Supermarkets as a Natural Oligopoly

Paul B. Ellickson*
Simon School of Business Administration

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Abstract

This paper uses a model of endogenous sunk cost (ESC) competition to explain the industrial structure of the supermarket industry, where a few powerful chains provide high quality products at low prices. I exploit the nature of supermarket competition, namely the existence of geographically distinct markets, to provide explicit tests of the predictions of the ESC model, to identify features of the observed market structure which are inconsistent with alternative models, and, in so doing, deepen our understanding of the nature of retail competition. This empirical characterization is achieved by exploiting a novel dataset of store level observations in 320 geographical markets, where a market is a Metropolitan Statistical Area. Examining these markets, I establish the existence of an oligopolistic structure that does not fragment as market size expands. By narrowing the focus to the store level, I demonstrate that this natural oligopoly extends all the way down to the most local levels. Unable to carve out distinct geographic markets, the natural "oligarchs" compete head to head for the same consumers. I then use this very local nature of competition to demonstrate that quality choice is a strategic complement among supermarkets in the same local markets. Using store size to measure quality, I provide evidence that the presence of rival high quality firms forces competing stores to increase their own level of quality. I account for endogeneity using instruments constructed from the average size of rival's stores outside of the local market. While consistent with the ESC framework, evidence of strategic complementarity in equilibrium investment is inconsistent with several competing models of competition, including most standard models of capacity competition, horizontal product differentiation, cost-reducing investment and product proliferation.

1 Introduction

This paper demonstrates the relevance of the endogenous sunk cost (ESC) model of product differentiation to supermarket competition. This framework, developed fully in the book

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by John Sutton (1991), links endogenous sunk costs to industrial structure. Building on the earlier vertical product differentiation literature (Shaked and Sutton, (1983, 1990); Gabszewicz and Thisse, 1980), Sutton argues that the distinction between industries subject to sunk costs which depend endogenously on market structure and industries in which sunk costs are largely independent of such influence leads to a robust conclusion concerning the relationship between concentration and market size. Industries with endogenous sunk costs remain relatively concentrated regardless of market size, while the level of concentration in exogenous sunk cost industries asymptotes to zero as markets become larger. In both types of industry, bigger markets allow sunk costs to be spread over larger sales. What sets ESC industries apart is a countervailing force in which rivalry among firms to produce a higher quality product leads to escalating investment in sunk costs. Consequently, markets are served by roughly the same number of firms, regardless of the size of the market. The goal of this paper is to demonstrate how this natural oligopoly result applies to the supermarket industry and suggest how it may be used to explain retail competition in general.

In the past two decades, several retail industries have become dominated by strong regional or even national chains. Whether the market is video rentals, auto supplies, books, or office supplies, these stores share several common features: a wide selection, aggressive pricing and advertising, quick turnover, and significant investment in advanced information and distribution systems (Bendetti and Zellner, 1992; Chakravarty, 1991; Chanil, 1991; Messinger and Narasimhan, 1995; Power and Dunkin, 1990; Saporito, 1991; Zinn and Power, 1990). Firms such as Home Depot, Staples and Crown Books have become household names by providing a staggering array of products at very competitive prices (Bagwell et al., 1997). While there are clearly strong forces encouraging the formation of larger and larger chains, what is unclear is whether these industries will remain competitive oligopolies or eventually become dominated by a single firm. Because the nature of competition is so different across these two outcomes[1], discerning the nature of competition in these markets is important both for antitrust policy as well our more general understanding of retail competition. The challenge of applying the ESC model to retail industries, in particular supermarket competition, lies in identifying the form and mechanism of endogenous investment. Although, previous applications of the ESC framework have focused exclusively on industries where firms make competitive investments in either advertising or R&D (Sutton, 1991; Robinson and Chiang, 1996), the framework is much more general, applying to any industry where market share is sensitive to variations in fixed costs, so that rivalry is both tough and focused on sunk outlays (Schmalensee, 1992). What is essential is that sunk investments are beneficial to all

[1] For example, suppose concentration is the result of a cost-reducing investment game (e.g. Bagwell et al., 1997) where vigorous price competition results in the emergence of a low-cost, low-price leader. The market leader only has an incentive to lower price as long as his competitors remain in the market. If cost differences become large enough, the rival firms may exit, and, if the cost of re-entry is high enough, the surviving firm may be able to charge the monopoly price indefinitely (Athey and Schmutzler, 1999). A similar argument might be applied to the level of quality selected by the surviving monopolist. In the endogenous sunk cost framework, high quality and low prices (below monopoly) are sustained by the presence of rival firms (and the threat of entry).

consumers[2] but require little or no increase in marginal cost.[3] Therefore, endogenous sunk investment may produce either an increase in quality for a given price or a decrease in price for a given quality. In the context of supermarket competition, where large scale advertising plays a relatively minor role and R&D is non-existent, I argue that brandwidth (product variety) provides a natural measure of quality that is increased by sunk, store level investments. Furthermore, since increasing brandwidth requires building a physically larger store and land prices increase with population, the *fixed* cost of providing brandwidth naturally scales up with the size of the market.

The empirical challenge of this paper lies in testing whether the predictions of the ESC model hold in the supermarket industry. The emphasis here on retail suggests an alternative approach to previous studies. Because prior empirical tests of the ESC model have focused on manufacturing industries, the natural comparisons were either cross-national involving a single industry or cross-industry involving a single country. Although every industry is in some sense geographically bounded, the market boundaries in retail industries are typically much smaller than in manufacturing. Therefore, the focus here is on geographically defined markets within the United States. In the supermarket industry, the relevant geographic market depends on the level of analysis. At the firm level, I demonstrate the impact of ESC competition using data from every supermarket operating in 320 Metropolitan Statistical Areas (MSAs). However, establishing the existence of a lower bound to concentration at the MSA level does not directly address the mechanism of ESC competition emphasized in this paper, which takes place at the store level. Shifting attention to the 21,255 stores operating in these MSAs, I demonstrate that rival firms compete head to head at the store level, unable to carve out local monopolies. The analysis demonstrates that natural oligopoly, although rooted in store level competition, extends all the way to the regional level.

The empirical strategy of this paper is to provide a combination of results which support the ESC model of competition in the supermarket industry. Viewed in isolation, no result can conclusively eliminate every alternative explanation of market concentration. However, while competing theories may succeed in explaining a subset of the features observed in this industry, the ESC framework accords well with the entire structure, where a small set of high quality firms compete head to head, responding to rivals' quality increases with increases of their own. Consequently, the analysis in this paper takes place at several levels. I focus first on competition at the MSA level. At the market or firm level, Sutton argues for a bounds approach on the grounds that market equilibria are intrinsically indeterminate. When firms operate multiple stores and product differentiation may be both vertical and horizontal (as is the case in most retail industries), multiple equilibria are endemic. Nonetheless, we can often place bounds on the set of feasible market equilibria. In particular, in markets where sunk costs are endogenously determined, concentration will be bounded below. In my first set of empirical results, I demonstrate that this prediction holds in the supermarket industry:

[2] A vertical product differentiation (VPD) model is typically used to motivate ESC competition. In models of VPD, consumers agree on a single metric of quality: for a given price, everyone prefers high quality to low. In models of *horizontal* product differentiation (HPD), consumers each have a unique ideal point in product space. In this case, if two distinct products are offered at the same price, consumers will disagree about which they prefer.

[3] If sunk investments *decrease* marginal costs, it is not necessary that they also increase consumers' willingness to pay.

there is a clear lower bound to concentration at the MSA level. Above the bound, we observe a scattered cloud of points, consistent with the multiplicity of specific outcomes. However, by examining the size distribution of firms in each market, it is possible to push the analysis further. By identifying a set of high quality firms[4], I find strong evidence at the MSA level for the natural oligopoly hypothesis: four or five firms dominate each market (MSA) regardless of size. This is true for markets as small as Abilene, Texas (whose population is under 90,000) and as large as Los Angeles, California. While larger markets do have more firms, the increase is reflected almost exclusively by the expansion of a fringe of small firms. Moreover, consistent with the ESC framework, the dominant firms provide significantly higher quality than firms in the fringe. Natural oligopoly at the MSA level suggests that competition at the *firm* level is focused on endogenous sunk costs, perhaps reflecting cost reducing investment in supply or information technology.

However, in the framework described here, quality is both provided and consumed at the *store* level (although firm and store level investments are undoubtedly complementary). If investment brandwidth is the true product of ESC investment, the natural oligopoly result should extend to the local level. Moreover, the mechanism of competition should be apparent in the actions of individual stores. The local analysis incorporates the previous results by focusing on the high quality oligarchs identified at the MSA level. Furthermore, a store level analysis provides a sharp contrast with the principal predictions of horizontal differentiation, an alternative explanation for persistent concentration. In particular, if firms are able to enter preemptively and pack the product space, the oligopolies observed at the MSA level might in fact be *local* monopolies (Schmalensee, 1978). While the horizontal dimension is clearly important (distinct geographic markets are meaningless without it), it does not drive market structure. I demonstrate this by focusing on the structure of local (neighborhood level) markets, where the ESC model predicts tough, head to head competition. In local markets (as proxied by zip codes and four digit zip codes), I find that the high quality oligarchs (identified at the MSA level) indeed compete for the same consumers, unable to carve out local monopolies. I find no evidence that stores cluster by ultimate owner or serve distinct niches. Each firm faces high quality rivals in the vast majority of local markets in which it competes.

While focusing on competition at the local market level establishes the store level impact of the ESC mechanism, analyzing the strategic interaction of stores provides the final and most restrictive test of the ESC framework. Most models of strategic investment imply strategic substitution between rival firms (Bagwell and Staiger, 1994; Athey and Schmutzler, 1999). In the ESC framework, investments may be either substitutes or compliments. In the Appendix, I demonstrate that when quality enhancements expand the size of the market[5], investments by rival firms can be strategic complements[6]. Therefore, although natural oligopoly may arise without it, strategic complementarity provides a powerful method of eliminating competing models of strategic investment. In particular, while consistent with the

[4] In this context a firm refers to a supermarket company, which may operate several stores.

[5] By inducing consumers to devote a larger fraction of their income to the quality good or by inducing new consumers who previously consumed an outside good to join the market

[6] Additional examples of strategic complementarity in VPD models are provided by Ronnen (1991) and Lehman-Grube (1992).

ESC framework, evidence in favor of strategic complementarity is inconsistent with several competing models of competition, including most standard models of capacity competition, horizontal product differentiation, cost-reducing investment and product proliferation.

Using store size (as a proxy for brandwidth) to measure quality, I provide evidence that the presence of rival high quality firms forces competing stores to increase their own level of quality. Since quality choices by rival firms are jointly determined variables, I account for endogeneity using instruments constructed from the average size of rival's stores outside of the local market. The quality level of rival firms outside the market in focus are likely to be highly correlated with the rival's choice of quality in this market (because quality choice requires investments above the market level such as advertising, distribution or reputation) but uncorrelated with specific market conditions (e.g. size or unobserved consumer attributes) or a competitor's behavior in this market[7].

The paper is organized as follows. Section 2 provides a context for the study through an overview of the history and competitive structure of the supermarket industry. Section 3 contains a theoretical framework aimed at adapting the ESC model to the supermarket industry. In particular, I identify a dimension of store quality that satisfies the assumptions of the ESC model and demonstrate how strategic complementarity is consistent with a subclass of ESC models (the details are provided in the Appendix). The dataset is described in Section 4. In section 5, I present empirical results aimed at determining whether competition in the supermarket industry indeed constitutes a stable natural oligopoly. Section 6 addresses the strategic interaction between rival firms, demonstrating that increases in quality are strategic complements. Section 7 concludes.

2 The Evolution of the Supermarket Industry

This section provides a brief historical overview of the supermarket industry, with an emphasis on the innovations that contributed to its current structure, as well as a discussion of previous research on supermarket competition. A more detailed description of the industry's evolution is presented in Ellickson (1999).

From 1880 to the present, the retail food industry evolved from the general store to the current mix of modern supermarkets and corner grocery stores. While the general store operated on a premise of low turnover and high margins, the modern supermarkets offers wide variety and exploits high turnover and low margins. Grocery stores offer convenience (typically geographic proximity) at the expense of both price and variety (Tedlow, 1990; Lebhar, 1952; Adelman, 1958; Messinger and Narasimhan, 1995). During this time, the retail food industry experienced two periods of major change. From roughly 1910 to 1930, the chain store format supplanted the general store, while the period from 1930 to 1960 brought the shift to self-service and the introduction of the supermarket format (Tedlow, 1990; Progressive Grocer, 1995).

The rise of the chain stores, led by the Atlantic and Pacific Tea Company (A&P), reflected a cost advantage of integrating backward into wholesaling and manufacturing (Adelman, 1958). Due at least in part to decreases in transportation costs, chains were able to create a

[7] A similar approach is used by Hausman (1994) in the context of new good valuation.

large network of stores which could take advantage of quantity discounts on the products they didn't make themselves and economies of scale on self-produced items. The large number of stores and intricate distribution network allowed the chains to centralize accounting and better forecast demand, resulting in more efficient inventory management and site selection. These cost savings were passed through to consumers in the form of lower prices. Various price studies performed in the late 1920s and early 1930s found that chain store prices were 4.5-14% lower than their independent counterparts (Tedlow, 1990). Concentration also rose sharply. Between 1919 and 1932, the share of the top 5 firms in the U.S. increased from 4.2% to 28.8% (Lebhar, 1952), and the share of all chain stores increased to over 35%. However, as demonstrated in Ellickson (1999), the innovations introduced by the chain stores did not lead to natural oligopoly. The introduction of scale economies and tougher price competition increased concentration at all levels, but the focus of competition never shifted from price-cost margins to endogenous sunk outlays. Grocery stores continued to operate stores which were physically similar to their independent counterparts (Tedlow, 1990). By the late 1920s, the price differences between chains and independents shrank as independent grocers formed cooperative buying groups (Lebhar, 1952).

