Maximum or Minimum Differentiation?
An Empirical Investigation into the Location of Firms

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November 1998

Abstract: We empirically test some 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 – the total number of stations, the proportion of independent stations, and the proportion of same-brand stations in a market – 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 correlation and controlling for market characteristics as well as non-spatial product attributes, we find that firms locate their stations in an attempt to spatially differentiate their product as general market competition increases. In other words, the incentive to differentiate in order to soften price competition dominates the incentive to cluster locations to attract consumers from rivals. We also find that spatial differentiation increases as stations become more differentiated in other station characteristics.

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JEL Classifications: L22, L13, D43, L90

Keywords: product differentiation, spatial theory, location theory, retail gasoline

Acknowledgments: We thank Jack Barron, Vrinda Kadiyali, Dan Kovenock, Pat McCarthy, Lars Sørgard, Jerry Thursby, John Umbeck, Klaus Wallner, seminar participants at Baylor University, Purdue University, and the 1997 International Atlantic Economic Society Meetings, and especially Jon Haveman, for helpful comments. Valuable research assistance was provided by Scott Blanchard, Stephanie Chang, Jesse Ramirez, Brittyn Russell, and Filip Vesely. Financial support was provided by the Purdue Research Foundation and the Hankamer School of Business.

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1. Introduction

Hotelling's (1929) integration of spatial (product) differentiation into market models has spawned a vast theoretical literature. While Hotelling suggested that firms would tend to minimally differentiate,[1] subsequent work has demonstrated that almost any equilibrium configuration can be obtained, including the extremes of minimum and maximum differentiation, depending on the assumptions of the model. In the location decision, firms face two opposing incentives that generate the mixed results. First, firms have an incentive to locate close to competitors in physical space or the space of product attributes 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).

Relatively little empirical work has analyzed locational patterns to discern whether firms are likely to choose clustered rather than dispersed locations.[2] Borenstein and Netz (1998) and Salvanes, Steen, and Sørgard (1997) empirically analyze departure times of airlines for the U.S. 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.[3] However, after

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

[2] Earlier work includes several case studies. See, in particular, Swann, 1985, on the microprocessor industry, and Shaw, 1982, on the fertilizer industry. Both interpret the pattern of product characteristics to indicate a tendency towards clustering, though products are generally not identical (that is, are not minimally differentiated).

[3] Models in which price is exogenous are more likely to predict minimal differentiation. An exogenous price essentially eliminates the market power effect; firms can reduce the distance between locations in order to attract customers from rivals without an increase in the intensity of price competition.

deregulation of prices and entry in the U.S., Borenstein and Netz find mixed results. The direct effect of an increase in competition continues to reduce departure-time differentiation, but 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 arrangements with refiners are more likely to cluster with respect to their physical location. Because contract types are associated with certain station characteristics, 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 (though not so far as minimum differentiation). Yet, when price is endogenous, theoretical models are more likely to predict a movement away from bunching as the market power effect becomes relatively more important.[4]

We investigate location choice in the Los Angeles Basin retail gasoline market. Due to posted prices and the homogeneity of gasoline, when gasoline stations are located in close proximity, 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. Our results support this hypothesis: price competition in the retail gasoline market is sufficiently strong to induce firms to differentiate their product in order to reduce price competition. That is, we find empirical evidence that gasoline stations spatially differentiate rather than cluster.

We discuss in Section 2 the inferences we draw from the theoretical literature that are consistent with the characteristics of the retail gasoline industry. We then construct an empirical model of the station location decision in Section 3. Each station is assumed to lie at the center of a circular market. Locational differentiation in each "market" can be described by the characteristics of all stations in the market, by the characteristics of

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4 Indeed, several authors have characterized the literature on location choice as being more supportive of differentiation than of clustering. See, *e.g.*, Irmen, 1998, and Stuart, 1979.

the central gasoline station, and by the characteristics of the market surrounding the center station. 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 away from rival stations. Controlling for censoring of the dependent variable and for spatially correlated errors, our results, reported in Section 4, suggest that, given the characteristics of the retail gasoline industry, a more competitive market – as measured by the number of firms in the market, the proportion of locations operated by independents, and the proportion of locations operating under the same brand – results in a more spatially differentiated locational pattern of stations. We find support for the hypothesis that gasoline stations locate at a distance from rivals in an effort to subdue the severity of price competition. In addition, we find that spatial differentiation increases as stations become more differentiated in other station characteristics. We conclude in Section 5.

2. Theoretical Motivation

Reconciling the institutional details of the retail gasoline industry and the theoretical literature on location choice is not trivial. In order to be tractable, the models are relatively simple, while 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 likewise costly, though not prohibitively so.[5] 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. While refiners control the location of gasoline stations, either by owning the station or choosing with which stations to contract, pricing authority is delegated to the manager of the station.[6] Finally, stations may offer other services in conjunction with gasoline. While it is beyond the scope of this paper to develop a theoretical model explaining location decisions incorporating these complications, we survey the literature to develop insights into the factors likely to determine the locational pattern of stations.

5 Relocation and exit are so costly because the station is legally responsible for the environmental clean-up of the site.

6 The exception is company-owned and operated stations. We describe the different contractual relationships between the refiner and the station in detail in section 3.

The literature analyzing location in a one-dimensional space has illustrated a variety of parameters that affect the degree of differentiation. The assumptions that seem to be most important in driving the equilibrium location results include: the distribution of consumer locations; 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 non-uniform, then locations will be more concentrated. Relaxing the assumption of inelastic demand (see Smithies, 1941, and 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.[7] d'Aspremont, Gabszewicz, and Thisse (1979) demonstrate that by changing Hotelling's assumption of linear transportation costs to quadratic costs, firms maximally differentiate.[8] DePalma, Ginsburgh, Papageorgiou, and Thisse (1985) introduce consumer heterogeneity.[9] If demand is sufficiently heterogeneous, minimum differentiation obtains, regardless of the number of firms making location decisions. The conclusion that we take from the 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 these influences.

