

MAXIMUM OR MINIMUM DIFFERENTIATION? LOCATION PATTERNS OF RETAIL OUTLETS

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Abstract—We empirically test implications from location theory using the location of Los Angeles–area gasoline stations in physical space and in the space of product attributes. We consider the effect of demand patterns, entry costs, and several proxies for competition on the tendency for a gasoline station to be physically located more or less closely to its competitors. Using an estimation procedure that controls for spatial autocorrelation and spatial autoregression, and controlling for market characteristics and nonspatial product attributes, we find considerable evidence that firms locate their stations in an attempt to spatially differentiate their product as market competition increases.

I. Introduction

Hotelling's (1929) integration of spatial (product) differentiation into market models has spawned a vast theoretical literature. Whereas Hotelling suggested that firms would tend to minimally differentiate,¹ subsequent work has demonstrated that almost any equilibrium configuration can be obtained depending on the assumptions of the model, including the extremes of minimum and maximum differentiation. In the location decision, firms face two opposing incentives that generate the mixed results. First, firms have an incentive to locate products close to competitors' products in an attempt to capture more consumers. (Following Pinske and Slade (1998), we call this the *market share* effect.) Working against this incentive, however, is the fact that reducing spatial or product differentiation leads to greater competition in the price dimension; thus, a firm has an incentive to locate farther from its rivals in order to reduce price competition (the *market power* effect). Although clustering or differentiation may obtain depending on the assumptions of the model, Irmen and Thisse (1998) characterize the theoretical literature as being more supportive of differentiation than of clustering. However, with the exception of some mixed results in Borenstein and Netz (1999), the empirical literature has found that the market share effect dominates, leading to clustering of product locations.

Using data on the location and attributes of all gasoline stations in the Los Angeles basin, we contribute to the empirical analysis of location choice in two ways. First, we analyze a market in which, based on industry characteris-

tics, we expect to find that the market power effect dominates. We expect the market power effect to be particularly strong due to posted prices and the homogeneity of gasoline. When gasoline stations are located in close proximity, for example, at the same intersection, consumers can compare prices without leaving their car. Thus, the effects of price competition are likely to be particularly strong. As a result, the market power effect may dominate the market share effect, leading to locations away from competitors rather than a clustering of locations. Second, we allow firms to differentiate in two dimensions: in physical space and the space of product attributes. For example, a gasoline station may complement gasoline sales with repair services, a convenience store, a car wash, and so on. A gasoline station may be able to mitigate price competition by differentiation in terms of physical location and/or in terms of product offerings. Previous empirical studies have examined locational patterns in a single-dimension space only.

We discuss in section II the inferences that we draw from the theoretical literature that are consistent with the characteristics of the retail gasoline industry. We then survey related empirical studies. In section III, we construct an empirical model of the station location decision. Each station is assumed to lie at the center of a circular market. We control for the effects of the factors that vary across stations and markets in order to analyze the strategic incentives of stations to locate either closer to or farther from rival stations. Controlling for censoring of the dependent variable, for spatially correlated errors, and for spatial autoregression, our results, reported in section IV, support our hypothesis that price competition in the retail gasoline market is sufficiently strong to induce firms to spatially differentiate their product in order to reduce price competition. That is, we find empirical evidence that gasoline stations spatially differentiate rather than cluster. In addition, we find that spatial differentiation increases as stations become more differentiated in other station characteristics. We conclude in section V.

II. Review of Related Theoretical and Empirical Literature

Reconciling the institutional details of the retail gasoline industry and the theoretical literature on location choice is not trivial. To be tractable, theoretical models are relatively simple, whereas the industry is characterized by a number of complicating characteristics. For example, gasoline stations are physically located in a two-dimensional space. The spatial patterns of stations arise from sequential entry (and exit). Relocation is so costly as to be prohibitive, and exit is

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¹ d'Aspremont, Gabszewicz, and Thisse (1979) demonstrate the problems with Hotelling's proposed equilibrium.

likewise costly, although not prohibitively so.² The analysis of the location of gasoline stations is further complicated by the fact that location and pricing decisions are often made by different entities. Although refiners control the location of gasoline stations, either by owning the station or choosing with which stations to contract, pricing authority is generally delegated to the manager of the station.³ Finally, stations may offer other services in conjunction with gasoline. Although it is beyond the scope of this paper to develop a theoretical model explaining location decisions incorporating all of these complications, we briefly review the theoretical literature to identify those factors likely to determine the locational pattern of stations. We then examine the recent empirical literature on location choice.

The literature analyzing location choice in a one-dimensional space is large compared to the literature examining location choice in multidimensional space. Because many of the multidimensional results are consistent with those in the one-dimensional location choice literature, we concentrate here on the one-dimensional case.⁴ The characteristics that seem to be most important in driving the equilibrium location results include the distribution of consumer locations, the elasticity of demand, the form of the transport cost, and consumer heterogeneity. For example, Eaton and Lipsey (1976) show that, if the distribution of consumers is nonuniform, then locations will be more concentrated. Relaxing the assumption of inelastic demand (Smithies, 1941; Eaton, 1972) mitigates the incentive for firms to minimally differentiate, because, if they move too far from the endpoints of the market, firms will lose consumers; in other words, the market share effect is moderated. d'Aspremont, Gabszewicz, and Thisse (1979) demonstrate that, by changing Hotelling's assumption of linear transportation costs to quadratic costs, firms maximally differentiate.⁵ De Palma et al. (1985) introduce consumer heterogeneity.⁶ If demand is sufficiently heterogeneous, minimum differentiation obtains, regardless of the number of firms making location decisions. The conclusion that we take from the one-dimensional literature is that equilibrium locational patterns may be characterized by a tendency towards minimum or maximum differentiation; which dominates depends crucially on the particular assumptions of the model. Therefore, the empirical analysis must attempt to control for each of these influences.

Other theoretical considerations that are important for our empirical analysis include the possibility of sequential entry in the presence of relocation costs, differentiation on attributes other than physical location, and location choices among firms locating more than one plant or outlet. When relocation costs are quite high, the location choice of a firm will reflect an incentive to deter entry in the future. If there is a tendency towards minimum (maximum) differentiation, firms will increase (decrease) differentiation in the face of potential entry to ensure that there is no market niche large enough to sustain entry.⁷ Several studies have examined the simultaneous choice of differentiation in multiple dimensions. The general consensus is that firms maximally differentiate on one characteristic (that from which consumers derive the most utility), while minimally differentiating on the others. For example, Ben-Akiva, De Palma, and Thisse (1989) show that brand differentiation may reduce price competition sufficiently that minimum differentiation with respect to geographic location can be sustained.⁸ As Neven and Thisse (1990, p. 191) summarize: "[F]irms will have a tendency to select similar strategies with respect to some characteristics, if at the same time they are sufficiently differentiated along the remaining dimensions." Finally, we must consider that refiners in the gasoline industry locate multiple stations, whereas the models that have been discussed so far assume that each location choice is made by an independent firm. As in the single-outlet literature, the possibility of entry causes firms to locate plants close enough to rivals' (or their own) plants so that the resulting market "gaps" are not large enough to support entry.⁹ The incorporation of multiple outlets does not appear to alter the conclusions drawn from the single-outlet literature: whether maximum or minimum differentiation obtains depends crucially on the assumptions of the model.

Relatively little empirical work has analyzed locational patterns to discern whether firms are likely to choose clustered rather than dispersed locations.¹⁰ Borenstein and Netz (1999) and Salvanes, Steen, and Sjørgard (1997) empirically analyze departure times of airlines for the United States and Norway, respectively. When price is exogenous (due to regulation and, in the case of Salvanes et al., an alleged cartel), both find evidence that an increase in competition on a route leads to a reduction in departure-time differentiation.¹¹ However, after deregulation of prices and entry in the

² Relocation and exit are costly because the station is legally responsible for the environmental cleanup of the site.