The second era of change was marked by the introduction of the supermarket format, which heralded a new era of endogenous sunk cost investment. This new type of store, located on the outskirts of town to take advantage of low rents, sold nationally advertised goods and advertised heavily (Tedlow, 1990). A typical supermarket was 5 times larger than a grocery store, carried far more products, and required customers to serve themselves. While chains may have introduced economies of scale to the food industry, the creation of the supermarket format changed the nature of the store itself, introducing a new, vertically differentiated product. Over time the supermarket and grocery segments became increasingly distinct, with supermarkets becoming the primary food providers. Grocery stores evolved into convenience stores and corner stores, capturing a much smaller portion of the overall food market (Progressive Grocer, 1995).

The rise of the supermarket industry carried the fingerprint of the endogenous sunk cost escalation mechanism (Sutton, 1991): falling margins, escalating sunk outlays, and the appearance of a lower bound to concentration bounded well above zero.[8] While the overall number of food stores decreased from 386,900 to 126,000 from 1939 to 1997, the number of supermarkets increased from less than 1,000 to 30,300. Across 154 Metropolitan Statistical Areas (MSAs), the average four firm concentration ratio (C_4) increased from 45.4% in 1954 to 74.8% in 1998 (U.S. Department of Agriculture, 1992). The increase in concentration coincided with the rise of multi-market chains, which today account for 79% of supermarket sales. Growth was strongest among regional and sectional chains. Local chains (operating in only a single MSA), which grew considerably during the 1970s and 1980s, have been bought out by larger firms in the 1990s (Manchester, 1992).

[8] The *quality escalation mechanism* emphasized in Sutton (1991) refers to the process by which outcomes that are "too fragmented" are broken as markets tend toward equilibrium. In particular, "as market size increases, the incentives to escalate spending on fixed outlays rises. Increases in market size will be associated with a rise in fixed outlays by at least some firms and this effect will be sufficiently strong to exclude an indefinite decline in the level of concentration" (Sutton, 1997). See Ellickson (1999) for a formal empirical analysis of the increasing importance of ESC in the period 1920-1998.

From 1950 to 1980, supermarkets grew mostly at the expense of the grocery segment, steadily eroding the grocery stores' share of retail food sales. However, the share of food sales accounted for by supermarkets leveled off at around 75% in the 1970s (Messinger and Narasimhan, 1995). Most of the competition now occurs within the supermarket format as opposed to across foodservice formats, with *chain supermarkets* (firms operating 11 or more stores) gaining an ever increasing share of the market (Manchester, 1992). Store formats have also changed as superstores[9] and stores offering both food and drug products have begun to replace the conventional supermarket format. Furthermore, the firms providing these extended formats make complementary investments in information technology (satellite communication systems, electronic inventory control systems) which reduces the cost of stocking a large number of products (Messinger and Narasimhan, 1995). Advertising, which helped drive the diffusion of the supermarket format, now plays a much reduced role.[10] Nevertheless, the number of products offered per store has increased from 14,145 in 1980 to 21,949 in 1994, while average store size has increased at a rate of about 1,000 square feet per year (Progressive Grocer; Messinger and Narasimhan, 1995).

The structure of the supermarket industry has been the focus of several recent studies. Chevalier (1995), focusing on the impact of capital market imperfections, demonstrates that leverage makes supermarket firms weak, encouraging tough price competition and entry by rival firms. Cotterill and Haller (1991) look at entry by large chains. They find that supermarket firms are more likely to enter markets which are closer to their base of operations and experienced recent growth. Entry is negatively correlated with concentration and the number of incumbent firms, except in the case of the market leader (Albertson's), which chose to enter more concentrated markets.[11] Finally, Simpson and Hosken (1998) study the effects of mergers on price competition. In only 1 of 3 supermarket mergers analyzed do the authors find any evidence that the merger increased rival firms' performance, suggesting that supermarket mergers are undertaken for efficiency reasons rather than collusive motives. It appears therefore, that, despite high levels of market concentration, competition among the top firms in the supermarket industry remains fierce.

3 Endogenous Sunk Costs and Supermarkets

This section presents a theoretical framework which will both guide the empirical investigation and assist in interpreting the findings. Based closely on Sutton (1991), the model is geared toward explaining competition at the store level. In particular, I will identify the conditions that result in natural oligopoly and illustrate their implications for the equilibrium level of quality, the number of entrants, and the level of sunk investments.

[9] Superstores are larger versions of the conventional supermarket that provide at least 30,000 square feet of selling area and offer more than 14,000 items. These formats often include a service deli and seafood department. The superstore is a distinct concept from the (non-food item intensive) hypermarket and the low-margin, reduced variety warehouse format.

[10] The Advertising/Sales ratio is currently about 2%. Since 89% of advertising dollars are spent on newspapers and circulars, it is unlikely that large chains benefit significantly from scale economies in advertising (Adweek, 1998).

[11] Perhaps Albertson's was the "one smart agent" envisioned in Shaked and Sutton (1997).

In this model of competition, firms are assumed to produce a single product[12]. Stores differ only in their level of quality z, which represents the brandwidth or variety provided by the store[13]. On the demand side, M identical consumers have preferences consistent with willingness to pay non-decreasing in quality: i.e. I assume that a wider choice set, prices held fixed, appeals to all consumers and allows supermarkets to draw from a broader customer base. Consequently, if two goods of differing quality are offered at the same price, all consumers will choose the product of higher quality. Utility is given by

$$u(x_1, x_2, z) = (1 - \alpha)\ln(x_1) + \alpha \ln(zx_2) \tag{1}$$

defined over two goods, a Hicksian composite commodity x_1 and the quality differentiated good x_2 that is the focus of our analysis. Each consumer is endowed with Y units of good 1. The composite good is a numeraire ($p_1 = 1$) so that, ignoring any distribution of profits, each consumer has wealth Y. I let $p(z)$ denote the price of a differentiated good of quality z.

Because most stores are part of a chain, increasing the quality (z) of stores involves a joint investment in fixed costs at the store and the firm level. Firms build larger stores[14] and invest in both information technology and distribution systems to stock a wider array of products (Messinger and Narasimhan, 1995). The fixed costs associated with expanding store size are largely sunk: because of their unique, single-floor, space-intensive design, supermarkets are not easily converted into other uses.[15] The focus here is on competition at the store level and the associated store level investments. Therefore, increasing brandwidth requires outlays which are both fixed and sunk at the store level.[16]

I assume there are N identical firms, where firm j uses input $F(z_j) + cq_j$ of the composite good to produce quantity q_j of the differentiated good of quality z_j. Following Sutton (1991), I assume the fixed cost function takes the form $F(z) = \sigma + \frac{s}{\gamma}(z^\gamma - 1)$, which includes both the exogenous fixed entry cost σ and a second term that depends on the level of quality chosen. Competition is modeled as a three stage game. In the first stage firms choose whether or not to enter. Firms that choose to enter incur a fixed entry cost σ. In the second stage,

[12] Thus, when firms own more than one store, I tacitly assume that all stores owned by the chain provide the same level of quality.

[13] Clearly there are several other dimensions of quality along which supermarkets compete, such as offering deli bars, fresh produce, and shorter check-out lines. In practice, the stores offering the widest selection tend to invest in other quality enhancements as well (the exception of course being ultra high quality specialty stores such as Gelson's Markets or Whole Foods Markets). Moreover, cost reducing investments create complementarities across several forms of quality. However, the focus here is on quality that 1) increases the willingness to pay of all consumers and 2) is itself increased primarily through investments in fixed costs.

[14] Surveys consistently indicate that consumers place a high value on wide aisles and easily accessible products (Progressive Grocer). It is not sufficient to simply cram a wider selection into smaller, existing stores.

[15] The owners of a supermarket chain that recently chose to close down and sell off their assets claimed that the most recently built stores were the most difficult to unload (personal communication with author).

[16] If sunk costs increase with the size of the market, maintaining a fixed level of quality is more expensive in larger markets. In this case, the larger number of consumers over which to spread sunk costs is offset by the rising level of sunk costs, providing an alternative mechanism through which sunk costs may be endogenized. Furthermore, since the cost of land increases with metropolitan size, store level sunk costs may actually increase with the size of the market, holding store size constant.

firms choose a level of quality z, incurring the fixed cost $F(z)$. In the third and final stage, firms compete in the product market. Product market competition is modeled as Cournot. Using this basic framework, I will now illustrate both the exogenous and endogenous sunk cost cases.

3.1 The Exogenous Sunk Cost Case

In the exogenous sunk cost case, quality is fixed and no longer a decision variable for the firm. Firms still pay a fixed cost of entry, determined by the industry's underlying technology. Without loss of generality, assume all stores offer quality $z_j = 1$ and let $p(1) = p$. Since quality is a constant in this case, fixed costs are given by $F(1) = \sigma$, the (exogenous) fixed cost of entry. Maximizing profit at store j and solving the resulting symmetric first order conditions yields equilibrium quantities

$$q = \left(\frac{N-1}{N^2}\right)\frac{\alpha YM}{c}$$

and price

$$p = \left(\frac{N}{N-1}\right)c$$

Assuming entry will occur until profits are driven to zero, and ignoring the constraint that N be an integer, the equilibrium number of entrants is $N = \sqrt{\frac{\alpha YM}{\sigma}}$, which increases monotonically with the size of the market.

3.2 The Endogenous Sunk Cost Case

We now allow quality z_j to be a choice variable of the firm. We proceed via backwards induction, analyzing the final product market competition stage first. Since stage 3 is Cournot and quality enters the consumer's utility function multiplicatively, consumers choose products that maximize the quality/price ratio. In equilibrium, the prices of goods supplied by all firms with positive market shares must be proportionate to quality, say $\frac{p(z_j)}{z_j} = k$ for all j. Looking now at the second stage, calculate equilibrium quality given the quantity response in the third stage. It is easy to see that the only equilibrium in this model is symmetric. Alternative models of VPD can yield asymmetric equilibria in quality.[17] The equilibrium

[17] In both Shaked and Sutton (1983) and Ronnen (1991), income is heterogeneous, competition is Bertrand, and consumption is restricted to unit demand (unrealistic in the context of supermarket competition). In equilibrium, a finite number of firms enter, each offering a unique quality and price combination and targeting a distinct "income band" of consumers. Lehman-Grube (1997) establishes a similar asymmetric *natural oligopoly* result when entry is sequential rather than simultaneous. The first entrant chooses the highest level of quality and earns the largest profit in equilibrium. Nevertheless, symmetric strategies are common in retail industries. For example, the stores operated by Circuit City and Best Buy, Walmart and Kmart, Office Depot and Staples, and the dominant supermarket chains are often difficult to distinguish and are frequently located close to their competitors' stores, suggesting that these firms are not necessarily targeting distinct consumer segments, as the asymmetric models imply, but competing instead for the same customers. Since the focus here is on explaining firm behavior in these industries, I follow Sutton (1991) in characterizing symmetric equilibria in both quantity and quality.

quantities and prices are

$$q = \left(\frac{N-1}{N^2}\right)\frac{\alpha YM}{c}$$

and

$$p = \left(\frac{N}{N-1}\right)c$$

which are identical to the results obtained for the exogenous sunk cost case. Here they hold irrespective of the level of z. Differentiating the profit function

$$\pi(z_1) = \alpha YM\left[\frac{(N-1)z_1 - (N-2)z}{(N-1)z_1 + z}\right]^2 - F(z_1) \tag{2}$$

yields the equilibrium level of quality

$$z = \left(\frac{2\alpha YM(N-1)^2}{N^3 s}\right)^{\frac{1}{\gamma}} \tag{3}$$

Therefore, quality increases monotonically with market size YM. Since both quality and fixed costs grow proportionately with market size (they were constant in the exogenous case), it should not be surprising to find an equilibrium where the number of firms does not expand with the size of the market.[18] Furthermore, since fixed costs grow more slowly for larger values of γ, we might also expect a larger number of entrants when γ is larger. To make this intuition precise requires solving for the equilibrium number of entrants. Entry in the first stage will drive profits to zero, ignoring integer constraints on the number of firms.[19] The equilibrium profit with N firms is

$$\pi = \frac{\alpha YM}{N^2} - F(z)$$

Assuming that firms will enter as long as $\pi_i \geq 0$ and treating the number of firms as a continuous variable, I can write the zero-profit condition as

$$\left(\frac{s-\gamma\sigma}{\alpha YM}\right)N^3 - 2N^2 + (4+\gamma)N - 2 = 0 \tag{4}$$

[18]This argument hinges on the assumption that marginal costs increase only slightly with higher levels of quality, allowing firms to shift the focus of competition onto fixed outlays. If quality were provided through increases in marginal costs, the fragmented Hotelling result would obtain in the vertical case as well, with firms stratifying along the quality dimension and serving distinct consumer groups, segmented by income bands (Tirole, 1988).

[19]In the discrete case, firms will enter until the next potential entrant would earn negative profits, so that large profits (and margins) are sustainable in equilibrium.

The fact that the number of firms will not increase indefinitely with the size of the market is immediately obvious from equation (4). In the limit, as market size YM increases to infinity, the lead term drops out, leaving a quadratic polynomial with root[20]

$$N = 1 + \frac{1}{4}\gamma + \frac{1}{4}\sqrt{8\gamma + \gamma^2} \tag{5}$$

which depends only on γ and is finite for all finite γ.[21] This finiteness result follows from the fact that z, and therefore $F(z)$, grows more slowly with larger values of γ. This allows more firms to "fit" into the market, reflecting the lower level of fixed costs that must be recovered in equilibrium. This non-fragmentation property is the central result of the endogenous sunk cost literature. Since only a finite number of firms will be able to cover the increased fixed costs necessary to provide a high quality product, a finite number of firms will enter regardless of the size of the market. The equilibrium that obtains in this baseline case is referred to as a natural oligopoly (Shaked and Sutton, 1983).

3.3 Extending the Baseline Model

When this simple model is extended to include horizontal differentiation, the results are more complicated (Shaked and Sutton, (1987, 1990)). To understand how the addition of a horizontal dimension impacts the outcome, it is informative to begin by considering the purely exogenous case developed above. When the efficient level of sunk cost is exogenously determined, the number of firms increases proportionately with the size of the market, causing concentration to decrease indefinitely. Intuitively, the number of firms which fit into a market depends only on the relationship between fixed cost and market size. As market size increases, fixed costs fall relative to the size of the market, increasing the number of firms that may profitably enter in equilibrium.