Most spatial models assume that firms locate in a one-dimensional space. Yet the problem we face involves location in a two-dimensional space. While a number of papers have considered location in a two-dimensional plane, the insights of the literature are not well-developed. Lösch (1954) hypothesized that, with free entry and costless relocation, the equilibrium locational pattern in an unbounded, two-dimensional plane was characterized by a uniform distribution of firms with hexagonal market areas. The distribution of firms would be dense enough so that firms would earn zero profits.[10] Eaton and Lipsey (1976) show that

[7] Economides, 1984, considers a similar issue by assuming that reservation prices are low; typically reservation prices are assumed to be high enough that all consumers purchase the product. With low reservation prices, the market power effect dominates and firms locate at a distance from each other.

[8] Economides, 1986, considers a range of transport cost functions, from linear to quadratic. While not all equilibria are maximally differentiated, firms always locate at some distance from each other.

[9] 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.

[10] Free entry need not lead to zero profits. Rather, the equilibrium condition is that a potential entrant would earn negative profits upon entry, which is consistent with existing firms earning small profits. Eaton, 1976, illustrates the issue in the one-dimensional case.

hexagonal market structures are not the only possible locational pattern; other equilibrium patterns include squares, rectangles, and regular and irregular hexagons. Whether entry and exit is or is not possible, all equilibria are characterized by a reasonably uniform distribution of firms over the plane.[11,12]

When the plane is bounded, a uniform distribution of firm locations no longer obtains. Eaton and Lipsey (1975) consider locational equilibria on a unit disk for different fixed numbers of firms, assuming price is exogenous and that relocation is costless. The equilibrium for two firms is minimum differentiation in the center of the market, a lá Hotelling's one-dimensional result, but they cannot derive an equilibrium for higher numbers of firms. They are able to show that a Löschian-type configuration and that a uniform location of firms around the circumference of the circle (with or without one firm located at the center of the circle) are *not* equilibria. The Löschian configuration breaks down because firms at the edge of the disk prefer to locate more closely to interior rivals. Eaton and Lipsey then consider the dynamic location pattern.[13] While no equilibrium emerges, at least some firms tend to stay clustered together. They interpret their results as evidence of a "principle of local clustering." Recall, however, that they assume that price is exogenous. We know from the literature on one-dimensional location models that endogenizing price mitigates the incentive to locate close to rivals.

More appropriate models for analyzing the location of gasoline stations assume prohibitive relocation costs and sequential entry. Given that each firm knows entry may occur in the future, the location choice of the firm that locates initially reflects an incentive to deter entry in the future. To illustrate the issues, consider Prescott and Visscher (1977), who analyze entry in a model where price is assumed to be exogenous, so that the market power effect is eliminated. They show that if there is only one potential entrant, minimum differentiation is obtained a lá Hotelling. If more than one potential entrant exists, the first two

[11] The uniform spacing of firms is driven in part by the assumption that consumers are uniformly distributed on the plane. Assuming the insights of the one-dimensional literature carry over, we would expect, following Eaton and Lipsey, 1975, that the distribution of firms would be clustered in a manner similar to the distribution of consumers if consumers are not distributed uniformly.

[12] A uniform distribution of firm locations arises because firms are able to relocate in response to entry. However, such a process is not appropriate to the retail gasoline industry, where relocation is very costly, perhaps prohibitively so.

[13] They allow each firm to enter sequentially, then allow each firm to relocate in the order in which the firm entered. For example, with three firms, they allow firm 1 to enter, then firm 2, firm 3, then they allow firm 1 to relocate, then firm 2, *etc.* Locations do not converge to an equilibrium.

firms locate symmetrically and away from the midpoint in order to deter entry. Assuming price is endogenous, Anderson (1987) shows that the initial firm to enter the market locates at the midpoint, while the second firm then locates very close to one of the endpoints.[14] Hay (1976) considers entry with no exogenous limit on the number of potential entrants. He shows that the expected locational pattern involves an even spread of firms located at intervals roughly twice the minimum market size required for profitable entry.[15] Thus, potential entry can mitigate clustering even when price is exogenous; when price is endogenous, the market share effect is even further reduced.

Gasoline stations locate not only physically but also with respect to other ancillary services.[16] Ben-Akiva, de Palma, and Thisse (1989) assume that the location in a circular brand space is exogenously fixed, that firms first permanently choose a physical location along a bounded line, and then compete in prices. Consumers bear linear transport costs in geographic space and quadratic transport costs in brand space. Based on an assumption that firms are exogenously uniformly spread over the brand space and that no entry occurs, minimum differentiation in geographic space obtains.[17] Essentially brand differentiation reduces price competition sufficiently that minimum differentiation with respect to geographic location can be sustained. Several more recent papers (Irmen, 1998; Ansari, Economides, and Steckel, 1998; and Tabuchi, 1994) endogenize locational choice in multiple horizontally-differentiated dimensions,[18] making largely the same assumptions.[19] These papers arise at the same result: firms maximally differentiate on the characteristic that consumers care most about and minimally differentiate on the remaining characteristics.[20,21] Tabuchi shows

[14] Thus, endogenizing price eliminates the minimum differentiation equilibrium of Prescott and Visscher.

[15] Then a firm entering between two existing firms will capture a market share not quite large enough to allow profitable entry.

[16] Notice that locating in multiple dimensions in this setting is inherently different than a physical location in a two-dimensional space. In the latter case, consumers care only how far the physical location is from them in Euclidean distance, regardless of the direction of the distance. In the former case, consumers separately care about deviations from their most preferred point in each dimension.

[17] With n firms, a uniform distribution over the space is the analog of maximal differentiation.

[18] Horizontal differentiation refers to differentiation on attributes over which consumers have different preferences (or most preferred points); for example, sizes and colors.

[19] These include: firms choose a permanent location in the first stage and compete in prices in the second stage; transportation costs are quadratic in each dimension; transportation costs in each dimension can have different weights in the consumer's utility function; consumers are distributed uniformly over the N-dimensional product space; consumers have unit demands; the N-dimensional space is bounded and represented by a hypercube; and that two firms locate simultaneously with no threat of entry.

[20] If consumers care equally about all dimensions, then multiple equilibria arise with maximum differentiation on one dimension and minimum differentiation on the others.

[21] The papers do not establish uniqueness; that is, other equilibria may obtain. They do show that locational patterns characterized

that this result is somewhat mitigated when sequential entry is assumed. Firms continue to maximally differentiate in one dimension, but they do not minimally (nor maximally) differentiate in the other dimension.