³ The exception is refiner-owned (vertically integrated) stations, in which case the refiner controls location and pricing.

⁴ For studies of location choice in two-dimensional spaces, see Eaton and Lipsey (1975, 1976) and Lösch (1954).

⁵ Economides (1986) considers a range of transport cost functions, from linear to quadratic. Although not all equilibria are maximally differentiated, firms always locate at some distance from each other.

⁶ The form of the heterogeneity considered involves brand preferences: at identical total prices (mill price plus transportation costs), some consumers prefer one brand to another.

⁷ See, for example, Anderson (1987), Hay (1976), and Prescott and Visscher (1977).

⁸ See also Ansari, Economides, and Steckel (1998), Irmen and Thisse (1998), and Tabuchi (1994).

⁹ See Bensaid and De Palma (1993), Gabszewicz and Thisse (1986), and Martinez-Giral and Neven (1988).

¹⁰ Earlier work includes two case studies; Swann (1985) studied the microprocessor industry, and Shaw (1982) the fertilizer industry. Both interpret the pattern of product characteristics to indicate a tendency towards clustering, although products are generally not identical (that is, are not minimally differentiated).

¹¹ Models in which price is exogenous are more likely to predict minimal differentiation. An exogenous price eliminates the market power effect;

United States, Borenstein and Netz find mixed results. Although the direct effect of an increase in competition continues to reduce departure-time differentiation, they also find that more scheduling flexibility causes airlines to increase differentiation in departure times. The latter suggests that firms would like to differentiate themselves more in terms of departure time than they are able. Pinske and Slade (1998) empirically examine whether gasoline stations with similar contractual agreements with refiners are more likely to cluster with respect to their physical location. Because contract types are associated with certain station characteristics,¹² they interpret their results as implying that firms with similar characteristics tend to cluster. Finally, Stavins (1995) finds evidence that a firm developing a new personal computer model will locate its model more closely to existing models in product space as the number of firms in the industry increases. Thus, with the exception of some evidence in Borenstein and Netz, the empirical findings generally support a degree of clustering (although not so far as minimum differentiation). Yet, when price is endogenous, theoretical models are more likely to predict a movement away from clustering as the market power effect becomes relatively more important.

Our goal, in part, is to reconcile the theoretical literature, which more often arrives at equilibrium location patterns that exhibit differentiation, with the empirical literature, which thus far has found more evidence of clustering than of differentiation. We use the insights of the theoretical literature to control for other determinants of location choice to empirically isolate whether the market share effect or the market power effect dominates.

III. An Empirical Framework

A. The Empirical Model

To identify whether a tendency towards minimum or maximum differentiation dominates, we are particularly interested in how the general degree of competition in a market affects the location decisions of firms. The monopoly equilibrium in any model will be characterized by locations that minimize transportation costs because such locations maximize the amount of consumer surplus that can be appropriated via a higher price. Whether competition leads to more or less differentiation depends on whether there is a tendency towards maximum or minimum differentiation. As a simple example, comparing Hotelling's proposed outcome of minimum differentiation with the monopoly outcome suggests that, in the Hotelling model, more competition leads to clustering. On the other hand, models that predict maximal differentiation, such as d'Aspremont et al. (1979), suggest that an increase in competition leads to

more differentiation than would be obtained by a monopolist. If competitive firms have a tendency toward minimum differentiation, then increases in competition will lead to more clustering, but if there is a tendency toward maximum differentiation, as we expect in the retail gasoline industry, then increases in competition will lead to more dispersed locations.

Given the previous discussion on important theoretical considerations, the model we estimate can be written as

$$DIFF_i = \alpha + \beta C_i + \zeta A_i + \gamma X_i + \epsilon_i, \quad (1)$$

where i indexes the station. $DIFF$ measures the degree of spatial differentiation. The variables included in matrix C measure general competition in the market and in matrix A station differentiation in attributes, and matrix X contains control variables related to demand conditions and entry costs.

To measure the degree of spatial differentiation, we assume that each station lies at the center of a circular market. We then calculate the average Euclidean distance between the center station and each of its rivals.¹³ Several shortcomings are associated with measuring the degree of spatial differentiation using our measure. First, the Euclidean distance between stations may be an inaccurate measure of proximity for some stations. The measure may not capture actual driving distance or whether two stations are truly substitutes. For example, three stations may be close in Euclidean distance, but two of the three may lie on a major road and the third may lie off the beaten path. Thus, the two on the major road may compete more with each other than they do with the third station. Second, our data do not identify unusual traffic patterns that may prohibit consumers from visiting two stations that are close in proximity but far in real driving distance. For most cases, however, our measure of differentiation is likely to be a good proxy for true spatial differentiation.

To capture the relationship between the level of competition and the degree of spatial differentiation, we examine three measures related to the degree of competition in the defined market: the total number of stations, the proportion of stations that are independent (nonmajor) gasoline stations,¹⁴ and the proportion of stations that carry the same brand of gasoline as the center station. The literature does not offer an expectation for the effect of an increase in competition. To reiterate, as competition increases, stations will spatially differentiate themselves more or less, other things constant, depending on whether the market power or the market share effect dominates. We expect that the retail

firms can reduce the distance between locations in order to attract customers from rivals without an increase in the intensity of price competition.

¹² See Shepard (1993).

¹³ A second measure of differentiation, defined as the average of squared distances between the center station and each of its rivals, was also examined. This measure incorporates the assumption that closer stations offer more competition than do more distant stations. The qualitative results are unaffected by this variation of the dependent variable.

¹⁴ Our sample includes seven major brands: Arco, Chevron, Exxon, Mobil, Shell, Texaco, and Unocal. All other stations are treated as independents.

gasoline industry is subject to sufficiently strong price competition that the market power effect will dominate, in which case an increase in competition will increase spatial differentiation.

We use the number of firms as a measure of the degree of competition in the market to capture the fact that, as the number of firms in the market increases, consumers will have additional prices to sample.¹⁵ Ideally, any measure of competition would be something akin to the number of potential customers per firm. For example, if one market has two firms and 1,000 potential consumers and another has four firms but 40,000 potential consumers, presumably the first market would be more competitive than the second market. However, we do not possess an accurate measure of potential demand for gasoline in a given market. Although we do have data on the characteristics of consumers who reside in the vicinity of each station, consumers of gasoline are, of course, mobile. As a simple example, consider the market for gasoline at a highway interchange. Demand for gasoline is presumably high, but residential population is likely to be quite small.

Nonetheless, the number of firms will be directly related to the degree of competition in the market for gasoline if one considers search costs. Suppose that, in the Los Angeles basin, many consumers routinely travel along a fixed traffic route; for example, assume that workers travel the same route to and from work each day. If an additional station enters the market, at least some consumers will have reduced search costs in the sense that, without deviating from their regular travel route, they will observe an additional price. Thus, from a search cost perspective, (price) competition will increase as the number of observable prices increases.¹⁶

Location and competition may also be influenced by brand-name issues. Gasoline stations may be "branded," meaning that they sell gasoline under the brandname of one of the major refiners, or unbranded (that is, carried by an independent dealer). This influence depends on consumers' perceptions concerning the homogeneity of gasoline. Suppose that gasoline is homogeneous within each grade (regular, mid-grade, and premium). Then the proportion of the stations in the defined market operated as independents may proxy for increases in price competition because independent stations typically offer lower prices.¹⁷ We expect more-aggressive price competition to strengthen the market power effect; more price competition will increase the incentive to

locate farther from competitors in order to reduce price competition. Some consumers, however, may perceive unbranded gasoline to be inferior to the gasoline sold by branded stations. To the extent that this is true, an increased presence of independent stations may provide less competition to a branded station than an increase in the number of branded competitors. If the former effect dominates, then, as the percentage of independents increases, the market power effect will increase, and we should see an increase in the degree of spatial competition. If the latter effect dominates, then the market power effect will decline with an increase in the percentage of independents, and we should see a decline in the degree of spatial competition.¹⁸