This simple result is complicated when firms enter sequentially or own multiple stores (Shaked and Sutton, 1990; Sutton, 1991). There may no longer be a unique equilibrium. Therefore, the relationship between market size and the equilibrium number of firms is no longer a unique mapping. However, it is still possible to demonstrate that, in the exogenous sunk cost case, the maximal number of equilibrium entrants corresponding to a given market size increases without bound as market size expands (Shaked and Sutton, 1990; Sutton, 1991). Therefore, given a large sample of markets, we should observe some outcomes in which the market fragments, yielding a lower bound to concentration that asymptotes to zero.

When the endogenous and exogenous cases are combined (as in Sutton (1991) pp. 65-66), a dual structure may emerge in which firms belong to one of two tiers. In the simplest, symmetric example, the top tier of firms compete in sunk outlays and provide high quality to retail consumers. Only a finite number of these firms will enter, regardless of the size of the market. The second tier of firms provides the minimum quality level to consumers

[20] The second root is always less than 1.

[21] For finite values of YM, the solution to equation (4) depends on the sign of the lead term. In particular, whether the equilibrium number of entrants approaches the limit (5) from above or below depends on whether $s - \gamma\sigma$ is positive or negative.

who do not care about quality, investing only in the (exogenous) sunk cost of entry.[22] The number of these firms increases indefinitely with the size of the market. Clearly, the total number of firms in the industry will increase without bound as well.

Because of the indeterminacy associated with multiple equilibria and the aggregate nature of most data on industry structure, tests of the endogenous sunk cost framework have tended to focus on the non-fragmentation property of these models. The non-fragmentation property states that when sunk costs are endogenously determined, the maximal market share of the largest firm is bounded above zero, independent of the size of the market. This property can be tested by estimating the lower bound to observed levels of (some measure of) concentration (Sutton, 1991; Robinson and Chiang, 1996; Ellickson, 1999). However, if it is feasible to identify the firms making investments in high quality, then it is possible to test directly whether these firms exist only in bounded numbers. Furthermore, by looking at the geographic locations of stores, we can observe whether stores indeed compete head to head for the same consumers as the theory implies. The challenge of the empirical work presented in this paper is to identify the high quality set of supermarket firms (which takes place at the MSA level), demonstrate that they exist only in bounded numbers (do not increase proportionately with the size of the market), and document that at the local market level, high quality stores compete head to head. Moreover, as I demonstrate in the following section, it is possible to formulate a much more restrictive test for a particular subclass of ESC models. Specifically, when increases in quality induce consumers to spend a higher fraction of their income on the quality good, investment in quality is a strategic complement. While this result does not hold over the entire class of ESC models, if it holds in the data, it provides a strong test of the ESC mechanism. The following section discusses when and how complementarity arises in the context of ESC models.

3.4 Vertical Product Differentiation and Strategic Complementarity

How firms react to investments by rival firms provides direct insight into the mechanisms that shape competition. In particular, cost reducing investments are rarely strategic complements, since the optimal response to a rival's investment in cost reduction is typically to reduce own investment due to the smaller expected market share over which to spread costs (Athey and Schmutzler, 1999). This is also the case when the investment takes the form of a capacity increase (Dixit, (1979, 1980); Spence, (1977, 1979)). Strategic complementarity in investment games is relatively rare (Bagwell and Staiger, 1994). In particular, the baseline model of Sutton (1991), essentially the model discussed above, implies that the quality choices of firms are substitutes, at least locally. But the ESC model is also consistent with strategic complementarity. Which result obtains depends critically on the manner in which quality enters the indirect utility function.

In the baseline model of Sutton (1991), quality enters in a ratio of quality to price, meaning that consumers care only about quality per dollar. The implied (log) linear relationship between equilibrium quality and price is common to several models of quality differentiation.

[22] The two-tiered industry structure is also analyzed in Lancaster (1996), although the focus there is not on endogenous versus exogenous sunk costs.

Proposition 1 in the appendix demonstrates that, in this baseline model, quality choices are always (local) strategic substitutes. This result hinges on the fact that increases in quality do not induce consumers to spend a higher fraction of their income on the quality differentiated good. Therefore, if a single firm raises its quality (and price), it will need to capture a larger share of the market to cover the increased fixed costs of providing higher quality. Since the level of demand is fixed, the optimal reaction of a competitor is to reduce quality (and price).

A similar result holds across a wide class of models of cost-reducing investment (Bagwell and Staiger, 1994; Athey and Schmutzler, 1999), which suggests the possibility that the Sutton baseline model might be reformulated as a model of cost reduction. Proposition 2 of the Appendix demonstrates that this is so: the baseline model can be reformulated as a model in which sunk cost investment leads to a reduction in the cost of output in "quality adjusted units", so that quality does not enter the utility function at all. Reinterpreted as a model of cost reducing investment, Sutton's baseline model implies strategic substitutes. Interpreted in this manner, the natural oligopoly result follows directly from the fact that "rivalry is both tough and focused on fixed outlays" (Schmalensee, 1992), irrespective of the particular product of those outlays.

The baseline model is, however, rather special; variations that are consistent with strategic complements seem more consistent with the verbal interpretation of quality escalation that Sutton uses to motivate his theory. In particular, when the relationship between quality and price is *non-linear*, increases in quality can induce consumers to spend a higher fraction of their income on the quality good, shifting the strategic interaction between firms from strategic substitution to strategic complementarity. In the Appendix, I present a model of demand-enhancing brandwidth in which quality choices are (locally) strategic complements. The set-up is identical to Sutton (1991), except that quality and price no longer enter as a ratio: in the context of supermarket competition, consumers are willing to pay more for groceries if they are offered a broader selection. As a result, in equilibrium, increases in quality induce consumers to devote a larger fraction of income to the quality-differentiated good, substituting out the composite good.[23] Consequently, firms are no longer splitting a "fixed pie", so that consumption and the level of quality are endogenously determined. The effect on strategic interaction is a shift to strategic complementarity: firms react in kind to increases in quality by their rivals.

The complementarity result is not confined to the example presented here. Analogous findings for the VPD model are presented in Ronnen (1991) and Lehmann-Grube (1997), although the assumptions of each depart markedly from Sutton's baseline model. In Ronnen's example, which is based on Shaked and Sutton (1983), consumers' incomes are allowed to vary and competition is Bertrand. In the resulting equilibrium, firms offer a staggered set of qualities. In the two-firm case, when the high quality firm raises quality, the low quality firm follows suit and vice versa. The result follows from the fact that the market is not fully covered in equilibrium so that changes in quality induce consumers who previously consumed the outside good to join the market. Again, quality enhancements effectively increase the available "pie". Lehmann-Grube presents similar results to Ronnen in a model

[23] The fraction of income devoted to the quality-differentiated good is constant in the baseline Sutton (1991) model.

with sequential entry.

This set of results indicate that strategic complementarity is consistent with several models of VPD and at least one model of ESC, suggesting a potentially powerful way to distinguish ESC models from alternatives. In the following section, I describe several competing explanations for the observed structure of the supermarket industry. In many cases, strategic substitution is an empirical implication, so that finding strategic complementarity rules them out of consideration As indicated below, those models that are not ruled out by a finding of strategic complementarity can be ruled out by other means.

3.5 Alternative Explanations for Concentrated Market Structure

Our discussion of the ESC-VPD framework was motivated by the high levels of concentration in the supermarket industry across geographic markets of varying size. Of course, there exist a variety of alternative explanations for the observed data (such as sequential entry, horizontal product differentiation, or complementarities in cost reducing investment). The question arises of how we can distinguish among these alternatives. The remainder of this section reviews some principal alternative explanations and identifies empirical implications that can distinguish between ESC-VPD and each of these alternative theories. In particular, I demonstrate how standard models of product proliferation or capacity competition can be rejected by the data. Finally, I consider two alternative forms of endogenous sunk cost investment, quality enhancement and cost reduction, and demonstrate how the strategic choices of firms can be used to distinguish between models of endogenous cost.

Several alternative explanations of supermarket industry structure can be rejected immediately by simply re-emphasizing the central theme of the section 3: exogenous sunk costs imply fragmentation. Specifically, even if large chains are able to take advantage of economies of scale in the form of quantity discounts and more efficient distribution, so long as these economies are *exogenously determined*, fragmentation will occur eventually (Shaked and Sutton, 1987; Sutton, 1991) and, as a consequence, we should observe cases in which a firm monopolizes an entire local, or even regional, market. Small markets should consistently be served by a single firm. Observing the same number of firms serving markets of vastly differing sizes is simply not consistent with a static model of scale. Only when sunk costs are endogenously determined will we observe a positive lower bound to concentration. Therefore, evidence of non-fragmentation alone is sufficient to discredit the exogenous scale hypothesis.[24]

A natural class of alternative models to consider are horizontal product differentiation (HPD) models of sequential entry. While Shaked and Sutton (1987) demonstrate that HPD

[24] The static scale economies story is more consistent with the chain store era of grocery store competition, when large chain stores were vertically integrated into production (manufacturing). The market share of A&P, one of the first truly national grocery chains, rose and fell on the merits of its private label brands. A&P established a large market share in the 1920s by offering much lower prices on their own brands. However, the introduction of the supermarket format and the concomitant rise of national brands has all but wiped A&P out of existence (they no longer depend on own-brand sales). Some supermarket chains continue to offer private label products in addition to national brands. Their popularity grew in the 1970s but has since waned. Since private labels are much more common in Europe, a cross-national comparison of markets would be enlightening.

with *simultaneous* entry yields fragmentation.[25] Shaked and Sutton (1990) demonstrates that the fragmentation result continues to hold when entry is sequential. However, the non-fragmentation result is not the only empirical implication which can distinguish the HPD mechanism from VPD. Consider a standard product-proliferation model with sequential entry, such as Schmalensee (1978), where a small group of firms, acting as a cartel, try to pack the product space by filling all available niches and thereby, soften price competition among their products. In equilibrium, competition is localized, with single firms (or the cartel) producing all the products along a continuous segment of the product space. Bonano (1987) extends this analysis to include strategic location choice by a monopolist. Further persistence of local monopoly results are established by Prescott and Visscher (1977), Eaton and Lipsey (1979) and Reynolds (1987). In each of these models, competition is *localized* (Schmalensee, 1985) meaning that firms enjoy a monopoly over continuous regions of the product space. Consequently, a finding of head to head competition, where firms compete directly for the same consumers, is inconsistent with most standard models of HPD with concentrated equilibria.[26] Moreover, Tirole (1989) demonstrates that in HPD models of competition on the line where firms are able to choose their unit costs by investing in sunk outlays, the fixed investments behave as strategic substitutes.

Another class of models consistent with highly concentrated equilibria are models of entry deterring capacity investment. In fact, the measure of quality proposed in this paper - brandwidth - could easily be interpreted as a capacity choice, especially when brandwidth is measured by store size. In a standard Stackelberg (1934) model of capacity choice (Spence (1977, 1979); Dixit (1979, 1980)), large firms invest in excess capacity to deter entry, resulting in highly concentrated equilibria. However, in all of these models, capacity choices behave as strategic substitutes. While Bulow et al. (1985a) construct a model where capacity choices are complements, the complementarity result relies on extreme convexity of the demand function. Moreover, the complementarity result applies only to the Stackelberg leader; for the Stackelberg follower, capacity choice remains a strategic substitute. Again, a finding of strategic complementarity for all firms in the market is sufficient to rule out most Stackelberg games of capacity competition.[27] By estimating the reaction curves[28] of rival firms, we can distinguish capacity competition from the endogenous sunk cost VPD framework.

A growing literature, extending the capacity choice/entry deterrence framework, is aimed at explaining the high degree of concentration in retail markets using models of cost-reducing investment (Bagwell and Ramey, 1994; Bagwell et al., 1997). In these models, vigorous price competition leads to the emergence of a dominant low-cost, low-price leader.[29] Although

[25] In the standard circle model (Salop,1979), for example, although there is no formal measure of market size, the number of entrants increases monotonically with the ratio of transportation costs to fixed costs. Since transportation costs are increasing in distance, it is clear that the number of entrants increases proportionately with the "size" of the market.

[26] An exception is Eaton and Lipsey (1982), where firms cluster around certain "poles", such as shopping districts and shopping malls.

[27] Obviously, when capacity choice is simultaneous, competition is Cournot and reaction functions are downward sloping (Bulow et al, 1985b).

[28] Note that in this exercise the reaction curves are between *capacity* choices in the Cournot capacity model and *quality* choices in the endogenous sunk cost model. Of course, both concepts are measured by the same brandwidth (store size) parameter.

[29] The emergence of a monopolist who, if re-entry is costly, can charge the monopoly price once his rivals

these investments in cost reduction are not endogenous, they are clearly strategic and consistent with a very high degree of concentration (monopoly, in fact, in the limit). As discussed earlier, cost reducing investments can be endogenous investments as well. However, in both models, investment in cost reduction is a strategic substitute among rival firms. In fact, the substitution result holds across most standard models of cost-reducing investment. Bagwell and Staiger (1994) demonstrate that investments in cost-reducing or quality enhancing R&D are strategic substitutes under fairly general conditions (satisfied by both Bagwell and Ramey, 1994 and Bagwell et al., 1997) and Proposition 1 of the Appendix demonstrates that the same is true of the baseline Sutton model. Athey and Schmutzler (1999) extend Bagwell and Staiger's results to include several additional classes of models, including Bertrand or Cournot competition with differentiated goods, constant marginal costs and linear demand (e.g. Dixit, 1979), HPD on the line (d'Aspremont et al., 1979) or the circle (Salop, 1979) with quadratic transportation costs, and the VPD model of Shaked and Sutton (1983). Indeed, it seems that only when investments are quality enhancing, as in the brandwidth model of supermarket competition presented earlier, are investments complements. Specifically, it is only when quality enhancing investments induce consumers to substitute out of an outside good and devote a larger share of income to the quality good, that VPD models lead to complementarity in quality.[30] Therefore, although strategic complementarity in investment may not rule out every conceivable model of cost reduction, it is inconsistent at least with the standard models, allowing broad classes of models to be eliminated from consideration.[31] Moreover, estimating reaction functions provides an empirical method of not only distinguishing models where investments result in monopoly, but distinguishing between competing models of endogenous investment as well.