It is possible that consumers consider the attributes chosen by gasoline stations as a form of vertical differentiation.[22] That is, at identical prices, consumers may agree that the presence of other services is preferred to their absence.[23] Neven and Thisse (1990) analyze locational choice when products are characterized by one horizontal attribute and one vertical attribute. Assuming that consumers' utility rises linearly with an increase in the vertically differentiated dimension and decreases quadratically by deviations from their most preferred point in the horizontal dimension, that consumers are distributed uniformly, Neven and Thisse show that if the range for vertical differentiation is large relative to the horizontal dimension, then firms will maximally differentiate on the vertical dimension and minimally differentiate on the horizontal dimension, and vice versa.[24] Neven and Thisse (p.191) nicely sum up the insights of both types of multiple dimension location models: "[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."

As a final consideration for the retail gasoline industry, we must consider that refiners locate many stations, while the models that have been discussed thus far assume that all locations are made by independent firms. Gabszewicz and Thisse (1986), assuming price is exogenous, allow two firms to locate as many plants as they desire.[25] Equilibrium is characterized by an evenly-distributed competitive pairing (*i.e.*, the two outlets at each location include one for each firm) of plants over the space, where the pairs are sufficiently close to other pairs that locating additional plants is not profitable. Martinez-Giralt and Neven (1988) arrive at very different results. When allowing each of two firms to locate two plants, they find that each firm clusters its own plants and maximally differentiates its plants from its rival's plants. However, they assume quadratic transportation costs,

by maximal differentiation in more than one dimension are not equilibria.

22 Vertical differentiation refers to differentiation on attributes over which, at identical prices, consumers have similar preferences; for example, at identical prices all consumers would prefer high quality to low quality.

23 Even if consumers do not use the other services, their availability may provide an option value.

24 If the two ranges are similar, both equilibria arise.

25 Aside from allowing multiple locations, the model is identical to Hotelling's. Thus, the one-outlet equilibrium is characterized by minimum differentiation.

which generates severe price competition, which may be too strong an assumption to allow interesting analysis. As the authors note, it is commonly observed that firms often locate several outlets, but these outlets are geographically dispersed, which is not consistent with the findings of the model. Bensaid and de Palma (1993) extend the model to allow for three firms, each with two outlets. While one possible equilibria is the analog of the two-firm equilibrium (each firm pairing its plants with as much space as possible between each pair), two other equilibria are identified. One involves an even spacing of the six plants, with each firm's plant maximally differentiated from its other plant. Alternatively, two firms may locate their plants in clusters, with the plants of the remaining firm between the two clusters. Bensaid and de Palma also consider entry deterrence. As in the single-outlet literature where differentiation dominates, the possibility of entry causes firms to locate plants closer to rivals' plants so that the resulting market "gaps" are not large enough to support entry.[26] The incorporation of multiple outlets does not appear to alter the conclusions drawn from the one-outlet literature: whether maximum or minimum differentiation obtains depends crucially on the assumptions of the model.

To conclude, we assemble from the literature insights into the variables that are important determinants of location choice. Our goal is to empirically examine whether, in an industry where the market power effect is expected to be quite strong, the insight from the literature that firms will differentiate their product in an effort to soften price competition holds. To identify whether minimum or maximum differentiation occurs, 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.[27] Whether competition leads to more or less differentiation depends on whether there is a tendency towards minimum or maximum differentiation. As a simple example, comparing Hotelling's proposed outcome of minimum differentiation with the monopoly outcome suggests that, in this model, more competition leads to less spatial differentiation. On the other hand, models that predict maximal differentiation,

[26] Stavins, 1995, empirically tests whether incumbents locate models in product space in order to deter entry in the market for personal computers. She finds that entrants locate their products more closely to existing products than do incumbents, which she interprets as evidence of preemption.

[27] Such locations maximize the amount of consumer surplus that can be appropriated via a higher price.

e.g., d'Aspremont, *et al.* (1979), suggest that an increase in competition leads to more differentiation than would be obtained by a monopolist. Thus, we examine the influence of the general competitiveness of the market on location choice. 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 this industry, then increases in competition will lead to more dispersed locations.

3. An Empirical Framework

In this section, we develop an empirical model to investigate the location decisions of gasoline stations. For any station in our sample of every gasoline station in the Los Angeles Basin from 1992-1996, 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 quite difficult. Gasoline stations that are located at the same intersection offer substitutes to consumers;[28] there is, however, a critical distance at which a gasoline station is too far away to offer an effective substitute for the consumer. Because the extent of the market is an empirical issue, we follow the literature (see Shepard, 1991, and Barron, Taylor, and Umbeck, 1998) in using market radii of one-half mile, one mile, and two miles. Spatial differentiation is then measured as the average Euclidean distance between the center station and each of its rivals in the defined market.[29]

We consider two samples – "entry" stations and "stable-market" stations. Entry stations are stations that are new in any given sample year.[30] During our sample period, a total of 352 gasoline stations entered the LA market: 4.1% (177) of the stations in LA were new in 1993, 1.7% (72) in 1994, 1.1% (48) in 1995, and 1.3% (55) in 1996. Next, we identify another set of stations that we characterize as belonging to "stable" markets. This sample

[28] 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.

[29] 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 more distant stations. The qualitative results are unaffected by this variation of the dependent variable.

[30] Because we have a complete census of gasoline stations, a station appearing in any year that did not appear in previous years is identified as an entry station. These stations may not represent *de novo* entry, in the sense that the station may have simply changed hands. It appears, however, that less than 1% of entry stations are those that simply changed hands.

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. Therefore, these stable markets are completely static with respect to location decisions; *i.e.*, there was no entry into or exit from these markets. The percentages of stations that are in stable markets are 49.5%, 21.9%, and 3.0% for radii of $\frac{1}{2}$-mile, 1-mile, and 2-miles, respectively.

Examining entry stations is likely the most direct method of examining a station's location decision. 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.

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,[31] the proportion of stations that are independent (non-major) gasoline stations,[32] 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 the number of firms on spatial differentiation. 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 gasoline industry is subject to sufficiently strong price competition that the market power effect will dominate, so that an increase in competition will increase spatial differentiation.

The proportion of the stations in the defined market operated as independents proxies for increases in price competition because independent stations typically offer lower prices.[33] We expect more aggressive price competition to strengthen the market power effect; more

[31] The number of firms in a market is a traditional, rough, measure of the degree of competition. An alternative measure of competition, the Herfindahl index, is inappropriate because stations that fly the same brand-name flag operate, to a large degree, independently. Since we do not have information on stations that are operated by the same manager, a Herfindahl index for each market would simply be an inverse monotonic transformation of the number of firms.