Additionally, unbranded stations' location decisions may be different than those made by branded stations because of quality perceptions and organizational differences. To control for such an effect, we include a dummy variable indicating whether the center station is independent. If gasoline is perceived to be homogeneous, we would expect independents to locate no differently than branded stations. If there are quality differences (or perceived quality differences) across branded and unbranded gasoline, then independents may locate differently than branded stations. Consistent with the theoretical literature as a whole, models that allow differentiation in a vertical dimension (quality) and a horizontal dimension (spatial location) give ambiguous results. Depending on the range of the quality dimension relative to the range of the horizontal dimension, firms will maximize differentiation in one dimension and minimize differentiation in the other. Because the quality range for gasoline is quite small, we would expect independents to locate with more spatial differentiation.¹⁹ In addition, an independent station faces different incentives in locating than do refiners. A refiner may extract rents from stations in two ways: from sales of gasoline and from franchise fees. From the literature on vertical relationships, we know that a refiner will wish to increase interbrand competition at the retail level in order to reduce or eliminate the double markup problem. An independent station will not have that incentive; profits are made only from retail sales of gasoline. Thus, the independent will face a stronger market power incentive than will a refiner. We therefore expect independent stations to be located with more spatial differentiation than branded stations, other things constant.

Our final measure of competition is the percentage of the market that carries the same brand as the center station. Stations that carry the same brand can be operated under a variety of contractual arrangements. For example, stations

¹⁵ Stavins also uses the number of firms in the market as a measure of competition in an examination of product space location. The number of firms is not uncommonly used in empirical studies to measure market-level competition; see, for example, Borenstein and Rose (1994) and Png and Reitman (1994).

¹⁶ Controlling for other station-level characteristics, Barron, Taylor, and Umbeck (2000b) find that the average price and the level of price dispersion are lower in gasoline markets with more stations.

¹⁷ Controlling for demand and cost considerations, Barron et al. (2000a) find that branded (major) stations charge significantly higher prices than do independent (nonmajor) stations.

¹⁸ To test whether the percentage of independent stations has a different effect for branded and unbranded stations, we interacted the variable capturing the percentage of independents in the market with the dummy variable indicating whether the center station is independent or a major brand. We could not reject the null hypothesis that the coefficients on the interaction terms were equal, and allowing for differential effects did not alter our results.

¹⁹ See Neven and Thisse (1990).

may be owned and operated by the refiner (that is, company operated), stations may be leased to the station manager from the refiner (lessee dealers), or stations may be owned by a manager who contracts to carry the refiner's brand (jobbers or contract dealers). Stations are located by the refiner, either by physically locating the station or by choosing with whom to contract. Although the refiner controls the locational decision for all types of stations, the refiner controls the pricing decision only for company-operated stations. Essentially, the refiner can internalize the location externality but cannot always internalize the price externality.²⁰ Again, refiners can extract rents from stations in two ways: through sales of wholesale gasoline and through franchise fees (for lessee dealers only). With respect to extracting rents via wholesale prices, the refiner would be interested in stimulating interbrand competition to avoid the double-marginalization problem. We would expect to see refiners crowding their stations with those of their competitors to increase interbrand competition, but refiners will increase the distance between same-brand stations. The same result is expected if refiners appropriate rents primarily through franchise fees that, in turn, are directly related to station-level profits. A refiner will not be interested in attracting consumers away from one of its stations, but rather the refiner will want to attract consumers away from rival stations. We expect, therefore, to see increases in the percentage of same-brand stations in the market to be associated with greater spatial differentiation.

Because relocating a gasoline station is extremely, if not prohibitively, costly, the firm must consider not only the existing competitive makeup of the market when choosing its location, but also the potential for future entry. Even if a station preferred to locate near to (far from) competitors in the absence of entry considerations, the potential for future entry may lead the firm to locate farther from (closer to) competitors in order to minimize market niches in which future firms can locate. Whether minimum or maximum differentiation obtains in the absence of entry, stations will become more evenly spaced as the ease of entry increases. We proxy for entry costs by including two variables: the proportion of the gasoline stations in the defined market requiring prepayment and the proportion of housing in the market that is rented rather than owner-occupied.²¹ In addition, for the smaller of the two samples we analyze, we have data on the median value of housing in the defined market area.²² As the cost of entry increases (median housing value rises, the fraction of the market requiring prepayment falls, and the fraction of the market that is rental property falls), the degree of differentiation may rise or fall.

²⁰ By externality, we refer to the fact that a station's location and price choices affect the profits of its rivals.

²¹ The proportion of stations requiring prepayment may serve as a proxy for crime rates, which are likely to be correlated with land values.

²² We describe each sample in the following text.

If observed differentiation rises (falls), then firms prefer to strategically increase (reduce) spatial differentiation.

Median household income can proxy for several factors that have important roles in the theoretical analysis. First, median income can be a measure of the price elasticity of demand. As income increases, consumers become less sensitive to price changes, which dampens the loss of consumers at the extremes of the station's market area for a given price. With a decline in the elasticity of demand, stations can locate more closely to rivals without losing sales at the "end" of the market if they prefer less differentiation, whereas stations can locate farther from rivals without losing customers located between stations if they prefer more differentiation. Second, the income level of consumers can also serve as a proxy for the costs of entry. If it is assumed that entry costs increase as the income level in the surrounding area increases, then in markets with higher incomes stations can locate strategically without fearing entry. Thus, if we observe that an increase (decline) in median income leads to an increase (decrease) in differentiation, we can infer that firms prefer to strategically locate farther from (closer to) rivals. Finally, areas with higher incomes may indicate consumers with higher search costs. If this is the case, we may observe that areas with higher incomes are associated with decreased spatial differentiation to compete for the high-search-cost consumers.

Zoning laws limit the ability of gasoline stations to freely locate. Our variables that proxy for entry costs may also capture, to some degree, the restrictiveness of zoning. For example, an increase in median property values and median income may be correlated with an increase in zoning restrictiveness. Likewise, an increase in the proportion of stations requiring prepayment or in the fraction of the market that is rental housing may indicate a decline in zoning restrictiveness. If the observed degree of differentiation decreases (increases) as zoning restrictiveness increases (indicated by an increase in median property values or in median income or by a decline in prepayment requirements or rental housing), we can infer that firms prefer to differentiate (cluster) spatially, but are limited in their ability to do so.

A direct influence on the pattern of location, regardless of market structure, is the distribution of consumers. The theory indicates that locations are more clustered if the distribution of consumers is more clustered. To control for the distribution of consumers, we use a dummy variable equal to 1 if the station is within 0.25 miles of a "major road," as defined by the Census Bureau. We expect that there is higher demand along major roads, and hence gasoline stations will be located more closely together than otherwise.

Closely tied to consumer distribution, another aspect of the market that will influence location are differences in within-area demand across markets. In particular, markets may differ in the number of intersections with sufficient

demand to support a gasoline station. Suppose that our results indicate that markets with greater competition, measured by the number of stations, are associated with a greater degree of spatial differentiation. This might be driven by differences across markets in the number of good intersections, rather than a strategic move to differentiate. For example, one market may include only one “good” intersection, whereas another may include two.²³ In the former, two stations would be more likely to cluster, but in the latter they could separate. Suppose, further, that we observe two stations (at the only intersection) in the first market, and four stations (two at each intersection) in the second. This type of heterogeneity across markets could drive the empirical result that more stations are associated with more differentiation, when, in fact, stations prefer to cluster. Although we do not have information on each market reflecting the number of “good” intersections, we include a variable indicating the percentage of each station's rivals that are near a major road. As this percentage increases, it is not unreasonable to suspect that the number of “good” intersections in the market may be larger.