The collection of alternative models and empirical implications discussed here (the main results are summarized in Table 1) illustrate how the empirical methods utilized in this paper cannot rely on a single result to prove that ESC-VPD is the most appropriate model of competition in the supermarket industry. Rather, I will present a combination of results which, taken together, correspond closely to the predictions of the ESC-VPD framework, but contradict central implications of the alternative hypotheses discussed here. After providing an overview of the data in the following section, I will proceed to the central empirical exercises of this paper.

have exited, suggests that welfare may be lower in this case than in the case where oligopolists must continue to compete for customers.

[30] There are, in fact, three distinct versions of this result: Ronnen (1991), Lehmann-Grube (1997) and the model presented in the Appendix. The first two examples utilize Bertrand competition and characterize asymmetric equilibria in quality. Consumers are restricted to consuming at most one unit of the quality good. In the example presented in the Appendix, competition is Cournot, consumers are allowed to consume any quantity of the quality good, and symmetric equilibria in quality are characterized.

[31] Those familiar with the literature on patent races know that strategic complementarity is fairly common in models of R&D and innovation. However, the complementarity result does seem to depend on the "winner take all" aspect specific to patent races (Reinganum, 1989).

Table 1
Principal Empirical Predictions of Alternative Models

Source of concentration	Principal Predictions	References
Scale economies/capacity (exog. sunk costs)	Monopoly in small markets, fragmentation, strategic substitution	Dixit (1979, 1980) Spence(1977, 1979)
HPD with preemptive entry (exog. sunk costs)	Localized competition, strategic substitution	Schmalensee (1978) Bonano (1985)
Cost-reducing investment (exog. sunk cost)	Monopoly, strategic substitution	Bagwell et al. (1997)
VPD with cost-reducing investment (endog. s. c.)	Natural oligopoly, strategic substitution	Sutton (1991)
VPD with income effect (endog. sunk cost)	Natural oligopoly, strategic complementarity	Ronnen (1991), Ellickson (1999)

4 Data

Documenting the competitive structure of an industry requires very detailed data that can be disaggregated down to the store level. In particular, for each supermarket in every market, we need to observe the ultimate owner or parent company, a measure of sales volume, several measures of quality (e.g. size, features), and its exact location. The data come from Trade Dimension's Retail Tenant Database. Trade Dimensions collects store level data on nearly every supermarket in operation in the U.S. for use in their *Marketing Guidebook* and *Market Scope* publications, as well as selected issues of *Progressive Grocer* magazine. The data is also sold to marketing firms and food manufacturers for use in the marketing of supermarket products. The definition of a supermarket used by Trade Dimensions is the industry standard: a foodstore with greater than $2 million in yearly revenues. Note that this is an establishment level definition. In 1998, there were 30,557 supermarkets in the U.S., 21,225 operating in counties within a designated MSA. Individual stores are identified by street address, zip code and county code. Each store is assigned a unique identifying code that remains with the *location*, even if ownership changes. Thus, newly built stores can be distinguished from remodels or buyouts. For each store in the database, its place in the organizational hierarchy is clearly documented, indicating the operating name, ultimate parent company, the number of stores in the chain and the principal supplier. The degree of vertical integration is therefore completely observable. Stores are already grouped according to several market definitions (zip code through MSA) and additional groupings are straightforward.

At the store level, Trade Dimensions collects information on average weekly volume, store size, number of checkouts, number of full and part time employees, whether scanners are in operation, and the presence or absence of various service counters (e.g. deli, seafood) as well as other measures of quality (atm, check cashing). This information is gathered through quarterly surveys sent to store managers and checked against similar surveys given to the principal food broker associated with that store. Demographic variables were collected from census projections for 1997 at the MSA, county and zip code levels. When different aggregations were needed (e.g. 4 digit zip code demographics), population weighted averages were used. Summary statistics are contained in Table 2.

From Table 2, it is clear that the average supermarket operates far above the $2 million cutoff. In fact, the largest supermarkets have revenues over $1 million per week. The average supermarket has a selling area of 30,700 square feet. The newest stores offer between 60,000 and 80,000 square feet of selling area (Progressive Grocer). The relatively small average size reflects the fact that many stores have been in place for 10 to 20 years. Only 54% of supermarkets supply themselves (vertically integrate into distribution), while the remaining stores contract with an independent supplier. 28% of supermarkets are owned by firms that operate in only one MSA. Most of these firms are independent (in fact, single store) firms. Finally, while scanning registers have diffused into the vast majority of supermarkets, other features such as ATM machines and service bakeries are less common.

Table 2

Variables

Variable	Definition	Mean	S.D.
Volume	Weekly Sales Volume	251432.2	166042.4
Size	Square Feet of Selling Area	30.7	17.0
Checkouts	Number of checkouts	9.5	5.5
VI	Vertical Integration Indicator	0.54	0.50
Stores	Total stores in parent comp.	418.4	479.2
Single Market	Single market firm indicator	0.28	0.45
Multi Market	Multi market firm indicator	0.72	0.45
Chain	National chain indicator	0.25	0.44
Scanner	Scanner indicator	0.88	0.33
Deli	Service deli indicator	0.83	0.38
Bakery	Service bakery indicator	0.74	0.44
ATM	ATM machine indicator	0.55	0.50
N	Number of observations	21255	

5 Evidence of Oligopoly in Supermarkets

The empirical analysis proceeds in four stages, the overall goal of which is to provide a body of evidence in favor of the quality enhancing ESC-VPD explanation of concentration in the supermarket industry, while providing several pieces of evidence to reject some of the key alternative hypotheses discussed in section 3. First, the existence of a positive lower bound to concentration is established – in most markets, 3-5 firms capture a 60-80% market share. This key finding is robust to the level of aggregation or the region analyzed; in large markets, the number of fringe firms expands, but the number and realized share of the oligarchs remains stable. Second, a "quality wedge" between oligarchs and fringe firms is identified; oligarchs offer approximately double the "brandwidth" of the fringe firms and are much more likely to provide additional quality enhancements such as bakeries, service counters and in-store ATM machines. The focus then shifts to demonstrating that oligarchs *compete* head-to-head, at least geographically. In particular, I am able to demonstrate that at numerous levels of aggregation, there is little geographic segmentation. Finally, in section

6, I refine the analysis to focus on the nature of strategic interaction, demonstrating that the quality choices of rival firms are strategic complements. This finding allows us to rule out several competing hypotheses, including several models of cost reducing investment. The challenge of the empirical work presented here is to document the existence of a set of high quality firms which a) exist only in bounded numbers and b) compete head to head for the same consumers. In addition, I will identify features of the market structure which are inconsistent with competing theories. The first set of results illustrates how concentration remains strictly positive, regardless of the size of the market.

5.1 The Lower Bound to Concentration

Our first set of results highlight the central non-fragmentation result presented in Ellickson (1999): equilibrium concentration remains strictly positive as market size increases. Figure 1 illustrates the relationship between concentration and market size using the share of the largest firm (C_1) to measure concentration.[32] Here, a market is taken to be an MSA, the definition used both by supermarket firms and in previous studies of the industry.[33] I measure the size of a market using the log of its population. There are 320 distinct markets in the sample. New York City was dropped from the sample because zoning laws place severe restrictions on the size of supermarkets in Manhattan.[34] The non-fragmentation result is immediate upon inspection. There is a clear lower bound to concentration which remains strictly positive as market size expands. Indeed, the lower bound reaches a minimum quite quickly and then actually increases with market size. This convex, bounded relationship suggests that while scale economies may play an important role, they are not the main determinant of market structure. With pure scale economies, concentration would tend to zero as the market expands. Only when sunk costs (and minimum efficient scale) are determined endogenously, can we expect to see markets remain concentrated indefinitely. The fact that the lower bound first falls and then increases can be explained with a model of endogenous sunk costs where investment only impacts willingness-to-pay beyond a certain threshold level (of investment).[35] However, this non-convex behavior cannot be explained by simple (static) scale economies, where a larger number of firms fit into larger markets.

The share of the second largest firm (Figure 2) is also bounded below, indicating that even the smallest markets do not converge to monopoly. Although the share of the market

[32] See Ellickson (1999) for a formal empirical analysis using an alternative measure of concentration (C_4).

[33] This definition has been widely used in previous studies of the supermarket industry (Chevalier (1995, 1996); Cotterill and Haller, 1992), in trade journals, and by the Federal Trade Commission in assessing merger activity. Its choice is justified on theoretical grounds by the fact that supermarket chains operate divisions and distribution centers at the MSA level, distribute advertising circulars at the MSA level, and consider their competitors to be firms operating in the same MSA (Baer, 1999; Chevalier, 1995).

[34] New York City is included in the analysis in Ellickson (1999). This is because a) it was not the only outlier in the earlier period (1972) and b) outliers play a central role in bounds analysis. Moreover, the non-fragmentation result continues to hold when New York City is included. However, because New York City is the only outlier in 1998 and a reasonable case can be made that the forces determining its observed level of concentration are outside the endogenous sunk cost framework (i.e. government regulation), I chose to exclude New York City from the current analysis.

[35] For example, advertising might only be effective beyond some minimal level or there might be minimum purchase requirements for television commercials (Sutton, 1991).

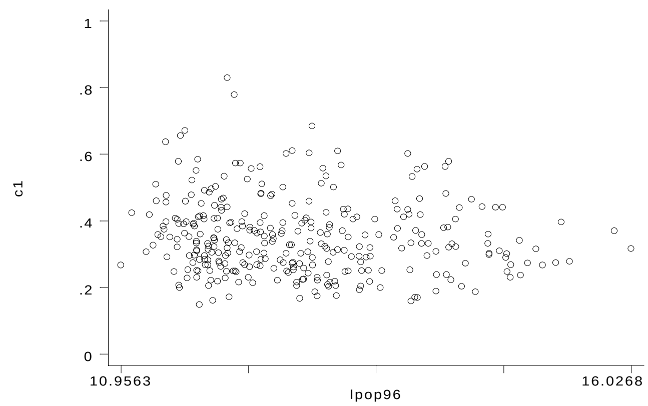

Figure 1: The lower bound to concentration

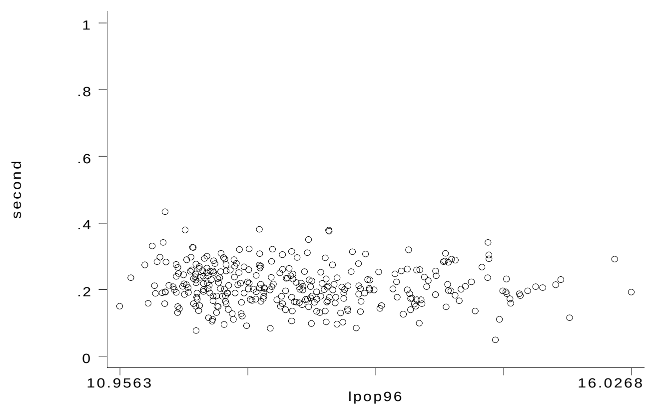

Figure 2: Share of the second largest firm

served by the second through fourth firms decreases substantially, it does not decrease to zero (the fourth firm serves on average 9% of a market). Moreover, in several instances the fourth largest firm in a market is the market leader somewhere else. These findings of non-fragmentation can be viewed as the first piece of evidence that supermarket competition must, at some level, be focused on sunk outlays. However, demonstrating that VPD is in fact the mechanism of competition requires identifying a natural oligopoly of high quality firms competing side by side. This can only be accomplished by looking above the bound.

5.2 Identifying an Oligarchy

In this section, I demonstrate that, in markets of differing sizes, roughly the same number of firms capture 70-80% of the market. This result is robust to the level of aggregation or definition of market. In the following sections, I demonstrate that a) these firms provide a distinct, higher quality product than the remaining fringe of firms and b) they compete head to head for the same consumers. However, in order to justify proceeding to these more

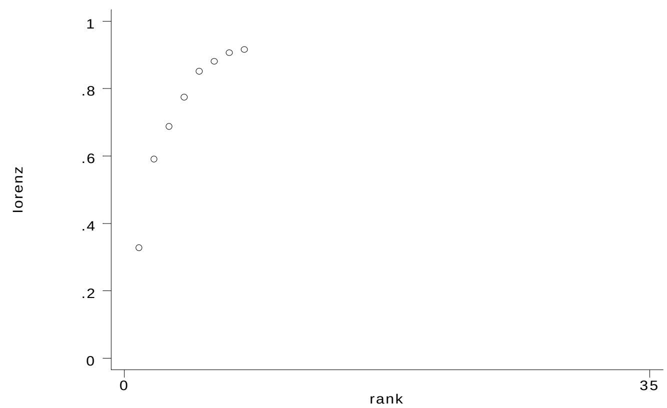

Figure 3: Cumulative market share (Eugene)

detailed results, it is first necessary to establish the existence of an oligarchy. Our second set of empirical results addresses this question by focusing on individual firms, establishing that roughly the same number of high quality firms enter a market, irrespective of its size. Figures 3 and 4 present Lorenz curves for two west coast markets (MSAs), Eugene Oregon and Los Angeles California. In this exercise, the horizontal axis measures the rank of the firm (from largest to smallest) in terms of sales while the vertical axis measures cumulative sales as a share of the total. Although the markets vary greatly in size, the larger market differs from the smaller one almost exclusively in the length of the tail of small firms.[36] Figure 5 presents Lorenz curves for MSAs in several west coast markets. The uniformity in outcomes across markets is striking. For a wide class of markets, 65-70% of the market is controlled by 4 or 5 firms, with the remainder of the market being served by a fringe of firms that expands with population. Figures 10 to 17 in the appendix extend this analysis to include every MSA in the sample. There are a few outliers (e.g. Minneapolis in the northwest, Oklahoma City in the southwest, Kansas City in the Ohio Valley, and New York in the Northeast), but the uniformity of outcomes remains. Again, these configurations are not consistent with an exogenous scale economy story, as there does not appear to be any tendency towards a single dominant firm. Among the 320 MSAs, only 36 have a single firm capturing over 50 percent of the market. Of these 36 markets, 12 have a single firm capturing between 60 and 70 percent and 2 have a single firm capturing between 70 and 85 percent. If concentration were being driven purely by exogenous economies of scale, we would expect to *consistently* observe one firm, especially in the smaller markets. The fact that we observe so few single-firm dominated markets even in the smallest markets, suggests that natural oligopoly is a stable outcome and that some additional force is driving industry structure.

