confirm that full-service stations are likely to be older than stations offering self-service. What is not clear in the data is the relative preference for MP versus self-service stations. The proportions of both types have increased over time, but there is no evidence that one of these types will come to dominate the distribution system.

5. Conclusion

This study presents strong evidence that retail gasoline pricing reflects price discrimination based on willingness to pay for service. It confirms the informal, anecdotal evidence on wide-spread price discrimination and is consistent with recent theoretical work demonstrating that price discrimination can occur in multi-firm markets. If there is some incremental cost to the consumer from purchasing at another outlet, a multi-product dealer can increase the price of the high quality product and still capture some rent

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[19]The data are reported each year, but the identity of the reporting companies changes from year-to-year. In addition, the accuracy of the data is questionable.

TABLE 7: DISTRIBUTION OF STATION TYPE
1974-1988

(%)

YEAR	FULL-SERVICE[1]	SELF-SERVICE[1]	MP[1]	FULL-SERVICE[2]	SELF-SERVICE[2]	MP[2]
1988	20	46	34	28	33	39
1986	10	42	42	11	33	56
1984	16	23	61	29	13	58
1982	52	9	38	40	9	51
1980	52	16	32	47	8	45
1978	64	7	31	62	4	34
1976	80	3	17	74	2	24
1974	88	2	10	91	1	8

[1] All firms with more than 1000 stations reporting in a given year.
[2] Firms reporting in most years.

from customers who defect to the low quality product at the same location rather than incurring the cost of purchasing high quality elsewhere. Using data on location, it is clear that price dispersion is not competed away even in settings where there appears to be minimal horizontal differentiation and therefore minimal incremental cost to purchasing elsewhere. The model used to generate predictions about pricing also has implications for the manufacturer's choice of outlet type that are inconsistent with the data. This failure could have been anticipated by recognizing that station configuration is not a choice variable in the short-run and is affected by a variety of factors outside the model.

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