[32] There are seven major brands in our sample: Arco, Chevron, Exxon, Mobil, Shell, Texaco, and Unocal. All other stations are treated as independents.

[33] Controlling for demand and cost considerations, Barron *et al.*, 1998, find that branded (major) stations charge significantly higher prices than do independent (non-major) stations.

price competition will increase the incentive firms have to locate farther from their competitors in order to reduce price competition. Thus, we expect an increase in the proportion of independent stations to increase the degree of spatial differentiation.

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 may be owned and operated by the refiner, stations may be leased to the station manager from the refiner (*i.e.*, lessee-dealer), or stations may be owned by a manager who contracts to carry the refiner's brand (*i.e.*, a jobber or contract-dealer). Stations are located by the refiner, either by physically locating the station or by choosing with whom to contract. Though the refiner controls the locational decision for all types of stations, the refiner controls the pricing decision only for refiner owned and operated stations. Essentially, the refiner can internalize the location externality but cannot always internalize the price externality.[34] Consider how an increase in the proportion of same-brand stations influences the two conflicting incentives facing a station. The refiner will no longer wish to locate one station more closely to a "rival" that carries the same brand, because the refiner would be stealing customers from itself.[35] Thus, the incentive leading to closer locations (the market share effect) is reduced. Because pricing is largely outside the control of the refiner (except for company-operated stations), the incentive to locate farther from rivals to reduce price competition (the market power effect) is not affected. Therefore, we expect that as the fraction of the market carrying the same brand increases, the center firm will locate farther from its rivals, other things constant.

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 (far from) its competition in the absence of entry considerations, the potential for future entry may lead the firm to locate farther from (closer to) its competitors in order to minimize the market 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

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

35 While it is the station that is making the sales, sales at each station influence the amount the refiner can extract from the station via rental payments or franchise charges.

increases. We attempt to control for entry issues by including costs that may be directly tied to the rental cost of the land in the defined market. For the sample of entry stations, we have data on the median value of housing in the defined market area. For the sample of stable-market stations, 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.[36] 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. If observed differentiation rises (falls), then firms prefer to strategically reduce (increase) 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. In a theoretical context, this 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 customers at the "end" of the market if they prefer less differentiation, while stations can locate farther from rivals without losing customers located between stations if they prefer more differentiation. Second, the income level 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 entry costs leads to an increase (decrease) in differentiation, we can infer that firms prefer to strategically locate farther from (closer to) rivals.

In addition, 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

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

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 define a dummy variable equal to one 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.

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 since consumers can buy a different "product" at each gasoline station, as predicted by the literature. Second, gaining market share is now relatively more advantageous as 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.

We attempt to measure relative differentiation on other station attributes using two different approaches.[37] First we define what we call "continuous" measures of differentiation. These variables are the product of a dummy variable equal to one if the center station does (does not) offer the service and the proportion of the market that does not (does) offer the service. 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, while not offering a service

[37] We consider differentiation based on offering the following services: full service, repair service, a car wash, a convenience store, and pumps that accept credit cards.

that a nearby rival does offer does not seem likely to attract marginal customers.[38] Thus, we include ten continuous measures, one indicating the presence of each of five services and the other indicating the absence of each of five services. In an alternative specification, we devise what we call an "index" measure of differentiation. The "have" ("don't have") index is constructed by first multiplying a dummy indicating that the center station offers (does not offer) the particular service with a dummy indicating that 50% or more of its rivals do not (do) offer the service. We then sum over the five services considered.

Thus, the model we estimate can be written as

$$DIFF_{ij} = \alpha + \beta C_{ij} + \zeta A_{ij} + \gamma X_{ij} + \epsilon_{ij}, \tag{1}$$

where i indexes the radius of the market defined around station j. $DIFF$ is our measure of spatial differentiation defined as the average Euclidean distance between the station at the center of the market and its rivals. The variables included in matrix C measure general competition in the market and in matrix A differentiation in attributes, while matrix X contains the control variables related to demand conditions and entry costs.

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

$$\epsilon_{ij} = \delta_k + \mu_{ij}, \tag{2}$$

where k indexes the city and μ is assumed to be independently and identically distributed with constant variance. The inclusion of a city fixed effect allows us to control for zoning laws that 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 scenario, we expect that the error terms for any stations located in city k are correlated, while the error terms for stations located in different cities are independent.

Alternatively, the error term for station j may be correlated with the error for station l regardless of the city in which the station is located. The closer two stations are in proximity,

[38] 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.

the more correlated we expect their error terms to be. Any exogenous change in the market environment not captured by the regressors will be captured by the error term for both markets. We correct for this spatial correlation by using a spatial error model where the error term can now be written as[39]

$$\epsilon_{ij} = \lambda W \epsilon_i + \mu_{ij}, \tag{3}$$

where ϵ_i is the vector of errors for all N stations; λ is the residual spatial autocorrelation coefficient; W is an $N \times N$ symmetric spatial 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 a 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 j and l; 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. Thus, the upper end of the distributions of the differentiation measure and the error term are cut off and probabilities will be piled up at the cut-off 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 requires augmentation of the usual spatial error likelihood function. For notational ease, let $\Gamma Z_i = \alpha + \beta C_i + \zeta A_i$ and let τ_i indicate observations where the dependent variable is censored. Then the log-likelihood function we maximize when allowing for spatial correlation of errors and adjusting for censored observations is given by

$$l = \ln(1 - \lambda w_i) - \frac{1}{2}\ln(2\pi) - \frac{1}{2}\ln(\sigma^2) - (1-\tau_i)\,\frac{1}{2\sigma^2}\,e_i^2 + \tau_i \ln\Big(1 - \Phi\Big(\frac{e_i}{\sigma}\Big)\Big), \tag{4}$$

where $e_i = DIFF_i - \lambda W DIFF_i - \Gamma Z_i + \lambda W \Gamma Z_i$ and w_i are the eigenvalues of the standardized spatial weights matrix.[40]

Our data contain detailed station-level characteristics on all of the more than 4,000 gasoline stations in the Los Angeles Basin from 1992-1996.[41] Station addresses were used to

39 See, *e.g.*, Cliff and Ord, 1973.

40 The standardized spatial weights matrix divides the entries of W by the sum of the entries in the appropriate row, so that the sum of entries in each row of the standardized spatial weights matrix is one.