Finally, consumers often buy more than gasoline at a station; for example, they may demand repair services or pay-at-the-pump convenience in addition to gasoline. Stations, therefore, also differentiate themselves with respect to station attributes or characteristics. If a station has effectively differentiated itself from the surrounding competition by offering some ancillary service, this may increase its incentive to locate close to rival stations for two reasons. First, price competition may be mitigated because consumers can buy a different “product” at each gasoline station, decreasing the market power effect. Second, gaining market share is now relatively more advantageous because the firm may profit from the sale of the other services, even if price competition for gasoline itself is extreme. Thus, we expect an increase in product space differentiation to reduce spatial differentiation.

To capture relative differentiation on other station-level attributes, such as whether stations offer full service, repair service, a car wash, a convenience store, and/or pay-at-the-pump technology that allows the use of credit and/or debit cards at the pump, we define a measure of attribute differentiation as follows. For example, if a station offers (does not offer) full-service gasoline, we define a dummy variable, *Full Service (No Full)*, set equal to unity if more than 50% of its rivals do not (do) offer full service, and 0 otherwise. An identical approach is utilized for the remaining attributes. We separate offering a service and not offering a service on the belief that the two may have different effects. In particular, it seems likely that offering a service that a nearby rival does not have is likely to attract more customers, and that not offering a service that a nearby rival

does offer does not seem likely to attract marginal customers.²⁴

B. The Data

For any station in our sample of every gasoline station in the Los Angeles basin from 1992 to 1996, we define its market by drawing a circle around it. The theoretical work presumes that the spatial extent of the market is well defined; in reality, especially in the retail gasoline industry, drawing the geographic boundary of a market is difficult. Gasoline stations that are located at the same intersection offer substitutes to consumers;²⁵ there is, however, some distance at which a gasoline station is too far away to offer an effective substitute for most consumers. Our goal is to define the market in such a way as to include most of the center station's rivals. Because the extent of the market is an empirical issue, we follow the literature (Shepard, 1991; Barron, Taylor, & Umbeck, 2000b) in using market radii of one-half mile, one mile, and two miles.

We consider two samples: “entry” stations and “stable-market” stations. Entry stations are stations that are new in any given sample year, and the stable market sample consists of any station that is present in each year of our sample and whose rivals appear in each year of the sample as well. These markets are completely static with respect to location decisions; that is, there was no entry into or exit from these markets during our sample period.

This specification ignores any time dimension, which is natural for the sample of stable markets because these are static with respect to entry and exit. For the sample of entering stations, however, any variable not included in our model that is correlated with time may cause the error terms in year t to be correlated. Year dummy variables proved to be consistently statistically insignificant and did not alter our results. These time dummies are therefore not included in the specification we report in the next section.

Examining entry stations is likely the most direct method of examining stations' location decisions. In this sample, each station is choosing its degree of spatial differentiation given the existing market attributes. However, the market characteristics existing at the time of entry may not represent an equilibrium; in response to entry, other stations may exit and/or change their attributes. Thus, analysis of the stable-market stations may be more appropriate for capturing the equilibrium relationship between market characteristics and the degree of spatial differentiation.

Our data contain detailed station-level characteristics on all of the more than 4,000 gasoline stations in the Los

²⁴ This may not be true for all services. For example, consumers with a high value for time may not like stations with convenience stores because convenience stores slow transaction times.

²⁵ This may be true in varying degrees as well. Traffic patterns may prevent two stations from competing effectively if it is difficult for a consumer to travel between two stations located at the same intersection.

²³ We thank one of the referees for this example.

Angeles basin from 1992 to 1996.²⁶ Station addresses were used to convert locations into coordinates of latitude and longitude for each station. Census tract numbers were recorded and used to collect market data from the 1990 *Census of Housing and Population*. Descriptive statistics are reported in table A1 in the appendix.

C. Econometric Concerns

We assume a linear relationship between all variables and spatial differentiation except with respect to the number of stations. Whether firms prefer to increase or decrease spatial differentiation as the number of firms increases, geography predicts that there exists a limit to this relationship. For example, if spatial differentiation dominates, there exists a point at which more stations in a defined market must decrease the average Euclidean distance between the center station and its rivals. If spatial clustering dominates, only so many stations can be located at the same intersection. We therefore include the number of stations squared as an independent variable in our estimation.

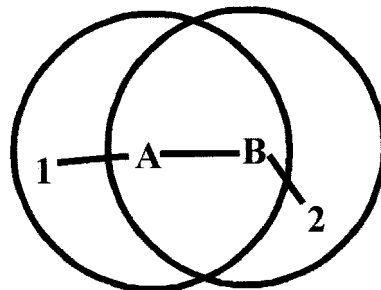
We consider two alternative treatments of the error term. The first is an error components model wherein the fixed effect is over municipalities. The error term can be written as

$$\epsilon_i = \delta_k + \mu_i, \quad (2)$$

where k indexes the city and μ is assumed to be independently and identically distributed with constant variance. To the extent that our control variables do not adequately capture the effects of zoning laws on the location decision, the inclusion of a city fixed effect allows us to control for zoning laws that may prevent a station from locating solely at its discretion. For example, if the area within a market is zoned in such a way that gasoline stations may locate at one intersection and nowhere else, we may observe less differentiation even if the stations prefer more differentiation. In this treatment, we assume that the error terms for any stations located in city k are correlated, whereas the error terms for stations located in different cities are independent.

Alternatively, we address the fact that the observations (and errors) are spatially related. The spatial relationship affects estimation in two dimensions. First, the degree of differentiation at one location may affect the degree of differentiation at another location, if the locations are close enough; this is referred to as a *spatial lag* or *spatial autoregressive relationship*. Second, the error term for station i may be correlated with the error for station j , where the degree of correlation depends on the distance between the stations; this is referred to as *spatial error* or *spatial autocorrelation*. The first effect is a statistical artifact; the second may reflect similarities in market characteristics not captured by the regressors, including similarities of zoning

FIGURE 1.—SPATIAL LAG ILLUSTRATION



laws that are specific to different types of areas (residential, business, rural) that do not follow municipality borders.

Figure 1 illustrates the spatial lag or autoregression issue. Consider two stations, A and B. If B is one of A's rivals (in which case A will be one of B's rivals), then the degree of differentiation for A and B will be correlated. In the simplest case, assume that stations 1 and 2 do not exist; A is B's only rival and vice versa. Then A and B will have identical differentiation measures: the distance between them. Now assume that A has another rival (station 1) and B has another rival (station 2). Then A's differentiation measure will be the average of the distance between A and B and between A and 1. B's differentiation measure will be the average of the distance between B and A and between B and 2. Because each differentiation measure has some overlap—the distance between A and B—the two will be correlated. The more rivals a station has, the less its differentiation measure will be correlated with that of its rivals.

To control for the spatial lag or autoregression issue, an additional term is added to equation (1). For notational ease, let $\Gamma Z_i \equiv \alpha + \beta C_i + \zeta A_i + \gamma X_i$. Then, with the addition of the spatial lag or autoregression term, equation (1) can be rewritten as

$$DIFF_i = \rho W_1 DIFF + \Gamma Z_i + \epsilon_i, \quad (1')$$

where ρ indicates the strength of the spatial lag relationship and W_1 is the spatial lag weighting matrix. In the weighting matrix, each entry for row (station) i is 0 if column (station) j is either not in i 's market or j is never a center station, and it is equal to 1 divided by the number of i 's rivals if j is in i 's market and is a center station.

The degree of spatial autocorrelation, on the other hand, is a function of the distance between the stations. The closer that two stations are in proximity, the more correlated we expect their error terms to be. Any exogenous change in the market environment not captured by the regressors (in particular differences in zoning restrictions) will be captured by the error term for both markets. We correct for this spatial correlation by using a spatial error model wherein the error term can now be written as

$$\epsilon_i = \lambda W_2 \epsilon_i + \mu_i, \quad (3)$$

where

²⁶ Survey data were obtained from Whitney-Leigh Corporation.

ϵ_i is the vector of errors for all N stations,
 λ is the residual spatial autocorrelation coefficient,
 W_2 is an $N \times N$ symmetric spatial error weighting matrix,

and

μ is an independently and normally distributed error term
 with constant variance.