The level of concentration clearly depends on market definition. While the MSA is widely considered to be the level at which large supermarket chains compete (both advertising and distribution take place at the MSA level), it is possible that these results could depend

[36] This analysis includes only firms which operate more than one store. The inclusion of single store firms merely increases the length of the tail of firms in large markets, but scale problems make the graphs difficult to compare.

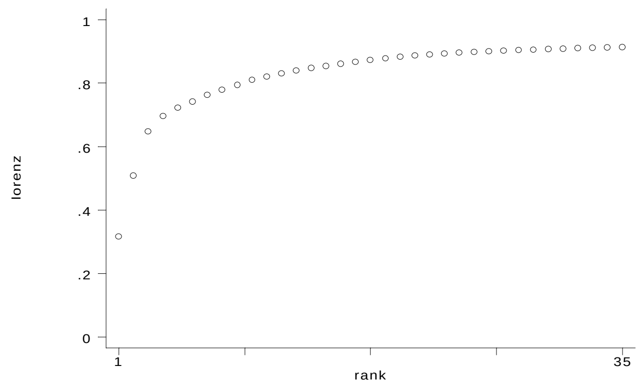

Figure 4: Cumulative market share (Los Angeles)

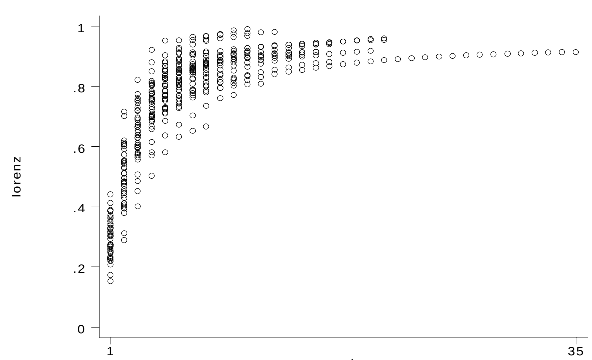

Figure 5: Cumulative market share (West Coast MSAs)

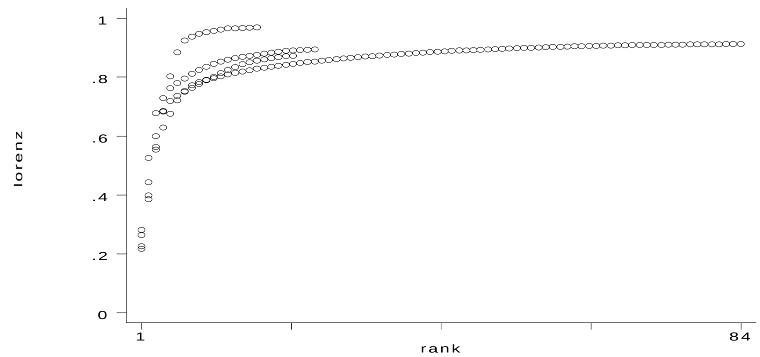

Figure 6: Cumulative market share (State level)

critically on the level of aggregation. I find that they do not. Table 3 presents average market concentration (C_4) for several market definitions, broken down by region. While concentration decreases significantly at the regional level, the state and MSA levels are quite similar. These results also indicate that while regional variation exists, it is not consistent across markets. For example, although the older markets appear less concentrated at the state and regional level, the effect is much less pronounced at the MSA level. Figures 6 and 7 demonstrate that the oligopolistic structure extends up to the state and regional levels respectively (the sample remains west coast markets for ease of comparison). At each level of aggregation, the top 4 firms in the market capture most of the total sales.

Taken together, these results suggest that supermarket competition indeed takes the form of natural oligopoly. In fact, although the oligopolistic structure extends up several levels of aggregation, MSAs are still served by 4-5 high quality firms. While economies of scale clearly play an important role and endogenous sunk costs may efficiently be sunk above the MSA level, firms still face direct competition in every market. In the following sections, I demonstrate how this result extends all the way down to the individual store.

Table 3
Concentration by Market

Area	MSA	State	Region	National
West	.73	.68	.61	.24
Northwest	.88	.78	.46	.24
Southwest	.79	.71	.55	.24
South	.82	.63	.45	.24
Ohio Valley	.75	.58	.46	.24
Great Lakes	.74	.51	.33	.24
Northeast	.76	.68	.30	.24
South Atlantic	.81	.69	.56	.24

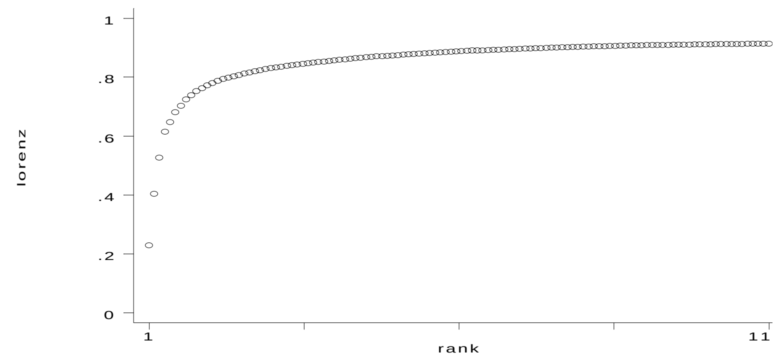

Figure 7: Cumulative market share (regional)

5.3 Top Firms Provide a Distinct Product

The preceding exercises established not only that concentration remains positive at all market sizes, but that the top 4 firms capture 70-80% of a market's sales, regardless of the size of the market. In this subsection, I extend this analysis by demonstrating that the product provided by top 4 firms is significantly different from that of the fringe. In particular, the quality level of the top firms (as measured by store size and the number of store features) is almost twice as high as the level chosen by firms in the fringe. Establishing that the oligarchs provide a distinct product justifies focusing on competition among firms in this set alone. In the following section, I demonstrate that this set of oligarchs compete side by side in local markets and do not carve out local (geographic) monopolies. This finding of competition at the local level reflects the rivalry emphasized in the VPD framework and casts doubt on the validity of alternative non-competitive explantations (e.g. product proliferation) which predict substantial balkanization of competition.

Although the optimal measure of quality suggested by the VPD model would combine a measure of brandwidth with store size,[37] Trade Dimensions does not collect information on the number of products offered by each store. Therefore, I will use store size alone to proxy for quality. As a robustness check, I present two alternative measures of quality constructed from store characteristics: the number of features present in a store (0-2 among an in-store bakery and deli) and a similar measure for scanners and atm machines (technology).

Table 4 investigates the relationship between store quality and firm type. For the entire sample of 320 MSAs, firms are divided into the top 4 firms in each MSA and the remaining fringe of firms (firms which operate in more than one MSA are treated as separate observations). The average store level characteristics are calculated for each class of firm across all MSAs. The top 4 firms offer significantly higher levels of quality along all three dimensions. In addition, top 4 firms are more than twice as likely to be vertically integrated and operate

[37] Providing a large brandwidth requires stocking a wide array of products and building a larger stores. Wide aisles and easily accessible products consistently rate highly in consumer surveys (Progressive Grocer). Therefore, even the number of stock keeping units (SKUs) offered in each store would not fully capture this measure of quality.

over three times as many stores.[38] The last two columns of Table 4 address the hypothesis that sunk cost outlays may be optimally sunk above the firm level. Stores are divided according to whether their parent company operates stores in one or more than one market. The results are broadly similar to the results from the top4/fringe division: multi-market firms choose higher levels of quality and are considerably more likely to be vertically integrated.

Table 4
Store Characteristics by Firm Type

	Firm Type			
Characteristic	Top 4	Fringe	Multi-market	Single-market
Size	40.4	24.1	33.5	20.0
	(16.0)	(15.2)	(17.0)	(15.0)
Technology	1.58	1.21	1.40	1.21
	(.42)	(.62)	(.58)	(.49)
Features	1.75	1.31	1.54	1.34
	(.42)	(.74)	(.68)	(.56)
% VI	0.68	0.31	0.57	0.01
	(.46)	(.46)	(.49)	(.10)
Stores	487.6	131.7	344.4	2.84
	(469.9)	(261.4)	(422.7)	(3.34)
Observations	1257	1735	2439	553

Table 5 uses regression analysis to test the significance of the quality "wedge" for the top 4 firms. Using the sample of firm-MSA level observations, each measure of average store quality is regressed on a dummy variable indicating whether the firm is in the top 4 in this MSA and a full set of MSA fixed effects. Quality is measured in levels, with average store size measured in 1000s. All three measures of quality are significantly higher among the top 4 firms. These results suggest that membership in the "oligarchy" entails providing a significantly different product than the fringe firms. If scale economies and quantity discounts alone were determining market structure, we would not expect the *store* characteristics of lead firms to differ from the followers. We would simply expect the market leaders to have lower prices.[39]

This set of findings justifies shifting our focus to competition among the oligarchs, treating the fringe as a separate industry,[40] which does not significantly impact competition among the oligarchs. To summarize, the preceding empirical results identified a high quality set of supermarkets that exist only in bounded numbers, regardless of the size of the market. The goal of the next set of results is to demonstrate that these firms in fact compete side by side for the same consumers, consistent with the rivalry emphasized in the VPD framework.

[38] The number of stores operated is the total number of stores operated by a firm across all MSAs.

[39] This was precisely the case when A&P dominated the grocery industry (Tedlow, 1990).

[40] This raises the question of what market is actually being served by the fringe firms. Cotterill (1986) finds that prices are 2.6% higher among independent supermarkets in the Vermont area, suggesting that independent firms may charge a premium for location or convenience. In addition, he finds a non-linear relationship between price and store size, suggesting that the largest stores are able to charge a premium for quality (size). These findings support the claim that independent supermarkets and premium chains serve distinct markets.

Table 5
Store Characteristic Regressions

	Dependent Variable		
	Size	Technology	Features
Top 4 Dummy	17.4	.39	.44
	(.61)	(.02)	(.02)
Constant	23.6	1.32	1.32
	(.38)	(.01)	(.02)
MSA Fixed Effect		Included	
R^2	.32	.23	.23
Observations		2992	

Standard errors in parentheses.

5.4 The Structure of Local Competition

The empirical exercises in the previous subsections establish that markets of varying sizes are served by roughly the same number of high quality firms. However, several forms of *local* competition are consistent with this structure. For example, in equilibrium, firms might serve distinct geographic regions (as in product proliferation models). Consumers would therefore face local monopolies in each submarket. On the other hand, each market might be served by several firms, so that each firm would face competition at each store location. These two cases have very different consumer welfare implications,[41] clearly illustrating the importance of market definition in any analysis of retail competition. This issue can only be resolved by narrowing our analysis to small geographic submarkets and focusing on local competition. Schmalensee (1985) provides an explicit statistical test for localization of competition in differentiated products markets. However, because the differentiation considered here is simply spatial, I am able to rely on simpler methodology. I present several complimentary pieces of evidence which demonstrate that firms are unable to carve out local monopolies at almost any level of aggregation. The fact that local monopoly is consistently so rare suggests that rivalry between firms is a central feature of the mechanism underlying the competitive structure of the supermarket industry.

Extending the results presented above, I focus on competition in local markets between supermarkets that are among the top 4 firms in an MSA. The top 4 concept is defined at the MSA level: the top 4 firms are identified for each MSA and then the number of distinct top 4 firms operating in each zip code within that MSA is calculated. Table 6 presents the average number of top 4 *firms* per zip code versus the average number of *stores* of any type per zip code. The sample is restricted to only those zip codes which are served by at least one top 4 store (5995 of 8174 total zip codes). Since zip codes vary considerably by region, results are broken down by region. For most regions, the average number of top 4 firms is well over 1, suggesting that monopoly is relatively rare. However, conditioning on the presence of at

[41] As noted earlier, once a local monopoly is established, the surviving monopolist may be able to charge the monopoly price so long as re-entry is costly, even if his monopoly position resulted from vigorous competition to become the low cost leader. Local monopoly can only serve to soften price competition and reduce the incentive to invest in future quality enhancements or cost reducing investments.

least one top 4 firm introduces selection that may confound this analysis. It also fails to control for the *size* of the market, an omission which could bias these findings.

Table 7 addresses this concern by conditioning instead on the number of supermarket stores of any type (including fringe stores). The number of stores is likely to provide an accurate measure of the size of the market that fully reflects differences not captured by population alone (e.g. the presence of shopping centers or other consumer attracting "poles"). Indeed, the number of top 4 stores increases quite quickly with the total number of stores, indicating that monopoly, when it does occur, is mostly confined to smaller markets. Table 8 extends this analysis by identifying the frequency of monopoly outcomes. Here, I present the frequency of one, two, three and four top 4 firm market configurations for two alternative market definitions. Although almost half the zip code markets are served by only a single top 4 firm, this simply reflects the small size of some zip codes: monopolies only account for a quarter of four digit zip code markets.[42] Table 9 further illustrates this point by conditioning on the number of top 4 *stores*. For zip code markets which contain two or more top 4 stores (3355 of 5595 markets), the frequencies of possible market configurations are presented. Multi-store monopoly is an extremely rare occurrence. When zip codes can fit more than one top 4 *store*, most often there is more than one top 4 *firm*.