41 Survey data were obtained from Whitney-Leigh Corporation.

convert locations into coordinates of latitude and longitude for each station.[42] Census tract numbers were recorded and used to collect market data from the *1990 Census of Housing and Population.* Descriptive statistics are reported in the appendix.

4. Results

Tables 1 and 2 present estimation results using the sample of entry stations for the continuous and index measures of attribute differentiation, respectively. Results for the sample of stable-market stations are reported in Tables 3 and 4. The qualitative results for each of the competition variables are robust across the different market sizes, the different estimation techniques, and across the alternative measures of differentiation in station attributes, with one exception. The results for both of the 2-mile samples show considerable differences depending on the estimation technique. We interpret this result as indicating that the market defined by the 2-mile radius is simply too large; that is, it contains stations that do not offer effective competition. If true, the large market definition would introduce considerable noise to the data, leading to the imprecise estimates. In addition, the stable-market 2-mile sample has a small number of observations (127). We therefore put much less confidence in the results for the 2-mile markets.

We find evidence that as the number of stations, the fraction of the market served by independents, and the fraction of the market offered under the same brand as the center station increase, stations prefer to locate farther from competitors. Each of these results is 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 differentiate their product rather than cluster.

The number of stations in the market is positively and significantly correlated with level of spatial differentiation for eleven out of the twelve specifications. For the entry sample, taking the average of the estimated coefficients across all four specifications for each radius, we find that when the number of stations in the defined market increases by one, locational

[42] This was performed using the Census Bureau's Landview II GIS software. This software also allowed us to calculate each station's distance to the closest major road.

Table 1: Entry Stations
Continuous Measure of Attribute Differentiation
(Standard errors in parentheses.)

	1/2 Mile		1 Mile		2 Mile	
	(1)	(2)	(1)	(2)	(1)	(2)
Constant	–15.77	–52.28	172.53	235.28***	1276.06***	938.72***
	(45.44)	(38.26)	(148.76)	(59.15)	(112.81)	(120.23)
Stations	31.99***	36.17***	10.78***	17.62***	–0.51	4.83**
	(6.31)	(5.44)	(3.30)	(3.51)	(1.96)	(1.94)
% Indep	0.19	0.24	1.22**	0.81*	7.15***	0.75
	(0.34)	(0.22)	(0.53)	(0.49)	(1.35)	(1.14)
% Same Brand	5.12***	5.22***	4.72***	4.92***	4.57***	5.11***
	(0.62)	(0.52)	(0.71)	(0.69)	(1.09)	(1.04)
Near Mjr Rd	–38.72**	–46.50***	–88.40***	–72.55***	–122.57***	–93.46***
	(15.76)	(11.75)	(19.80)	(19.62)	(26.35)	(26.33)
Income	–0.90	–0.83	–5.11***	–0.82	–11.64***	–3.06
	(0.95)	(0.57)	(1.41)	(1.23)	(2.24)	(2.22)
Med. Value	–0.21*	–0.13	–0.27*	–0.08	–0.06	0.09
	(0.11)	(0.08)	(0.14)	(0.13)	(0.19)	(0.18)
Full Serve	0.73***	0.28	1.50***	0.44	3.37***	2.48***
	(0.28)	(0.22)	(0.40)	(0.42)	(0.65)	(0.65)
No Full	1.02***	0.76***	2.69***	1.26***	6.96***	4.28***
	(0.32)	(0.22)	(0.53)	(0.42)	(0.99)	(0.88)
Car Wash	0.59*	0.48*	1.25***	0.74*	0.86*	0.94*
	(0.31)	(0.25)	(0.39)	(0.39)	(0.52)	(0.55)
No Wash	0.79***	0.80***	1.43***	1.73***	1.47	3.40***
	(0.30)	(0.24)	(0.51)	(0.49)	(0.97)	(0.92)
Repair	–0.06	–0.06	0.51	0.71	0.31	–0.28
	(0.30)	(0.24)	(0.47)	(0.44)	(0.75)	(0.70)
No Repair	–0.13	–0.06	0.83*	1.35***	1.10	0.64
	(0.23)	(0.19)	(0.46)	(0.36)	(0.83)	(0.79)
Conv. Store	0.51**	0.61***	–0.07	0.10	0.11	–0.01
	(0.20)	(0.14)	(0.32)	(0.30)	(0.50)	(0.46)
No Store	0.66**	0.97***	0.64	0.80*	–0.92	–1.06
	(0.30)	(0.22)	(0.52)	(0.48)	(0.82)	(0.74)
Cred. Card	0.09	–0.25	0.52	0.80**	0.21	0.72
	(0.24)	(0.18)	(0.32)	(0.33)	(0.51)	(0.51)
No CC	0.75***	0.25	0.54	0.78*	2.23***	1.87***
	(0.26)	(0.16)	(0.45)	(0.45)	(0.74)	(0.71)
λ		0.09		0.59***		0.78***
		(0.09)		(0.05)		(0.03)
Observations	352	352	352	352	352	352

(1) Estimated using city fixed effects. (2) Estimated controlling for spatial correlation.

***,**,* Significant at 1%, 5%, and 10% level, respectively.

differentiation increases by approximately 12.2% of the average differentiation for the $\frac{1}{2}$-mile market, by approximately 2.7% for the 1-mile market, and by approximately 0.4% for the 2-mile market. The comparable numbers for the $\frac{1}{2}$- and 1-mile stable-market samples

Table 2: Entry Stations
Index Measure of Attribute Differentiation
(Standard errors in parentheses.)