The spatial weighting matrix specifies the degree of correlation across observations and is an inverse function of the Euclidean distance between the two markets. The diagonal entries are zero and the off-diagonal entries are the negative exponential of the distance between stations i and j ; thus, the correlation between errors is weighted more heavily for stations in close proximity.

Regardless of our treatment of the error term, our measure of differentiation is censored for monopoly markets. When only one station exists in a defined market, the differentiation measure is set equal to the maximum value of differentiation, the radius of the market.²⁷ Thus, the upper end of the distributions of the differentiation measure and the error term are cut off and probabilities will be accumulated at the cutoff point. We correct for censoring by estimating the equation using a Tobit analysis. This is straightforward in the case of an error components model, but it requires augmentation of the usual spatial lag-spatial error likelihood function.²⁸ Again, let $\Gamma Z_i \equiv \alpha + \beta C_i + \zeta A_i + \gamma X_i$ and let τ_i indicate observations in which the dependent variable is censored. Then, the log likelihood function we maximize when allowing for spatial correlation of errors, spatial autoregression of observations, and adjusting for censored observations is given by

$$\begin{aligned}
 l = & \ln(1 - \lambda\omega_{1i}) + \ln(1 - \lambda\omega_{2i}) - \frac{1}{2} \ln(2\pi) - \frac{1}{2} \ln(\sigma^2) \\
 & - (1 - \tau_i) \frac{1}{2\sigma^2} e_i^2 + \tau_i \ln\left(1 - \Phi\left(\frac{e_i}{\sigma}\right)\right), \quad (4)
 \end{aligned}$$

where $e_i = DIFF_i - \rho W_1 DIFF_i - \lambda W_2 DIFF_i + \rho \lambda W_1 W_2 DIFF_i - \Gamma Z_i + \lambda W_2 \Gamma Z_i$ and ω_{1i} and ω_{2i} are the eigenvalues of the spatial lag weights matrix and the spatial error weights matrix, respectively.

The final econometric concern is the possibility of endogeneity. In our sample of entry stations, stations can be viewed as taking the current market characteristics as given and then choosing a location based on those characteristics.

²⁷ Among the entry stations, this occurs in 26%, 12%, and 4% of the observations for the half-mile, one-mile, and two-mile markets, respectively. Among the stable-market stations, this affects 20% of our observations for the half-mile markets and no observations for the one-mile and two-mile market definitions. Qualitative results are unchanged if these markets are eliminated from the analysis.

²⁸ See Anselin (1988) for a derivation of the likelihood function in the presence of a spatial lag and a spatial error, but without adjusting for censored observations.

Nonetheless, there still may be some degree of endogeneity. Consider a situation in which zoning laws influence the number of stations in a market and their location (and hence the degree of differentiation).²⁹ Then the same zoning laws that influence the degree of differentiation of the entering station may have influenced the number of stations in the past. If the zoning laws are stable, or at least highly correlated across time, then the number-of-stations variable (affected by past zoning laws) may be correlated with the error term (which captures current zoning effects, among other things). However, we do not expect such zoning influences to have a systematic effect. Zoning laws could lead to (i) a few firms with clustered locations, (ii) a few firms with differentiated locations, (iii) many firms, clustered, or (iv) many firms, differentiated. If there is no systematic relationship of zoning laws on the number of firms and the degree of differentiation, the number of firms may well not be correlated with the error term. Endogeneity is more likely for the stable sample. Market characteristics that may affect the locational pattern (for example, locations of heavily traveled roads) may also affect the number of stations that can be supported in the market.

A similar question arises for the attribute differentiation measures. For the entry sample, we again expect no systematic relationship between the zoning impact in different municipalities on relative station attributes and spatial differentiation. For the stable sample, it may be that entry causes existing stations to alter their attributes. Institutional knowledge of the retail gasoline industry and many conversations with executives in major retailing operations leads us to believe that station attributes are chosen before the entry decision. For example, many oil companies offer a standard station configuration to their retailers. Retailers must agree to these station characteristics before a supply agreement is signed. Thus, we acknowledge the possibility of endogeneity but believe the effects will be small, especially for the entry stations.

IV. Results

Tables 1 and 2 report estimation results using the sample of entry stations and sample of stable-market stations, respectively.³⁰ We note that the results are fairly robust to estimation technique (that is, whether using the error-components or spatial-error/spatial-lag specifications), to different definitions of market size (half-, one-, and two-mile radii), and to sample (entry-market and stable-market observations). This is particularly reassuring in light of the possibility of endogeneity. Recall that we expect the degree of endogeneity to be quite small, if present at all, for the entry stations, whereas endogeneity is likely to be present in the stable samples. In addition,

²⁹ We thank a referee for identifying this potential source of endogeneity.

³⁰ Approximately 10% to 40% of the city fixed effects are statistically significant at the 10% level or better. For brevity's (and interest's) sake, we do not report the estimated city fixed effects.

TABLE 1.—ENTRY STATIONS (STANDARD ERRORS IN PARENTHESES)

	1/2 Mile		1 Mile		2 Mile	
	(1)	(2)	(1)	(2)	(1)	(2)
Stations	54.62*	96.93*	13.03	56.86*	11.71***	25.36*
	(20.26)	(17.07)	(13.75)	(13.46)	(6.07)	(6.26)
Stations sq.	-1.29	-5.35*	0.03	-2.00*	-0.15	-0.35*
	(1.69)	(1.48)	(0.69)	(0.73)	(0.10)	(0.12)
% independent	-0.03	0.49	0.68	0.52	7.02*	-0.03
	(0.52)	(0.33)	(0.68)	(0.53)	(1.45)	(0.96)
% same brand	5.19*	5.84*	6.05*	7.69*	7.61*	11.27*
	(0.76)	(0.64)	(0.83)	(0.87)	(1.53)	(1.56)
Independent	20.15	9.43	85.38*	59.54**	87.20**	46.82
	(25.80)	(18.69)	(25.83)	(24.84)	(34.93)	(37.35)
% near major road	0.65	-0.19	-1.32**	-68.70	-2.80**	-333.00*
	(0.41)	(35.48)	(0.65)	(57.69)	(1.25)	(109.91)
Near major road	-59.08**	-56.58*	-56.13**	-79.31*	-100.12*	-76.56**
	(23.16)	(19.47)	(23.72)	(22.64)	(30.15)	(32.08)
Income	-0.37	0.16	-5.75*	2.83**	-9.50*	-1.43
	(1.32)	(0.71)	(1.80)	(1.43)	(2.99)	(1.75)
Med. value	-0.28**	-0.21**	-0.28***	-0.01	-0.14	0.05
	(0.11)	(0.08)	(0.15)	(0.13)	(0.20)	(0.19)
% prepay	-0.25	0.46***	0.62	0.88***	1.18	1.45***
	(0.37)	(0.26)	(0.63)	(0.49)	(1.17)	(0.83)
% rent	-0.22	0.93*	-1.84**	1.66**	-0.03	1.17
	(0.62)	(0.34)	(0.90)	(0.68)	(1.85)	(1.15)
Full serve	65.41	75.21**·†	9.71†	-14.02†	178.67	170.19
	(43.74)	(32.93)	(57.90)	(63.65)	(137.97)	(116.35)
No full	64.39**	70.09*	137.73*	137.24*	296.83*	310.99*
	(30.40)	(19.73)	(34.78)	(34.39)	(78.16)	(62.77)
Car wash	175.68*	97.47**	36.38†	123.45**	40.80†	144.43
	(54.05)	(39.39)	(59.72)	(61.17)	(162.71)	(167.30)
No wash	132.98*	78.03*	234.54*	189.16*	252.33***	243.40**
	(38.38)	(29.29)	(55.13)	(49.83)	(137.00)	(106.61)
Repair	-14.86	1.47	29.83	-20.59†	96.81	13.80
	(25.26)	(19.59)	(35.51)	(36.91)	(61.24)	(67.52)
No repair	-9.25	12.32	44.34***	56.75**	96.44**	44.57
	(20.19)	(14.38)	(26.24)	(24.94)	(42.35)	(41.22)
Conv. store	1.41	37.25***	281.14*·†	33.29	157.28*·†	119.98**
	(27.08)	(19.51)	(33.10)	(31.86)	(56.70)	(48.18)
No store	28.92	58.89*	-0.53	77.70**	33.85	119.05***
	(30.18)	(18.07)	(38.08)	(38.92)	(58.12)	(64.78)
Credit card	-14.05	30.89***	-110.05*	-45.20	42.65	29.58
	(29.21)	(18.07)	(41.24)	(33.14)	(54.23)	(50.07)
No CC	32.28	35.10**	-8.48	-7.49	112.57**	75.05
	(24.82)	(16.68)	(33.16)	(32.10)	(51.75)	(60.91)
Constant	-9.51	-304.89*	632.30*	-196.61***	1082.02*	464.62*
	(97.12)	(68.55)	(148.58)	(108.39)	(248.76)	(52.24)
λ		0.07		0.16*		0.15*
		(0.04)		(0.03)		(0.03)
ρ		0.11		0.13*		0.02*
		(0.07)		(0.04)		(0.03)
χ^2 test	607.72*	517.13*	607.31*	344.70*	570.25*	341.72*
Observations	352	352	352	352	352	352