In the appendix, I supplement this analysis by presenting maps of the actual locations of all the supermarkets in four markets (MSAs): Tampa (FL), Sacramento (CA), Los Angeles (CA), and Eugene (OR). Firm locations are matched to a zip code and plotted using symbols that correspond to their overall share in the market (MSA). In each case, top 4 firms appear to cluster in groups of 2 to 4. There is no evidence that, in equilibrium, firms serve distinct regions of the market: in no case is there a distinct geographic region which is controlled by a single top 4 firm, even though the share of the top firm approaches 30% in some markets. This result is particularly striking in Tampa, where natural boundaries might facilitate market power. Moreover, the interwoven structure of firm competition exists for both the smaller and larger markets. This finding is difficult to reconcile with most models of product proliferation.

Table 6
Top 4 Firms Per Zip Code

Region	Stores	Top 4 Firms	Observations	Population
West	3.6	1.9	1039	30297
Northwest	2.4	1.6	199	20296
Southwest	2.9	1.8	307	23255
South	3.0	1.8	738	23046
Ohio Valley	3.3	1.8	294	22463
Great Lakes	3.0	1.6	914	26628
Northeast	2.4	1.4	1333	21318
South Atlantic	3.3	1.9	1171	22632
Total Zip Codes			5995	

[42] It is important to keep in mind that a "monopoly" means only that the market is served by a single *top 4 firm*. Few of these markets are actually served by only one firm of any type.

Table 7
Top 4 Firms in Multi-Store Zip Codes

	Number of Stores						
	1	2	3	4	5	6	7+
Top 4 firms	.45	1.11	1.69	2.04	2.28	2.58	2.83
Population	11122	18711	25079	30957	54821	38835	48112
Observation	2934	1916	1278	853	546	294	353
Total zip codes				8174			

Table 8
The Frequency of Monopoly Outcomes

	Configuration				
Market Type	Monopoly	Duopoly	Triopoly	Quadropoly	Total Markets
Zip Code Markets	2943	1966	868	218	5595
4 Digit Markets	633	718	654	486	2481

Table 9
Monopoly: Conditional on
the Number of Top 4 Stores

	Number of Top 4 stores			
Configuration	2	3	4	5+
Monopoly	265	29	8	1
Duopoly	1354	437	129	46
Triopoly	-	428	276	164
Quadropoly	-	-	68	150
Total Markets		3355		

The preceding exercises attempt to demonstrate that top firms do not serve geographically distinct markets. Instead, firms compete directly with their rivals at every store location. However, I was forced to argue this point using a variety of methods, none of which captured the structure of competition in a single index. The final exercise of this empirical section proposes a single index of concentration to characterize the industrial structure of the full set of geographic markets. In particular, I construct an index of agglomeration which captures excess concentration relative to that which would occur randomly with suitably weighted potential locations (weighted, for example, by population). By comparing the calculated index for the industry as a whole (all stores) to the index calculated for only the top firm in each market, it is possible to test directly whether the lead firm chooses locations which are more localized than the industry as a whole (i.e. locating within only a few distinct submarkets). Localization is rejected if the index of concentration is the same or smaller for the top firm than for the industry as a whole. Using this methodology, I am able to demonstrate that the top firm does not select locations which are more clustered than the industry as a whole (or population), thereby rejecting the hypothesis of localized competition.

5.5 A Single Index of Competition

The basic finding demonstrated here is that the top firm in a market chooses store locations in manner which is no more geographically concentrated than the industry as a whole. To formalize this logic, I employ the "dartboard" method developed by Glenn Ellison and Edward Glaeser (1997). The authors propose a measure of spatial agglomeration that "'controls' for differences in industry and data characteristics without knowing what combination of natural advantages or spillovers is responsible for the agglomeration of each industry." In other words, their index measures excess concentration, accounting for differences in the number of stores owned by a firm and the size of the geographic region. The index was designed to capture the effect of spillovers or advantages causing (manufacturing) firms to locate plants in the same geographic regions. In practice, the index may be used to measure excess concentration among all plants in an industry or among only those plants owned by a specific firm. "Excess concentration" measures concentration beyond that which would be expected if firms chose plant locations by throwing darts at a suitably weighted "board" of potential locations. In the context of manufacturing, the weights are typically taken to be the share of overall manufacturing in a local submarket. In the supermarket industry, a more appropriate measure is the overall share of the consumer population residing in the local submarket. Using this index of excess concentration, we can then test the hypothesis that the top firm in a market chooses locations which are more agglomerated than the industry as a whole. This will not tell us whether the lead firm can enter first and occupy the best locations. However, it will identify firms that are attempting to serve distinct regions. Specifically, consider the following measure of concentration:

$$\gamma = \frac{\sum_i (s_i - x_i)^2 - \sum_i (1 - x_i^2) \cdot \frac{1}{N}}{\sum_i (1 - x_i^2) \cdot (1 - \frac{1}{N})}$$

where s_i is the share of stores in submarket i, x_i is the share of population in submarket i, and N is the total number of stores in the overall market area (MSA). While the overall market area for which each γ is defined is taken to be an MSA, I will utilize several potential definitions of the local submarket (e.g. zip code, 4 digit zip code, county). By evaluating this measure for both the top firm and the industry as a whole, we are able to make a direct comparison of the level of agglomeration among these two groups of firms. If firms succeed in dividing the market into local monopolies, the top firm should be more clustered than the industry as a whole, resulting in a larger value of γ. Since it is not clear how large a local submarket a potential monopolist might control, it is important to present a variety of local submarket definitions.

Table 10 presents parameter estimates of γ calculated for each set of firms using two alternative submarket definitions: zip code and county. The sample of MSAs includes all markets in the dataset where γ is defined; any market which contains only one submarket must be dropped from the sample. Focusing first on γ calculated for the industry as a whole (store γ), I find that, for each market definition, γ is very close to zero. Since we expect retail firms to locate close to their consumers, this is not surprising.[43] For each definition

[43] Ellison and Glaeser find that γ is closest to zero (no excess concentration) in markets where firms must locate close to their end users.

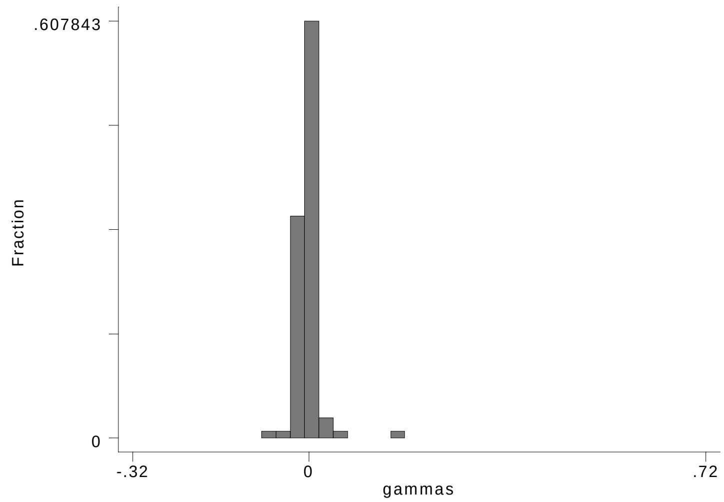

Figure 8: The distribution of γ (all stores)

of local market, the estimate of γ for the lead firm (top store γ) is smaller than γ for the industry as a whole (store γ), indicating that, in equilibrium, the store locations chosen by the top firm are not spatially clustered. However, because γ is a parameter estimate, the standard deviations of γ are much larger for the set of top firm stores, since fewer "darts" are being thrown. This is clearly illustrated in Figures 8 and 9, which plot the distribution of γ for the zip code markets (county markets are presented in the appendix).[44] Using this statistical evidence, the hypothesis that γ is larger for the lead firm can be clearly rejected.

Table 10
Concentration in Local Markets - The Dartboard

	All Markets	
	Zip Code	County
Store γ	-.013	-.004
	(.035)	(.021)
Top Store γ	-.087	-.015
	(.189)	(.111)
Observations	311	102

The preceding evidence indicates that competition in the supermarket industry indeed takes the form of natural oligopoly. This oligopolistic structure extends from the regional down to the local level, where firms face competition from rival stores at each location. However, whether the strategic interactions between oligarchs take the form of strategic complementarity or substitution depends on whether quality enhancing investments increase the effective size of the market, which we evaluate in the following section.

[44] Restricting the sample by population to include only large markets improves the precision of the estimates considerably. The hypothesis of greater agglomeration among the top firms is easily rejected.

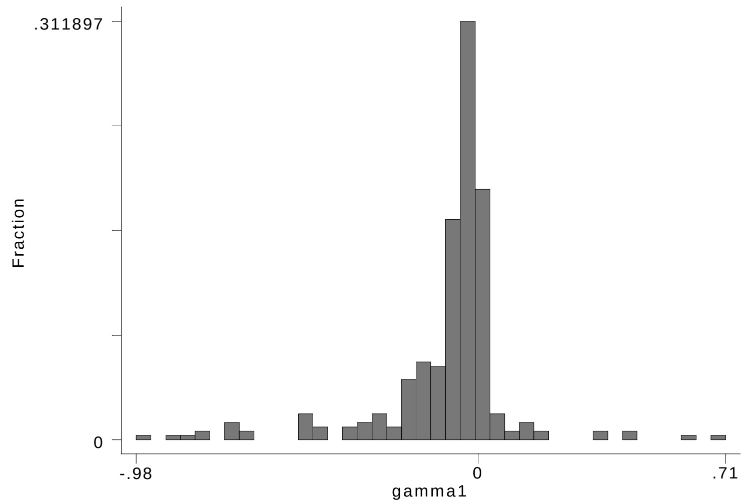

Figure 9: The distribution of γ (top store)

6 Quality Competition in the Supermarket Industry

The empirical results presented in the previous section demonstrate that many of the predictions of the endogenous sunk cost VPD framework can by documented in the supermarket industry. Moreover, several features of the industrial structure are difficult to reconcile with alternative explanations where sunk costs are exogenously determined. The purpose of this second set of results is not only to further distinguish exogenous from endogenous sunk cost models, but to differentiate among the set of endogenous sunk cost models as well. Specifically, I demonstrate that firms' quality choices are strategic complements. In addition to being inconsistent with most models of exogenous sunk costs, this finding is also inconsistent with most models of cost reducing exogenous or *endogenous* sunk investments. However, it is consistent with the brandwidth model of quality enhancing sunk cost investment presented in Ellickson (1999) and the model analyzed in Ronnen (1991). I begin by demonstrating that a central prediction of the VPD framework holds: that quality, market size and the number of entrants positively covary. As a result, we cannot estimate a firm's reaction function by simply regressing the firm's choice of quality on his opponents' choices. Therefore, I construct an instrument for the quality choices of competing firms and perform the analysis using instrumental variables (IV) regressions. Using this approach, I am able to demonstrate that quality choices by rival firms are strategic complements. This finding, together with the findings on the structure of local competition presented in the previous section, clearly demonstrates that the VPD framework provides a very accurate picture of competition in the supermarket industry. While the alternative explanations presented in section 3 may succeed in explaining one or even a few features of the industry, the VPD framework reconstructs the unique combination of all of these features.

Our first set of empirical results addresses the relationship between store size (quality), market size and the equilibrium number of entrants. According to the theory, larger markets should have a greater number of entrants (up to the oligopoly limit) and a higher level of quality. To document this covariation, I focus on the zip code as a local market,[45] and take quality choice to be a dependent variable. Starting from the dataset of store level observations for all 320 MSAs, I select out only those stores operated by firms which are in the top 4 at the MSA level.[46] Fringe firms are assumed not to strategically interact with the top 4 firms. A top 4 firm may then face between 0 and 3 other top 4 firms in a given zip code market. The following reduced form regression is specified:

$$\ln(size_{ij}) = \alpha_1 \cdot I_{1j} + \alpha_2 \cdot I_{2j} + \alpha_3 \cdot I_{3j} + \sum \alpha_4 \cdot Market_j + \sum \alpha_5 \cdot MSA + \varepsilon_i$$

where $size_{ij}$ is the size of store i in zip code j, I_{1j}, I_{2j}, and I_{3j} are dummy variables indicating the presence of 1, 2 or 3 other top 4 firms in zip code j, and $Market_j$ is a set of (logged) zip code level demographic and market characteristic variables. MSA is a full set of MSA level fixed effects and ε_i is an error term. Table 11 presents the regression results. The first two columns present results for zip code level regressions while the final two columns utilize the larger, 4 digit zip code market definition. Size is positively and significantly related to the presence of other top 4 firms. Moreover, the magnitude of the effect is monotonically increasing in the number of competitors. This suggests that either the true size of the market is not fully captured by our proxies or that some markets, for historical reasons, have fewer entrants and the lack of rivalry reduces both competition and the equilibrium level of quality. Size is also positively related to our measures of market size, population and income. In each case, the relationship is concave, although it is only significant for the larger market definition (suggesting that these measures are more accurate for the larger definition of a market). These results indicate that equilibrium quality levels are determined by a mechanism consistent with the VPD framework, where quality is an (endogenous) function of market size and the number of entrants. While this finding further justifies focusing on the VPD framework, it does not directly rule out any of the alternative mechanisms outlined in section 3. To do so, we must shift our focus to the strategic interaction between firms.

In order to isolate the pure escalation effect (and assess its magnitude) and understand the strategic interaction between firms, I must estimate the structural model underlying the competitive process. Specifically, I propose estimating the reaction functions of competing firms. The following regression is specified:

$$\ln(size_{ij}) = \alpha_1 \cdot \ln(Avgsize_{\setminus i}) + \alpha_2 \cdot \ln(Avgsize_i) + \sum \alpha_3 \cdot Market_j + \sum \alpha_4 \cdot MSA + \varepsilon_i$$

Here, $size_{ij}$ is again the size of a store i in zip code j. $Avgsize_{\setminus i}$ is the average size of store i's competitors in zip code j. $Avgsize_i$ is the average size of the stores of the firm that owns store i, outside of this MSA. $Market_j$ is a set of zip code level demographic variables, MSA is a set of MSA fixed effects (included in select specifications) and ε_i is an error term. As I documented above, firm size decisions are clearly endogenous. Unobserved factors such as an advantageous location in a shopping district, a disproportionate share of commuters, or

[45] I will also present results for a larger local market definition (4 digit zip codes).