	1/2 Mile (1)	1/2 Mile (2)	1 Mile (1)	1 Mile (2)	2 Mile (1)	2 Mile (2)
Constant	–27.82	–38.23	515.31***	266.96***	1293.56***	960.88***
	(46.10)	(37.53)	(59.77)	(54.52)	(115.96)	(116.93)
Stations	40.07***	40.72***	14.77***	21.73***	4.77**	7.75***
	(6.22)	(5.46)	(3.42)	(3.41)	(2.01)	(2.04)
% Indep	0.36	0.51**	1.54**	0.85*	7.85***	0.52
	(0.35)	(0.24)	(0.60)	(0.46)	(1.42)	(1.14)
% Same Brand	5.66***	5.24***	6.80***	6.84***	6.63***	6.67***
	(0.61)	(0.50)	(0.70)	(0.66)	(1.06)	(1.01)
Near Mjr Rd	–48.87***	–56.34***	–107.95***	–89.29***	–134.74***	–94.72***
	(15.56)	(12.46)	(20.30)	(18.72)	(28.33)	(25.81)
Income	–0.74	–1.21**	–4.04***	–0.30	–11.39***	–2.39
	(0.96)	(0.59)	(1.47)	(1.18)	(2.35)	(2.28)
Med. Value	–0.25**	–0.15*	–0.32**	–0.11	–0.08	0.00
	(0.11)	(0.08)	(0.15)	(0.13)	(0.20)	(0.17)
Have Serv.	23.76**	38.25***	3.18	4.35	89.76***	78.11***
	(11.43)	(8.65)	(16.62)	(14.49)	(26.51)	(25.65)
Don't Have	37.80***	40.65***	67.74***	64.03***	125.71***	111.78***
	(8.60)	(6.90)	(11.80)	(10.61)	(20.75)	(19.86)
λ		0.16*		0.55***		0.76***
		(0.09)		(0.05)		(0.03)
Observations	352	352	352	352	352	352

(1) Estimated using city fixed effects. (2) Estimated controlling for spatial correlation.
***,**,* Significant at 1%, 5%, and 10% level, respectively.

are 10.7% and 2%.[43] Alternatively, when the number of stations in a market increases by one standard deviation relative to the mean number of stations for the entry samples, the average degree of spatial differentiation increases by approximately 21.4% for the $\frac{1}{2}$-mile market, approximately 11% for the 1-mile market, and approximately 4.6% for the 2-mile market. The comparable numbers for the $\frac{1}{2}$- and 1-mile stable-market samples are 17.2% and 6.4%, respectively. So 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.

As the fraction of the market supplied by independents increases, indicating a higher

[43] We ignore the 2-mile stable-market sample since the point estimates across the two estimation techniques are so widely different.

degree of price competition, we find that the amount of spatial differentiation increases, though the results are less robustly statistically significant. The significant estimates for the $\frac{1}{2}$- and 1-mile samples suggest that a ten percentage point increase in the fraction of independent stations increases spatial differentiation by about one hundredth of a mile. Thus, the magnitude of the effect is quite small compared to the effect of an increase in the number of gasoline stations. This may suggest that consumers view gasoline supplied by independents as inferior to gasoline supplied by branded-stations, so that branded-stations can maintain higher prices when faced with an independent competitor.

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. We therefore expect to find greater locational differentiation in order to reduce the intensity of competition in the price dimension.[44] We find robust evidence that supports this hypothesis for the entry samples and the $\frac{1}{2}$-mile stable-market sample. The magnitude of the effect is quite similar across market sizes: when the proportion of the market served by the same brand increases by ten percentage points, the center firm increases its locational differentiation by 4-7 hundredths of a mile. The results for the 1-mile stable-market sample suggest that the effect of an increase in the fraction of the market carrying the same brand has a much smaller effect, increasing spatial differentiation by somewhat less than one hundredth of a mile.

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, though these results are notably less robust.[45] If firms prefer to increase spatial differentiation, 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. Consider the effects of the median housing value for the entry samples and the fraction of the market requiring prepayment for

[44] 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, since most of the stations carrying the same brand will have independent authority to set prices.

[45] The results from the variable indicating the fraction of the market that is rental housing are not very informative. Of the twelve alternative specifications, the estimate is statistically significant in only four cases, and we consider two of the cases (in the stable-market 2-mile sample) to be unreliable. Of the remaining two significant results, one is positive and one is negative. We therefore make no inferences from this sample.

the stable-market samples. Whenever 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. This result is consistent with the findings above, that the market power effect dominates the market share effect, so long as the effect of less restrictive zoning dominates the effect of a reduction in entry costs. The estimated coefficients on the prepay variable are negative when statistically significant. A negative coefficient implies that as entry costs fall or zoning becomes less restrictive (as proxied by an increase in the fraction of the stations requiring prepayment), spatial differentiation declines. This result is consistent with the competition results if the entry effect dominates the zoning effect. We conclude that there is weak evidence that a decline in locational constraints 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 (with the exception of the 2-mile stable markets). As income rises, the elasticity of demand may fall, reducing the likelihood that a station will lose customers at the boundary of the market. In a one-dimensional location model with a finite market, a decline in the elasticity of demand has been shown to lead to less spatial differentiation, which is consistent with our results. Income may also indicate entry costs and zoning restrictions. If income, as 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.

Consider the variables that attempt to measure differentiation in non-spatial station attributes. The literature on multi-dimension location suggests that when firms differentiate on two or more characteristics, they maximally differentiate on one attribute and minimally differentiate on the others. Because our station-attribute variables measure any significant differentiation on ancillary products or services, the theory suggests that the coefficients on these variables should indicate a negative correlation between spatial differentiation and differentiation on other station products or services. In general, however, we find, when significant, a positive relationship between measures of attribute differentiation and the degree of spatial differentiation for the entry samples and the $\frac{1}{2}$-mile stable-market sample. The

Table 3: Stable-Market Stations
Continuous Measure of Attribute Differentiation

(Standard errors in parentheses.)