(1) Estimated using city fixed effects.

(2) Estimated controlling for a spatial lag and a spatially correlated error term.

* Statistically significant at 1%.

** Statistically significant at 5%.

*** Statistically significant at 10%.

† Statistically significantly different than the coefficient below at 10% level or better.

as explained previously, we expect the sources of endogeneity to differ across the two samples.

The qualitative results for each of the competition variables are robust across samples, across market sizes, and across estimation techniques. We find considerable evidence that increases in the number of stations, the fraction of the market offered under the same brand as the center station, and the fraction of the market served by independents, lead stations to locate farther from their competitors. These

results are consistent with the idea that gasoline stations spatially differentiate when located in a more competitive marketplace; that is, the market power effect dominates the market share effect. Thus, we find empirical support that, for the retail gasoline industry, firms strategically spatially differentiate their product rather than cluster.

The number of stations in the market is positively and statistically significantly correlated with the level of spatial differentiation in ten out of the twelve specifications. As

TABLE 2.—STABLE STATIONS (STANDARD ERRORS IN PARENTHESES)

	1/2 Mile		1 Mile		2 Mile	
	(1)	(2)	(1)	(2)	(1)	(2)
Stations	29.31** (11.60)	25.24* (9.66)	33.33* (10.90)	28.80* (9.51)	-38.73 (29.48)	74.43* (21.12)
Stations sq.	0.14 (1.18)	0.47 (0.93)	-1.57** (0.66)	-0.99*** (0.57)	0.35 (0.91)	-2.02* (0.65)
% indep	0.96* (0.21)	0.89* (0.18)	1.09** (0.50)	0.68 (0.46)	10.77* (2.67)	6.01* (1.82)
% same brand	3.98* (0.31)	3.46* (0.24)	1.61* (0.56)	1.06** (0.44)	6.96* (2.17)	1.89 (1.44)
Independent	51.56* (9.18)	44.25* (7.23)	10.01 (18.16)	3.87 (15.59)	84.51 (105.68)	13.14 (55.31)
% near major road	0.03 (0.15)	-0.08 (0.11)	0.08 (0.30)	0.12 (0.26)	-3.68** (1.65)	-0.97 (0.81)
Near major road	-15.48 (12.67)	-10.97 (8.51)	-57.62* (20.55)	-59.38* (17.92)	-123.02*** (69.60)	4.29 (51.62)
Income	-0.52 (0.42)	0.54** (0.24)	-1.84** (0.85)	0.25 (0.61)	1.38 (7.13)	0.51 (1.44)
% prepay	-0.38** (0.16)	-0.10 (0.12)	-1.45* (0.35)	-0.36 (0.28)	-0.98 (1.46)	-0.70 (0.86)
% rental	-0.27 (0.23)	0.78* (0.15)	-0.85 (0.61)	0.11 (0.48)	15.00** (7.63)	-0.02 (1.80)
Full service	47.31* (8.60)	38.70* (6.33)	16.88 (16.29)	16.21 (14.14)	16.89* (56.27)	29.87 (44.15)
No full	34.49* (8.60)	33.58* (6.22)	14.46 (18.23)	23.99 (15.94)	98.96 (99.84)	103.83 (68.01)
Car wash	90.74* (10.63)	67.18* (8.10)	20.19 (21.77)	-9.60 (18.84)	9.39† (88.45)	10.27† (70.57)
No wash	77.01* (10.76)	69.62* (8.47)	-2.19 (28.92)	-24.49 (25.73)	-691.03* (260.32)	-412.64* (134.38)
Repair	14.28*** (8.12)	5.68 (6.02)	-25.62† (15.90)	-24.59***.† (13.86)	-214.68***.† (77.78)	-85.37*** (46.70)
No repair	14.12*** (7.99)	3.85 (5.62)	24.22 (15.83)	14.07 (13.48)	-47.81 (83.01)	-26.49 (56.82)
Conv. store	33.42* (7.93)	27.35* (5.88)	-6.97 (15.99)	-17.27 (13.72)	-198.38* (59.50)	-113.61*† (41.58)
No store	20.03** (7.98)	17.34* (6.04)	18.03 (17.34)	6.98 (14.73)	-138.13 (82.34)	24.22 (50.13)
Credit card	22.08* (7.61)	13.08** (5.75)	-7.60 (15.38)	2.03 (13.41)	17.86 (54.08)	22.89 (38.62)
No CC	29.75* (7.44)	21.05* (5.61)	16.51 (15.31)	10.98 (13.61)	-81.25 (68.32)	-9.75 (50.70)
Constant	26.75 (47.12)	-77.71** (34.47)	353.43* (108.38)	446.71* (66.93)	843.51 (530.55)	812.17** (198.26)
λ		0.24* (0.01)		0.31* (0.01)		0.25* (0.02)
ρ		-0.02* (0.01)		-0.03* (0.01)		-0.00 (0.01)
χ ² test	2547.16*	2025.93*	665.55*	64.83*	220.75*	220.59*
Observations	2101	2101	932	932	127	127

(1) Estimated using city fixed effects.
 (2) Estimated controlling for a spatial lag and a spatially correlated error term.
 * Statistically significant at 1%.
 ** Statistically significant at 5%.
 *** Statistically significant at 10%.
 † Statistically significantly different than the coefficient below at 10% level or better.

expected, the coefficient on the quadratic term, which is always negative when statistically significant, indicates a declining effect of the number of stations on the average spatial differentiation. For the entry sample, taking the average of the estimated coefficients across both specifications for each radius, we find that, when the number of stations in the defined market increases by 1, locational differentiation increases by approximately 24% of the average differentiation for the half-mile market, 6% for the

one-mile market, and 2% for the two-mile market. The comparable numbers for the half-, one-, and two-mile stable-market samples are 9%, 6%, and 2%, respectively. Alternatively, when the number of stations in a market increases by one standard deviation relative to the mean number of stations, the average degree of spatial differentiation increases by 42%, 23%, and 20% for the half-, one-, and two-mile entry samples and by 15%, 19%, and 11% for the half-, one-, and two-mile stable samples. We see that the

magnitude of the impact is somewhat smaller for the stable-market stations than for the entry stations. This may reflect continued entry. That is, the results from the entry sample indicate that a firm prefers more spatial differentiation in the face of competition. Continued entry, which will be reflected in the stable-market sample, however, reduces the degree to which a firm is able to spatially differentiate.