[46] I preserved the total number of stores of any type in each zip code to use as a regressor.

idiosyncratic consumer preferences might cause some zip codes to have larger or smaller stores on average. Not all of these effects will be captured by demographic variables. Furthermore, the solution of the overall game implies a positive correlation between store size, market size and the equilibrium number of entrants. We are interested not in the solution of the overall game, but the strategic interaction among quality choices in the second stage of the game. Therefore, an instrumental variables approach is warranted.

To perform this analysis, I propose instrumenting competitors store size using their average store size outside of the MSA market.[47] A similar approach is used to instrument for prices in the context of new good valuation in Hausman (1994). Here, a firm's store size is assumed to be correlated across markets for at least two reasons. First, there are clearly scale economies inherent in providing a wide variety of products that go beyond the single MSA (see section 5.1 and Ellickson (1999)). Second, the benefits of maintaining a reputation for high quality probably extend across markets, as do the returns from media advertising. However, the tendency to provide larger stores is probably not related to the idiosyncratic forces driving store size to be larger in any particular zip code market (such as elements of market size not fully captured by population (e.g. the presence of shopping malls or a high percentage of "soccer" moms and stay at home parents)).

The first column of Table 12 can be viewed as the first stage of a two stage regression and provides some justification for the choice of instrument. The remaining columns present several specifications of the regression proposed above. The second column of Table 12 contains a baseline specification involving only own size and competitor's size. The third and fourth columns test the robustness of this specification by adding MSA fixed effects and zip code demographics respectively. The fifth column contains both sets of controls. The magnitudes of the competitor's size coefficients are reduced but remain positive and significant for each specification. The final column presents the specification of column 5, using the larger 4 digit zip code market definition. The size effects are larger for the larger market size, which is not surprising. In every specification, the complementarity result is positive and significant at the 1% level. Together, these regression results provide strong evidence that the quality levels chosen by rival firms are strategic complements. While this results is consistent with several models of VPD which emphasize the demand expanding effect of quality enhancement, it casts a significant doubt on a number of competing explanations of market structure, particularly models of cost reducing investment. This evidence on the actual shape of firm's reaction functions, together with the picture of the competitive structure of local markets presented earlier, suggests that the competitive, rivalrous emphasis of the VPD framework accords well with the observed structure of the supermarket industry.

[47] This instrument may be constructed in several ways, using a firm's average outside this zip code but within this MSA, across all stores outside this zip code (all MSAs) or across all stores outside this MSA. I explored each alternative and concluded that the latter is the most appropriate instrument.

Table 11
Quality Regressions

	Log Size			
One Competitor	.086	.049	.162	.117
	(.010)	(.011)	(.017)	(.019)
Two Competitors	.147	.086	.192	.135
	(.011)	(.014)	(.017)	(.020)
Three Competitors	.175	.098	.220	.160
	(.015)	(.020)	(.017)	(.023)
Population		.090		.360
		(.079)		(.074)
$(\text{Population})^2$		-.003		-.015
		(.004)		(.004)
Income		.244		1.69
		(.569)		(1.07)
$(\text{Income})^2$		-.014		-.084
		(.027)		(.050)
Market Level Controls		Included		Included
MSA Fixed Effect	Included			
R^2	.15	.18	.15	.17
Observations	12554			

Standard errors in parentheses.

7 Conclusions

This paper attempts to explain how retail industries become dominated by a few large firms in equilibrium. In particular, the high levels of concentration observed in the supermarket industry are explained using an endogenous sunk cost model of vertical product differentiation. In this framework, fierce competition leads to the emergence of a few dominant firms competing in quality enhancing sunk outlays. The predictions of this model accord well with the features of the supermarket industry documented here. Using a novel dataset of store level observations, I demonstrate that the same number of high quality firms enter markets of varying sizes and compete side by side for the same consumers. In addition to documenting a local structure of competition consistent with the VPD framework, I demonstrate that the choice of quality by rival firms behaves as a strategic complement. This key finding, which is consistent with a VPD model of quality enhancing sunk outlays, eliminates several alternative explanations concerning the nature of supermarket competition, including most standard models of cost-reducing investment. As such, I conclude that the competitive mechanisms sustaining high levels of concentration in the supermarket industry are inherently rivalrous and unlikely to lead to the emergence of a single dominant firm.

These findings suggest several avenues of further research. First, the focus on providing a wide array of products is not unique to the supermarket industry. Data from other concentrated retail industries such as consumer electronics, book stores and video rentals might provide insight into whether similar forces are driving the emergence of dominant chains in other markets. Second, the types of endogenous sunk costs most often analyzed, R&D and advertising, have the property that firms can spend virtually infinite sums of money on them, albeit with diminishing returns. R&D has never played a role in supermarket competition and the importance of advertising appears to have decreased over time. Moreover, store size and product selection, which seem to play a central role in supermarket competition, are naturally bounded by physical constraints. Nevertheless, the high levels of concentration observed in the supermarket industry have remained relatively stable for at least 25 years, despite substantial changes in the identities of the dominant players. This suggests that competition may force firms to find new ways to raise quality, perhaps shifting the focus of competition from advertising to product selection. This can only be understood by building a truly dynamic model of quality competition with continuous investment. Finally, little is understood about the welfare implications of endogenous sunk cost investments. The equilibrium price charged by natural oligopolists is strictly less than the monopoly price, but is well above marginal cost. Moreover, natural oligopoly is consistent with high equilibrium profits. Do consumers benefit from the relentless investment in quality driving competition in these models? Examining the welfare properties of endogenous investment models is the subject of future research.

Table 12
IV Regressions

	Log Size					
Competitors' Size		.225	.224	.196	.190	.240
		(.026)	(.036)	(.027)	(.036)	(.054)
Own Size	.896	.866	.899	.851	.876	.899
	(.020)	(.020)	(.026)	(.020)	(.026)	(.029)
Population				-.076	-.104	.292
				(.098)	(.101)	(.111)
$(\text{Population})^2$				.004	.005	-.014
				(.005)	(.005)	(.005)
Income				-.592	.172	1.24
				(.761)	(.819)	(1.25)
$(\text{Income})^2$				.022	-.008	-.061
				(.036)	(.038)	(.059)
Constant	.327	-.372		4.74		
	(.072)	(.107)		(4.12)		
Market Level Controls				Included	Included	Included
MSA Fixed Effect			Included		Included	Included
R^2	.21	.23	.28	.23	.29	.28
Observations			7867			8163

Standard errors in parentheses.

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A Appendix 1

A.1 The Behavior of Best Response Functions

Sutton (1991) argues that industries in which firms engage in endogenous sunk cost investments will converge to concentrated equilibria via a *quality escalation mechanism.* In this process, outcomes which are "too fragmented" will be broken, resulting in a less fragmented naturally oligopolistic equilibrium. In particular, "as market size increases, the incentives to escalate spending on fixed outlays rises. Increases in market size will be associated with a rise in fixed outlays by at least some firms and this effect will be sufficiently strong to exclude an indefinite decline in the level of concentration" (Sutton, 1997). This follows from the fact that the relative increase in market share that a firm can achieve through an increase in fixed outlays is greater for a firm with a relatively small market share. This implies nothing, however, about the strategic interaction between firms in equilibrium, and attempts to interpret it in this way can be misleading.

In fact, the strategic interaction between firms in the baseline Sutton model has not been discussed explicitly in prior work,[48] despite the fact that it is both theoretically interesting and empirically informative to understand how quality choices interact within equilibrium. The following proposition demonstrates that quality choices between rival firms are always strategic substitutes in the baseline model.

Proposition 1 *In the baseline model of Sutton (1991), quality choices by rival firms are always (locally) strategic substitutes.*

Proof. While the baseline model does not afford an analytical solution for a firm's best response function, it is possible to calculate its slope by evaluating the cross partial derivative of the profit function (2):

$$\frac{\partial^2 \pi(z_1)}{\partial z_1 \partial z} = 2\alpha YM(N-1)^2 \frac{[(N-1)^2 z_1^2 - 2(N-1)^2 z_1 z + (N-2)z^2]}{[(N-1)z_1 + z]^4} \tag{6}$$

Evaluated at $z_1 = z$, equation (6) reduces to

$$\frac{2\alpha YM(N-1)^2}{N^4 z^2}(-N^2 + 3N - 3)$$

which is strictly negative. Therefore, near the equilibrium, quality choices are always strategic substitutes. ■

Away from equilibrium, quality choices may be either substitutes or complements, as the following example illustrates. Choosing parameters $\alpha = \frac{1}{2}$, $s = 1$, $\sigma = 1$, $YM = 512$ and $\gamma = 2$, yields equilibrium $z = 8$ and 2 entrants. Solving for firm 1's best response as a function of firm 2's quality yields

$$br(z_2) = 8\sqrt[3]{z_2} - z_2$$

[48] Ronnen (1991) evaluates the strategic interaction between firms in the Shaked and Sutton (1983) set-up. However, competition in that model is Bertrand, equilibria are asymmetric, and there is no notion of market size.

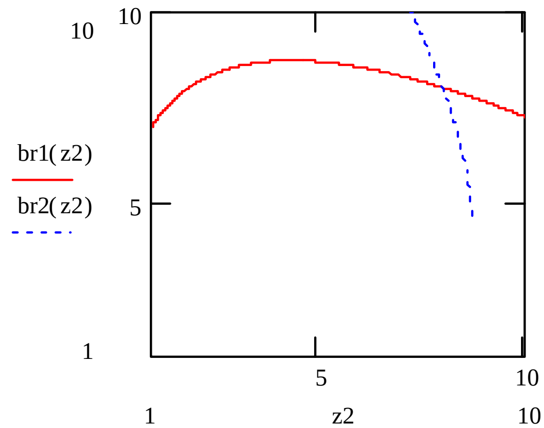

Figure 10: Best response functions

Figure 10 shows the best response functions of each firm. They are clearly negatively sloped at the equilibrium and the portions over which they are positively sloped occur quite far from the equilibrium. Nonetheless, if the fixed cost functions for rival firms are sufficiently different, it is possible for the reaction functions to cross at a point where quality is a complement for the low cost firm and a substitute for the high cost firm (imagine shifting the dotted curve in figure 10 far to the left). This outcome recalls the Bulow et al. (1985a) model of capacity competition with extremely convex demand functions, where the strategic interactions are also asymmetric and the reaction functions are nearly identical to those presented here.

A.2 Natural Oligopoly and Cost Reduction

In this section, I demonstrate that the baseline model can be reformulated as a model of cost-reducing investment, where quality does not enter consumers' utility functions at all. Nevertheless, all of the equilibrium properties presented in section 3.2 are preserved. In the baseline model, quality and price enter the indirect utility function as a ratio. As a result, consumers care about quality enhancements only in as much as they increase "quality per dollar." Since consumers cannot distinguish between an increase in the quality-price ratio stemming from an increase in the perceived level of quality and an increase in the ratio due to a fall of the "price of quality," the central insight of Spence (1975, 1976) applies directly to this model. Specifically, quality increases are equivalent to price reductions from the viewpoint of both buyer and seller. Consequently, the baseline model is equivalent to a model of cost reduction. This following proposition establishes that all of the equilibrium properties of the baseline model continue to hold in this case.

Proposition 2 *The baseline endogenous sunk cost model of Sutton (1991) is equivalent to a model of cost reducing investment.*

Proof. Assume the M identical consumers each have utility

$$u(x_1, x_2) = (1-\alpha)\ln(x_1) + \alpha\ln(x_2) \tag{7}$$

where x_1 is the quantity consumed of the composite good and x_2 the quantity of the differentiated good under analysis. There are N identical firms, where firm j uses input $F(z_j) = \sigma + \frac{c}{z_j}q_j$ of the composite good to produce quantity q_j of x_2. In particular, the firm may invest in fixed costs in order to reduce marginal costs by a fraction $\frac{1}{z_j}$.[49] Although x_2 does not appear to be a quality-differentiated good to consumers, it is clearly differentiated on the input side. Let $p(z)$ be the price of the differentiated good with cost reducing parameter z. Solving for the quantities demanded and plugging into the indirect utility function yields the following profit function for firm j

$$\pi_j = \frac{\alpha Y M}{\sum_{j=1}^{N} q_j} q_j - \frac{c}{z_j} q_j - F$$

Evaluating the associated first order conditions yields equilibrium quantities and price

$$q = \left(\frac{N-1}{N^2}\right)\frac{\alpha Y M z}{c}$$

and

$$p = \left(\frac{N}{N-1}\right)\frac{c}{z}$$

Allow firm j to vary its cost reducing parameter z_j, while continuing to assume Cournot competition, and suppose a single firm deviates from this symmetric equilibrium to choose parameter z_1 while the remaining $N-1$ firms choose the parameter z. The first order conditions yield equilibrium quantities

$$q_1 = \frac{\alpha Y M}{c}\left[\frac{(N-1)z_1 - (N-2)z}{[(N-1)z_1 + z]^2}\right](N-1)z_1 z \tag{8}$$

$$q = \frac{\alpha Y M}{c}\frac{(N-1)z_1 z^2}{[(N-1)z_1 + z]^2} \tag{9}$$

and price

$$p(z_1) = \frac{[(N-1)z_1 + z]c}{(N-1)z_1 z}$$

[49] For example, a supermarket building larger stores faces lower inventory costs per item and a microchip producer building a larger fabrication plant produces chips with a lower cost per bit.