	1/2 Mile		1 Mile		2 Mile	
	(1)	(2)	(1)	(2)	(1)	(2)
Constant	40.88	0.73	789.26***	553.21***	1562.45***	626.41***
	(38.42)	(28.81)	(85.67)	(71.93)	(511.14)	(194.67)
Stations	28.10***	24.64***	7.33**	11.94***	–7.95	22.22***
	(3.33)	(2.72)	(3.45)	(3.24)	(11.46)	(5.73)
% Indep	1.03***	0.77***	1.01**	0.66	7.85***	8.44***
	(0.21)	(0.19)	(0.49)	(0.48)	(2.82)	(2.24)
% Same Brand	4.00***	3.66***	0.74	1.00**	1.79	1.95
	(0.26)	(0.22)	(0.49)	(0.47)	(2.08)	(1.77)
Near Mjr Rd	–12.65*	–16.03***	–57.38***	–67.06***	–193.57***	–160.96***
	(6.91)	(5.85)	(14.24)	(13.13)	(65.45)	(52.22)
Income	–0.50	0.13	–1.86**	–0.41	–4.50	3.00**
	(0.43)	(0.31)	(0.86)	(0.81)	(6.27)	(1.48)
% Prepay	–0.40**	–0.16	–1.42***	–0.80**	–0.64	0.20
	(0.16)	(0.13)	(0.35)	(0.34)	(1.55)	(0.98)
% Rental	–0.18	0.36*	1.00	–0.24	3.60	3.88*
	(0.23)	(0.19)	(0.61)	(0.60)	(6.75)	(2.24)
Full Serve	–	1.90***	–1.20**	–0.52	3.60	–1.07
		(0.39)	(0.53)	(0.56)	(6.75)	(2.04)
No Full	0.60***	0.57***	–0.13	0.06	3.73	–1.51
	(0.11)	(0.08)	(0.26)	(0.23)	(2.52)	(1.17)
Car Wash	0.40***	0.39***	0.29	0.01	–2.59**	–0.67
	(0.12)	(0.12)	(0.26)	(0.23)	(1.17)	(1.04)
No Wash	1.53***	1.49***	0.63*	0.02	–2.30**	–3.06*
	(0.14)	(0.11)	(0.37)	(0.36)	(1.13)	(1.60)
Repair	0.03	0.06	0.12	–0.10	–4.86*	0.43
	(0.10)	(0.08)	(0.23)	(0.22)	(2.59)	(1.02)
No Repair	0.25**	0.19**	0.46*	0.21	0.38	2.04*
	(0.11)	(0.08)	(0.26)	(0.24)	(1.22)	(1.14)
Conv. Store	0.27***	0.23***	–0.17	–0.15	3.93***	–1.78**
	(0.09)	(0.07)	(0.23)	(0.20)	(1.30)	(0.86)
No Store	0.41***	0.33***	–0.07	–0.05	–2.93***	–0.84
	(0.11)	(0.08)	(0.27)	(0.25)	(1.03)	(1.19)
Cred. Card	0.19**	0.17**	–0.04	–0.12	–2.67	–0.62
	(0.09)	(0.08)	(0.23)	(0.21)	(1.72)	(0.81)
No CC	0.47***	0.41***	0.29	0.07	–1.08	–0.55
	(0.10)	(0.08)	(0.25)	(0.23)	(0.93)	(0.95)
λ		0.58***		0.72***		0.43***
		(0.03)		(0.03)		(0.09)
Observations	2101	2101	932	932	127	127

(1) Estimated using city fixed effects. (2) Estimated controlling for spatial correlation.

***,**,* Significant at 1%, 5%, and 10% level, respectively.

only statistically significant evidence we find for a negative relationship between spatial and product differentiation is in the 2-mile stable-market sample,[46] but we have the least confidence in this 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.

Averaging across the continuous measures of attribute differentiation, we find that a ten percentage point increase in differentiation leads to an average increase in spatial differentiation of 1.42% for the $\frac{1}{2}$-mile entry sample, 2.01% for the $\frac{1}{2}$- mile stable-market sample, 1.55% for 1-mile entry sample, and 1.20% for the 2-mile entry sample; the average effect for the 1-mile stable-market sample is miniscule. The effect of a one unit increase in the indices of attribute differentiation are of large magnitude. The effect in the entry samples is the same or larger than the effect of the addition of another firm in the market, increasing spatial differentiation by roughly ten percent relative to the average. The magnitude of the effect in the stable markets is smaller but still substantial. Both measures of attribute differentiation show an interesting pattern: not offering services that rivals do offer causes a firm to spatially differentiate itself by more than offering a service that rivals do not offer.[47] This is consistent with our priors. If a station does not offer a particular service, it seems less likely to attract customers away from its rivals that do offer the service. In addition, it may be more interested in mitigating price competition since it cannot profit from sales of other services. Thus, the station spatially differentiates itself to a higher degree because its market share effect is diminished and its market power effect is strengthened.

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.

[46] One coefficient out of ten in the 1-mile, stable-market sample, when estimated with city fixed effects, is also statistically significantly negative.

[47] In the case of the 2-mile stable sample, where an increase in attribute differentiation leads to less spatial differentiation, firms cluster to a larger degree when they do not offer a service.

Table 4: Stable-Market Stations
Index Measure of Attribute Differentiation
(Standard errors in parentheses.)

	1/2 Mile (1)	(2)	**1 Mile** (1)	(2)	**2 Mile** (1)	(2)
Constant	–76.22**	–113.57***	759.47***	551.80***	1169.46**	564.29***
	(37.71)	(27.27)	(84.61)	(71.41)	(500.51)	(184.18)
Stations	38.16***	35.17***	8.95***	12.28***	–2.87	23.44***
	(3.29)	(2.89)	(3.38)	(3.02)	(12.37)	(6.08)
% Indep	0.85***	0.70***	1.04**	0.68	11.94	8.58***
	(0.22)	(0.20)	(0.49)	(0.47)	(2.59)	(2.15)
% Same Brand	5.95***	5.62***	0.78**	0.80**	–0.50	–1.66
	(0.23)	(0.19)	(0.39)	(0.35)	(1.63)	(1.52)
Near Mjr Rd	–15.87**	–15.78***	–56.87***	–66.64***	–218.10***	–170.76***
	(6.97)	(5.82)	(14.13)	(13.17)	(71.69)	(57.08)
Income	–0.46	0.18	–1.73**	–0.44	–0.69	3.32**
	(0.42)	(0.32)	(0.85)	(0.82)	(6.23)	(1.56)
% Prepay	–0.27*	–0.11	–1.34***	–0.76**	–1.05	–0.04
	(0.16)	(0.12)	(0.34)	(0.33)	(1.64)	(1.05)
% Rental	–0.30	0.24	–0.89***	–0.20	5.07	4.49**
	(0.23)	(0.19)	(0.60)	(0.59)	(6.97)	(2.25)
Have Serv.	19.26***	17.25***	–4.07	–7.77	–14.22	3.06
	(3.26)	(2.88)	(6.29)	(5.93)	(27.94)	(24.72)
Don't Have	39.71***	36.11***	18.60***	8.31	–20.61	6.04
	(3.05)	(2.53)	(6.59)	(5.99)	(35.69)	(29.96)
λ		0.57***		0.72***		0.44***
		(0.03)		(0.02)		(0.09)
Observations	2101	2101	932	932	127	127

(1) Estimated using city fixed effects. (2) Estimated controlling for spatial correlation.
***,**,* Significant at 1%, 5%, and 10% level, respectively.