When significant (in only one of the entry sample specifications, but in all but one of the specifications for the stable market sample), the results indicate that, as the fraction of the market supplied by independents increases, the amount of spatial differentiation increases, although the magnitude of the effect is generally small compared to the effect of an increase in the number of gasoline stations (except for the two-mile samples). When the percentage of the market supplied by independents increases by ten percentage points, average spatial differentiation increases by 1% to 3% (except for the two-mile stable market, which increases by almost 9%). Recall that we had two hypotheses regarding this variable. If gasoline is viewed as homogeneous by consumers, we expect that an increase in the percentage of stations in the market that are independents proxies for an increase in price competition (because independents charge lower prices than do branded stations). On the other hand, if gasoline supplied by independents is perceived as inferior to gasoline supplied by branded stations, an increase in the percentage of the market supplied by independents might instead represent a decline in price competition, at least for branded stations. The positive coefficient suggests that the prior effect dominates, leading stations to increase spatial differentiation in order to mitigate price competition.

Finally, consider our third measure of competition. As the fraction of the market served by the same brand as the center station increases, the incentive to locate closer to firms in order to attract customers declines from the point of view of the agent choosing location because the agent only wants to attract consumers away from rival stations, not the agent's own stations. We therefore expect to find greater locational differentiation as the fraction of the market that carries the same brand increases.³¹ We find robust evidence that supports this hypothesis across all specifications. The magnitude of the effect is about as strong as the effect of an increase in the number of stations by 1. When the proportion of the market served by the same brand increases by ten percentage points, the center firm increases its locational differentiation by 0.55, 0.69, and 0.94 of a mile for the half-, one-, and two-mile entry samples, which is 18%, 11%, and 8% of the average spatial differentiation. For the stable-market sample, the comparable numbers are 0.37, 0.13, and

0.44 of a mile, or 13%, 3%, and 5% of the average spatial differentiation.

The results from the variables proxying for entry costs and zoning restrictions can also shed light on whether gasoline stations prefer more or less spatial differentiation, although these results are less robust. If firms prefer to increase spatial differentiation in the face of competition, as indicated by the results for the competition variables, then an increase in entry costs (lessening the likelihood of entry) or a reduction in zoning restrictiveness should allow firms to spatially differentiate as they wish. Unfortunately, the two effects (entry costs and zoning restrictions) are both captured in each of our related control variables. As the percentage of the market requiring prepayment and the percentage that is rented rather than owned increase and as the median value of property decreases, we expect that zoning restrictiveness declines, allowing stations to locate as they wish, but that entry costs also decline, leading stations to locate in an effort to block future entry. If the effect of zoning restrictiveness dominates the entry effect, we expect to find a positive coefficient on the prepay and rental variables and a negative coefficient on the median value variable.

The estimated coefficients on the prepay variable are generally positive (and statistically significant half the time) for the entry sample and always negative (and statistically significant a third of the time) for the stable sample. This suggests that the zoning effect dominates in the entry samples and the entry effect dominates in the stable samples. This difference may be due to the fact that entry can occur only if zoning restrictions allow entry. Thus, as zoning restrictiveness falls, stations can enter and have more freedom to locate as desired. The stable sample observations, on the other hand, arise after sequential entry and exit. Entry may no longer occur because the stations have spread out sufficiently so that there is no room to support more entry. When statistically significant, the coefficient on the fraction of the market that is occupied by tenants rather than owners is positive in four of five cases. Interpreted in light of the competition results, this suggests that the decline in zoning restrictiveness effect dominates. Finally, when statistically significant, the coefficient on the median property value is negative. This suggests that, as entry costs fall and as zoning becomes less restrictive, spatial differentiation increases, which again is consistent with the findings that the market power effect dominates the market share effect as long as the effect of less restrictive zoning dominates the effect of a reduction in entry costs. We conclude that there is weak evidence that a decline in locational constraints in the form of less restrictive zoning laws leads firms to increase spatial differentiation.

The coefficients on the median income of residents—which may proxy for price elasticity of demand, entry costs, and zoning restrictiveness—are negative more often than positive when statistically significant. As income rises,

³¹ Recall that, except for company-owned and -operated stations, price-setting authority is largely delegated to the owner/operator of the station. Thus, an increase in the proportion of the market served by the same brand does not indicate a reduction in price competition because most of the stations carrying the same brand will have independent authority to set prices.

search costs rise and the (absolute value of) elasticity of demand is likely to fall. Then a decline in the distance between stations will increase price competition by a smaller amount. Thus, firms can reduce differentiation with a smaller effect on price. In other words, the market share effect becomes stronger. Income may also indicate entry costs and zoning restrictions. If income, as does median property value, primarily picks up zoning restrictiveness rather than entry costs, the negative coefficient is consistent with our previous findings. A reduction in zoning restrictions, signaled by a reduction in median income, induces firms to spatially differentiate.

The estimated coefficient on the variable indicating an independent station is always positive and is statistically significant in approximately half of the regressions. Thus, independent stations are located 0.44 to 0.85 of a mile farther from rivals than are branded stations. As explained previously, this is likely to be related to the differing incentives of independent station owners and refiners. To the extent that refiners extract rents via sales of gasoline, refiners will want to stimulate price competition in order to reduce or eliminate the markup imposed by the station. This increases the incentive of refiners to locate their stations more closely to competitors' stations. Independent stations, on the other hand, are concerned with only profits to be earned from retail sales of gasoline, so they will face a stronger market power incentive, leading to locations that exhibit greater spatial differentiation.

As predicted by the theory, stations located in close proximity to a major road are less spatially differentiated, other things equal. This reflects the fact that stations tend to locate where consumers are located. As the distribution of potential consumers becomes more clustered, stations are willing to locate closer to rivals. This result explains the often-cited existence of gasoline stations at the corners of any major intersection, despite our finding that an increase in the degree of competition will lead firms to spatially differentiate. This result is robust across all specifications. Based on the average of the point estimates, when a station is located within 0.25 mile of a major road, it will reduce differentiation by 19% of the average distance from rivals for the half-mile entry sample, 11% for the one-mile entry sample, and 14% for the two-mile entry sample. For the stable markets, the effect is a 5% increase in average spatial differentiation for the half-mile markets, 11% for the one-mile markets, and less than 1% for the two-mile markets. When statistically significant, the coefficient on the fraction of the market that is near a major road is negative, and generally the result is small (with the exception of the two-mile entry sample). We interpret this result as indicative that our competition effect—that an increase in competition leads to an increase in differentiation—is not driven by the availability of “good” intersections in markets with larger numbers of stations.

Finally, consider the variables that measure differentiation in nonspatial station attributes. The literature on multidimensional location suggests that, when firms differentiate on two or more characteristics, they maximally differentiate on one attribute and minimally differentiate on the others. Therefore, we expect the coefficients measuring attribute differentiation should indicate a negative correlation between spatial differentiation and differentiation on other station products or services. In general, however, we find, when significant, a mostly positive relationship between measures of attribute differentiation and the degree of spatial differentiation for the entry samples and the half-mile stable-market sample. The only statistically significant evidence we find for a negative relationship between spatial and product differentiation is one occurrence in the one-mile entry sample, one occurrence in the one-mile stable-market sample, and six instances in the two-mile stable-market sample. Thus, assuming that our measures of station attribute differentiation do reflect the degree to which consumers view stations as differentiated, our results suggest that the theoretical models are not capturing the entire story.³² Contrary to the predictions of the theoretical literature, we find that firms increase spatial differentiation as differentiation in other attributes increases.

We allow coefficients to differ across different attributes and having versus not having a service that the station's rivals mostly do not or do offer.³³ The estimates are sufficiently imprecise to allow much inference. No pattern emerges as to whether having an attribute that rivals do not have has a larger or smaller effect than not having an attribute that rivals do have. Indeed, more often than not, the coefficients are not statistically significantly different. Tests for the null hypothesis of equality of coefficients for all variables indicating that a station has an attribute that rivals generally do not are rejected at the 10% level for the half-mile entry sample estimated with fixed effects, and for the half- and two-mile stable samples for both error specifications. The null hypothesis is rejected at the 15% level for the half-mile entry sample when estimated allowing for a spatial lag and spatial error and for the one-mile entry samples for both specifications. Tests for the null hypothesis of equality of coefficients for all variables indicating that a station does not have an attribute that rivals generally do are rejected at the 10% level in every case except for the

³² We tried several alternative measures of attribute differentiation. One alternative used a continuous measure of differentiation: a dummy variable indicating whether the center station had (didn't have) an attribute was multiplied by a variable indicating the proportion of rivals that did not (did) have the attribute. We also tried forming indices of differentiation by summing either the dummy variable approach described in the text or the continuous approach. However, tests generally rejected the equality of coefficients across different attributes. All of the approaches performed about equally, and the primary results (signs, magnitudes, and statistical significance) of interest—the effect of competition on spatial differentiation—were unaffected by the alternative measures.

³³ In tables 1 and 2, when the coefficients are statistically significantly different than each other, the entry is marked with a †.

one-mile stable sample; for that sample, the coefficient results are so imprecisely measured that it would be difficult to reject any null hypothesis. That equality of coefficients is generally rejected should perhaps not be surprising. Demand for different attributes will vary, as will competition from other providers of these services.

V. Conclusion

The theoretical literature on product differentiation points to both maximum and minimum differentiation as possible outcomes in the presence of competition. Which effect dominates—the market share effect or the market power effect—depends crucially on the assumptions made. Thus far, with the exception of the mixed results of Borenstein and Netz (1999), the empirical literature has found evidence only of clustering. We have contributed to the empirical literature by examining locational patterns of gasoline stations in the Los Angeles basin retail gasoline market, in which the market power effect is quite likely to dominate.

The results on our measures of competition are quite convincing. We see a strong and consistent relationship between the degree of spatial differentiation obtained and our market competition variables. The results strongly indicate that gasoline stations prefer to spatially differentiate themselves as competition increases. We hypothesize that this is due to the extreme nature of price competition in this industry: because gasoline stations are required to post prices, a consumer can easily observe prices of nearby stations. Thus, we would expect a priori that the market power effect would dominate, as the empirical evidence confirms.

Our empirical result that an increase in attribute differentiation generally leads to an increase in spatial differentiation suggests that more theoretical work is needed to understand firm location decisions in a multidimensional space. Thus far, the theoretical literature is united in viewing the outcome of competition in multiple dimensions as leading to maximum differentiation in one dimension and minimal differentiation in all other dimensions, a result that is mostly inconsistent with our empirical results. We hypothesize that, as in the one-dimensional models, relaxing various restrictions (such as quadratic transportation costs, bounded spaces, uniform distribution of consumers, elastic demand, more than two firms) may lead to alternative equilibria.³⁴ In addition, the theory thus far shows that, although max/min locations are equilibria and that max-max locations are not equilibria, it has not shown that intermediate locational positions are not possible. Perhaps our empirical results are indicative that other equilibria exist.

³⁴ For example, Ansari et al. (1994) show that the equilibrium location patterns in a product space with two vertically differentiated dimensions vary greatly depending on the distribution of consumer preferences.

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APPENDIX

 TABLE A1.—DESCRIPTIVE STATISTICS¹

	Entry Stations			Stable Stations		
	1/2 Mile	1 Mile	2 Mile	1/2 Mile	1 Mile	2 Mile
Average Difference ²	305.04 (154.16) [0, 500]	599.61* (238.79) [0, 1000]	1193.63* (362.86) [3, 2000]	293.28 (157.73) [0, 500]	509.19 (218.06) [0, 999]	976.62 (360.21) [475, 1852]
Number of stations	2.92 (1.75) [1, 12]	6.42* (4.08) [1, 19]	19.54* (13.09) [1, 54]	2.92 (1.60) [1, 10]	5.30 (3.23) [1, 19]	8.31 (6.10) [1, 28]
% Same brand	51.35 (30.52) [8, 100]	33.12 (27.86) [5, 100]	20.44* (20.14) [2, 100]	49.63 (28.48) [10, 100]	35.26 (25.18) [6, 100]	34.65 (31.14) [4, 100]
% independent	26.90* (33.97) [0, 100]	23.54* (27.71) [0, 100]	23.13* (22.69) [0, 100]	7.35 (15.14) [0, 67]	10.54 (15.49) [0, 75]	9.45 (15.04) [0, 75]
Independent	0.36	0.36	0.57*	0.51	0.55	0.67
% near major road	33.42 (37.79) [0, 100]	25.33 (33.08) [0, 100]	18.17 (28.19) [0, 100]	7.35 (15.14) [0, 67]	10.54 (15.49) [0, 75]	9.45 (15.04) [0, 75]
Near major road ³	0.57*	0.57	0.57*	0.51	0.55	0.67
Income ⁴	34.59* (14.04) [0, 97]	35.34* (12.67) [15, 79]	36.28* (11.77) [16, 78]	38.30 (14.26) [0, 120]	42.86 (14.81) [0, 107]	49.43 (18.55) [15, 96]
Median value ⁴	157.89 (92.79) [0, 500]	157.89 (92.79) [0, 500]	157.89 (92.79) [0, 500]	—	—	—
% prepay	83.99 (26.65) [0, 100]	85.18 (21.43) [0, 100]	84.20 (16.62) [0, 100]	84.78 (27.34) [0, 100]	82.11 (25.91) [0, 100]	69.60 (26.95) [0, 100]
% rental	45.38 (23.47) [0, 100]	44.72 (20.65) [4, 100]	43.97 (18.26) [5, 100]	46.85 (22.16) [0, 100]	40.03 (17.43) [2, 100]	32.35 (12.56) [8, 66]
Full ⁵	0.05* (0.21)	0.03* (0.17)	0.02* (0.14)	0.37 (0.48)	0.32 (0.47)	0.37 (0.48)
No full ⁵	0.33* (0.47)	0.20* (0.40)	0.09* (0.28)	0.31 (0.47)	0.21 (0.41)	0.24 (0.43)
Wash ⁵	0.05 (0.21)	0.03 (0.17)	0.01 (0.12)	0.26 (0.44)	0.16 (0.37)	0.21 (0.41)
No wash ⁵	0.25 (0.43)	0.13 (0.33)	0.05* (0.21)	0.26 (0.44)	0.13 (0.33)	0.16 (0.37)
Repair ⁵	0.13* (0.34)	0.11* (0.31)	0.07* (0.26)	0.43 (0.49)	0.34 (0.47)	0.39 (0.49)
No repair ⁵	0.39* (0.49)	0.30* (0.46)	0.24 (0.43)	0.32 (0.47)	0.28 (0.45)	0.28 (0.45)
Store ⁵	0.22* (0.42)	0.22* (0.42)	0.16 (0.37)	0.43 (0.50)	0.33 (0.47)	0.45 (0.50)
No store ⁵	0.09* (0.29)	0.09* (0.29)	0.07* (0.26)	0.32 (0.47)	0.25 (0.43)	0.23 (0.42)
Credit card ⁵	0.21 (0.41)	0.21 (0.41)	0.16* (0.36)	0.43 (0.50)	0.35 (0.48)	0.46 (0.50)
No CC ⁵	0.15 (0.36)	0.15* (0.36)	0.10* (0.30)	0.36 (0.48)	0.27 (0.45)	0.30 (0.46)
Observations	352	352	352	2101	932	127

* Indicates that the mean for the entry and stable samples, for that radius, are statistically significantly different at the 5% level.

¹ The first entry is the mean, the second entry (in parentheses) the standard deviation, and the third entry [in brackets] the range.

² In hundredths of a mile.

³ Dummy variable.

⁴ In thousands of dollars.

⁵ Dummy if station has (doesn't have) the service × dummy if 50% or more rivals don't (do) have the service.