This result is robust across all specifications. Based on the average of the point estimates, when a station is located within 1/4 mile of a major road, it will reduce differentiation by 15.6% of the average distance from rivals for the $\frac{1}{2}$-mile, entry sample, approximately 14.9% for the 1-mile, entry sample, and approximately 9.3% for the 2-mile, entry sample. For the stable markets, the effect is considerably smaller: 5.1% for the 1-mile, stable sample and 12.2% for the 2-mile, stable sample. In both cases, however, the effect is quite large.

5. 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, the empirical literature has only found evidence of clustering. We have contributed to the empirical literature by examining locational patterns of gasoline stations in the Los Angeles Basin retail gasoline market, where 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: since 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 leads to an increase in spatial differentiation suggests that more theoretical work is needed to understand firm location decisions in a multi-dimensional 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 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.[48] In addition, the theory thus far shows that while 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.

[48] For example, Ansari, Economides, and Ghosh, 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.

APPENDIX

Table A1: Descriptive Statistics[1]

	Entry Stations			Stable-Market Stations		
	1/2 Mile	1 Mile	2 Mile	1/2 Mile	1 Mile	2 Mile
Avg. Diff.[2]	305.05	599.61 *	1193.63 *	293.28	509.19	976.62
	(154.16)	(238.79)	(362.86)	(157.73)	(218.06)	(360.21)
	[0,500]	[0,1000]	[3,2000]	[0,500]	[0,999]	[475,1852]
No. Stations	2.92	6.42 *	19.54 *	2.92	5.30	8.31
	(1.75)	(4.08)	(13.09)	(1.60)	(3.23)	(6.10)
	[1,12]	[1,19]	[1,54]	[1,10]	[1,19]	[1,28]
% Indep.	26.90 *	23.54 *	23.13 *	7.35	10.54	9.45
	(33.97)	(27.71)	(22.69)	(15.14)	(15.49)	(15.04)
	[0,100]	[0,100]	[0,100]	[0,67]	[0,75]	[0,75]
% Same Brand	51.35	33.12	20.44 *	49.63	35.26	34.65
	(30.52)	(27.86)	(20.14)	(28.48)	(25.18)	(31.14)
	[8,100]	[5,100]	[2,100]	[10,100]	[6,100]	[4,100]
Near Mjr Rd[3]	0.57 *	0.57 *	0.57 *	0.51	0.55	0.67
Income[4]	34.59 *	35.34 *	36.28 *	38.30	42.86	49.43
	(14.04)	(12.67)	(11.77)	(14.26)	(14.81)	(18.55)
	[0, 97]	[15,79]	[16, 78]	[0,120]	[0,107]	[15,96]
Median Value[4]	157.89	157.89	157.89	—	—	—
	(92.79)	(92.79)	(92.79)			
	[0,500]	[0,500]	[0,500]			
% Prepay	—	—	—	84.78	82.11	69.60
				(27.34)	(25.91)	(26.95)
				[0,100]	[0,100]	[0,100]
% Rental	—	—	—	46.85	40.03	32.35
				(22.16)	(17.43)	(12.56)
				[0,100]	[2,100]	[8,66]
Full[5]	7.75 *	7.75 *	7.02 *	5.14	2.36	2.36
	(25.20)	(24.46)	(21.45)	(22.09)	(15.19)	(15.25)
No Full[5]	39.70 *	30.04 *	22.93 *	28.62	22.93	30.66
	(43.23)	(33.87)	(23.25)	(40.24)	(32.19)	(34.80)
Wash[5]	7.87	7.54	7.82	6.62	6.43	5.15
	(26.54)	(25.79)	(25.62)	(24.53)	(23.93)	(21.49)
No Wash[5]	28.07	17.40	11.05 *	24.90	14.54	21.19
	(42.64)	(32.95)	(21.25)	(40.62)	(30.41)	(35.29)
Repair[5]	11.87 *	11.26 *	10.48 *	26.74	23.82	22.26
	(29.12)	(26.04)	(23.26)	(39.77)	(34.70)	(32.40)
No Repair[5]	44.49 *	37.37 *	31.84	30.02	26.77	29.63
	(43.47)	(34.86)	(27.42)	(40.82)	(34.33)	(37.98)
Store[5]	35.78 *	31.76 *	25.99	23.66	21.90	28.18
	(45.23)	(40.76)	(33.95)	(39.60)	(35.88)	(37.90)
No Store[5]	22.38 *	19.07 *	18.09 *	30.51	25.97	26.09
	(36.00)	(26.87)	(22.63)	(40.66)	(33.42)	(33.23)

Table A1: Descriptive Statistics[1]

	Entry Stations			Stable-Market Stations		
	1/2 Mile	1 Mile	2 Mile	1/2 Mile	1 Mile	2 Mile
Cred. Card[5]	24.36	21.85	19.69 *	26.22	23.63	26.23
	(40.79)	(36.96)	(31.04)	(39.65)	(34.28)	(32.52)
No CC[5]	28.86	23.34 *	21.73 *	31.82	27.07	31.19
	(39.56)	(29.87)	(24.51)	(40.99)	(34.44)	(37.86)
Have Services[6]	0.75 *	0.59 *	0.43 *	1.16	1.14	1.19
	(0.94)	(0.85)	(0.72)	(0.97)	(0.96)	(0.89)
	[0,3]	[0,3]	[0,3]	[0,5]	[0,5]	[0,3]
Don't Have[6]	1.37 *	0.87 *	0.55 *	1.59	1.13	1.20
	(1.55)	(1.22)	(0.90)	(1.42)	(1.24)	(1.56)
	[0,5]	[0,5]	[0,5]	[0,5]	[0,5]	[0,5]
Obs.	352	352	352	2101	932	127

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

[2] In thousandths of a mile.

[3] Dummy variable.

[4] In thousands of dollars.

[5] Dummy if station has (doesn't have) the service $\times$ the proportion of rivals that do (don't) have the service. All range from 0 to 100 percent.

[6] An index measure indicating the extent to which the station offers (doesn't offer) services that rivals do not (do) offer. The index is defined over the range 0 to 5. See the explanation in the text for details.

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

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