The associated profit function is therefore

$$\pi(z_1) = \alpha Y M \left[\frac{(N-1)z_1 - (N-2)z}{(N-1)z_1 + z} \right]^2 - F(z_1) \tag{10}$$

which is identical to the baseline model (equation (2)). The remaining calculations, including both the non-fragmentation and strategic substitutability results are unchanged from the main derivation. ■

This proposition demonstrates that the emphasis on VPD in Sutton (1991) is not a requirement for non-fragmentation or natural oligopoly. In particular, it is possible for competition to be focused on endogenously determined sunk outlays and for the number of equilibrium entrants to be bounded when the product of the sunk outlays is simply a reduction in marginal costs. Therefore, it is not the case that, for the number of entrants to be bounded, sunk outlays must increase consumers willingness to pay, as argued in Sutton (1991). As argued in Schmalensee (1992), all that is required is that competition be focused on sunk outlays, not price cost margins. This finding suggests that the endogenous sunk cost framework may be applied to any industry where sunk investments are the focus of competition. For example, in several retail industries, the rise of dominant chains that invest heavily in advertising, information technology and advanced distribution systems (Bagwell et al., 1997) may reflect the endogenous nature of the sunk, cost-reducing investments necessary to compete in those industries. Consequently, the long-run equilibrium structure of those industries may be natural oligopoly, not the monopoly outcomes suggested by Bagwell et al. (1997). In the following section, I demonstrate that quality competition can be distinguished from cost reduction by focusing on the strategic interaction between firms, and in so doing, identify the role of increasing consumers' willingness to pay in the endogenous sunk cost framework.

A.3 A Model of Demand Enhancing Brandwidth

In this final theoretical section, I present the principal theoretical contribution of this paper: a formal model of retail competition where quality choices by rival firms behave as strategic complements. This result follows from the fact that, when quality and price enter the indirect utility function non-linearly, quality increases induce consumers to devote a larger fraction of their income to the quality good (in the baseline model this share of income is constant). This expansion of the market for the quality good causes the strategic interaction between rival firms to shift from substitution to complementarity.

Here, I modify the utility function of the baseline model so that quality and price no longer enter as a ratio and, as quality increases (with price held fixed), consumers spend a higher fraction of their income on the differentiated good. As a result, I identify regions of the parameter space for which quality is a strategic complement. Unfortunately, the derivation no longer permits a closed form solution. As a result, this example relies on a graphical presentation.

Starting with the direct utility function

$$u(x, z) = (1-\alpha)\ln x_1 + \alpha z \ln x_2 \tag{11}$$

and defining the function

$$\alpha(z) = \frac{\alpha z}{1-\alpha+\alpha z}$$

I find that

$$p(z) = \frac{kz}{(1-\alpha+\alpha z)^{1/\alpha}}$$

where k is a constant which depends only on α and Y. Defining

$$\phi(z) = \frac{z}{(1-\alpha+\alpha z)^{1/\alpha}}$$

I conclude that

$$p(z) = k\phi(z)$$

Following along the steps of the derivation of the baseline model, I calculate the first order conditions for the equilibrium quantity selected in the final stage. Solving these equations yields equilibrium quantity and price

$$q = \left(\frac{N-1}{N^2}\right)\frac{\alpha(z)YM}{c} \tag{12}$$

and

$$p(z) = \left(\frac{N}{N-1}\right)c \tag{13}$$

which are identical to the baseline model with $\alpha(z)$ replacing α. Supposing a single firm deviates, the first order conditions yield equilibrium quantities

$$q_1 = \frac{\alpha(z_1)YM}{c}\left[\frac{(N-1)\phi(z_1)-(N-2)\phi(z)}{[(N-1)\phi(z_1)+\phi(z)]^2}\right](N-1)\phi(z) \tag{14}$$

and

$$q = \frac{\alpha(z)YM}{c}\left[\frac{(N-1)\phi(z_1)\phi(z)}{[(N-1)\phi(z_1)+\phi(z)]^2}\right] \tag{15}$$

and price

$$p(z_1) = \left[\frac{(N-1)\phi(z_1)+\phi(z)}{(N-1)\phi(z)}\right]c \tag{16}$$

Consequently, the profit function of the deviant firm is given by

$$\pi_1 = \alpha(z_1)YM\left[\frac{(N-1)\phi(z_1)-(N-2)\phi(z)}{(N-1)\phi(z_1)+\phi(z)}\right]^2 - F(z_1) \tag{17}$$

which is simply the baseline model profit equation (2) with $\alpha(z)$ replacing α and $\phi(z)$ replacing z. Solving the game as a whole, I differentiate the profit function (17) to find the first order condition determining the equilibrium level of quality. Choosing the functional form of $F(z)$ used in the baseline model and setting $z_1 = z$ yields

$$\frac{\alpha z YM[N(1-\alpha z)+2(N-1)^2(1-\alpha)(1-z)]}{(1-\alpha+\alpha z)^2 N^3} = sz^\gamma \tag{18}$$

as the fundamental equation which determines equilibrium brandwidth z given the number of entrants N.

A.4 The Behavior of Best Response Functions

In section A.2, I demonstrated that, in the baseline model, a firm's choice of quality behaves as a strategic substitute near the equilibrium. While an analytic solution for each firm's best response function is still unavailable, it is possible to calculate its slope by evaluating the cross partial derivative of the profit function (17). Evaluated at $z_1 = z$, equation this reduces to

$$\frac{\partial^2 \pi_1}{\partial z_1 \partial z} = \frac{2\alpha YM(N-1)^2}{(1-\alpha+\alpha z)^2 N^3}\frac{\phi'(z)}{\phi(z)}\left[-(1-\alpha z)+\frac{2N-3}{N}(1-\alpha)(1-z)\right] \tag{19}$$

The term outside the brackets is strictly positive. Inside the brackets, the second term is negative for all $N > 1$ and $z > 1$, while the first term depends on the level of z, yielding an analog of the income and substitution effect. The following example demonstrates a case in which the effect of the first term outweighs the second. Choosing parameters $\alpha = \frac{1}{2}$, $s = 1$, $\sigma = \frac{85}{8}$, $YM = 75$ and $\gamma = 2$, yields 2 equilibrium entrants ($N = 2$) and equilibrium $z = 1.5$. Figure 12 plots the right hand side (rhs) and left hand side (lhs) of the first derivative of profit as a function of z_1. $lhs(z_1, 1.5)$ uses the equilibrium level of z, while $lhs(z_1, 2)$ uses $z = 2$. The effect of an increase in z is to shift $lhs(z_1, z)$ up, increasing the point of intersection and the equilibrium level of z_1. Therefore, at least locally, the slope of the reaction function is positive. Consequently, the optimal response to a rival's quality increase is to increase own quality. Unlike the model of cost-reducing investment presented in sections A.2 and A.3, investment by rival firms actually increases the return to own investment, resulting in strategic complementarity.

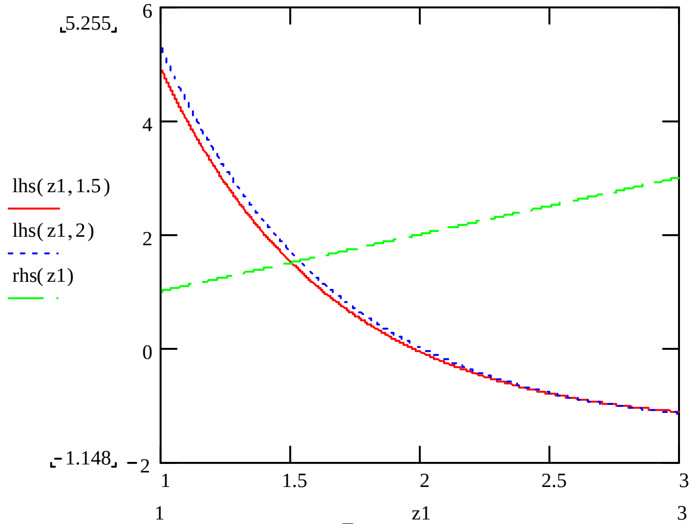

Figure 11: An example of strategic complementarity

B Appendix 2

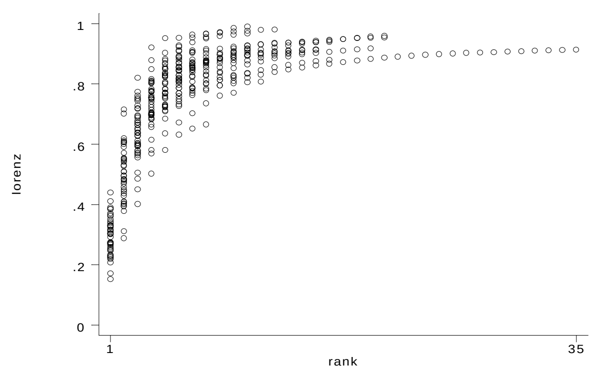

Figure 12: Lorenz Curves – Western Markets (MSAs)

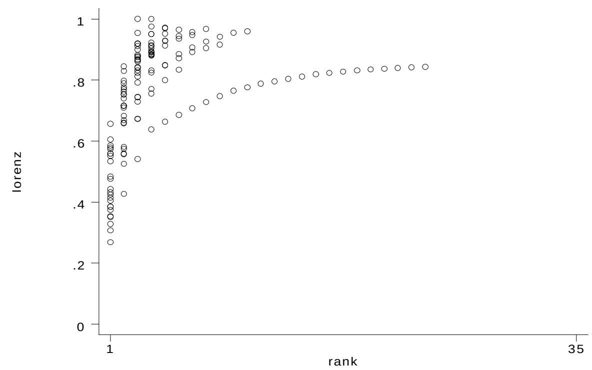

Figure 13: Lorenz Curves – Northwestern Markets (MSAs)

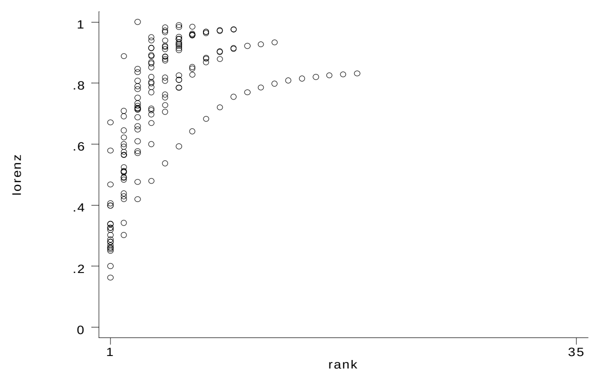

Figure 14: Lorenz Curves – Southwestern Markets (MSAs)

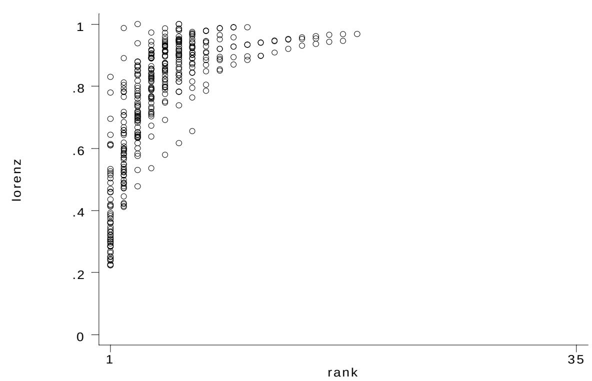

Figure 15: Lorenz Curves – Southern Markets (MSAs)

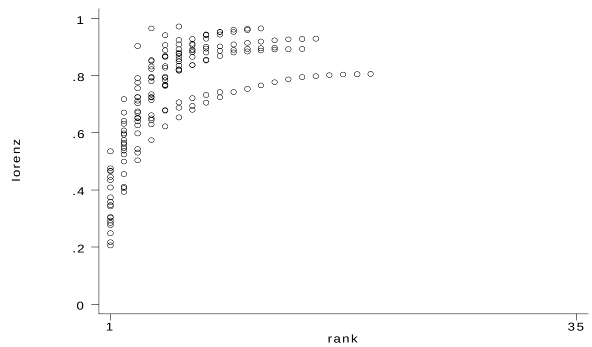

Figure 16: Lorenz Curves – Ohio Valley Markets (MSAs)

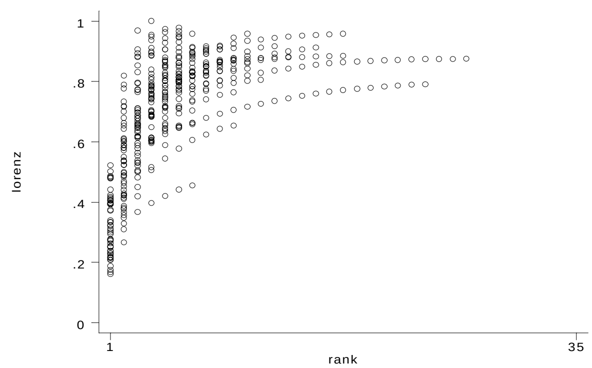

Figure 17: Lorenz Curves – Great Lakes Markets (MSAs)

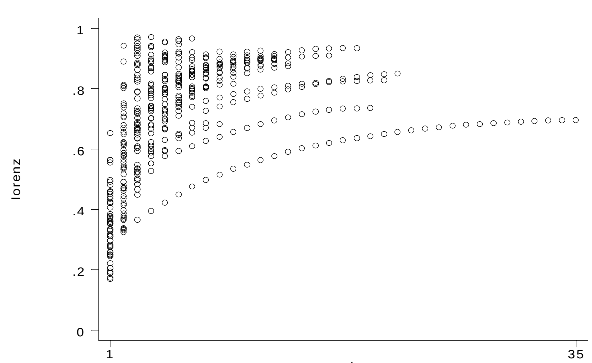

Figure 18: Lorenz Curves – Northeastern Markets (MSAs)

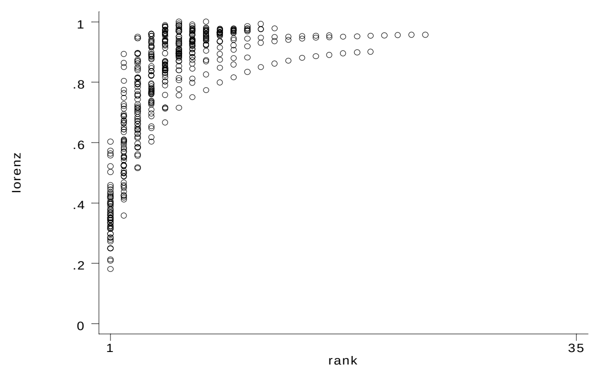

Figure 19: Lorenz Curves – South Atlantic Markets (MSAs)

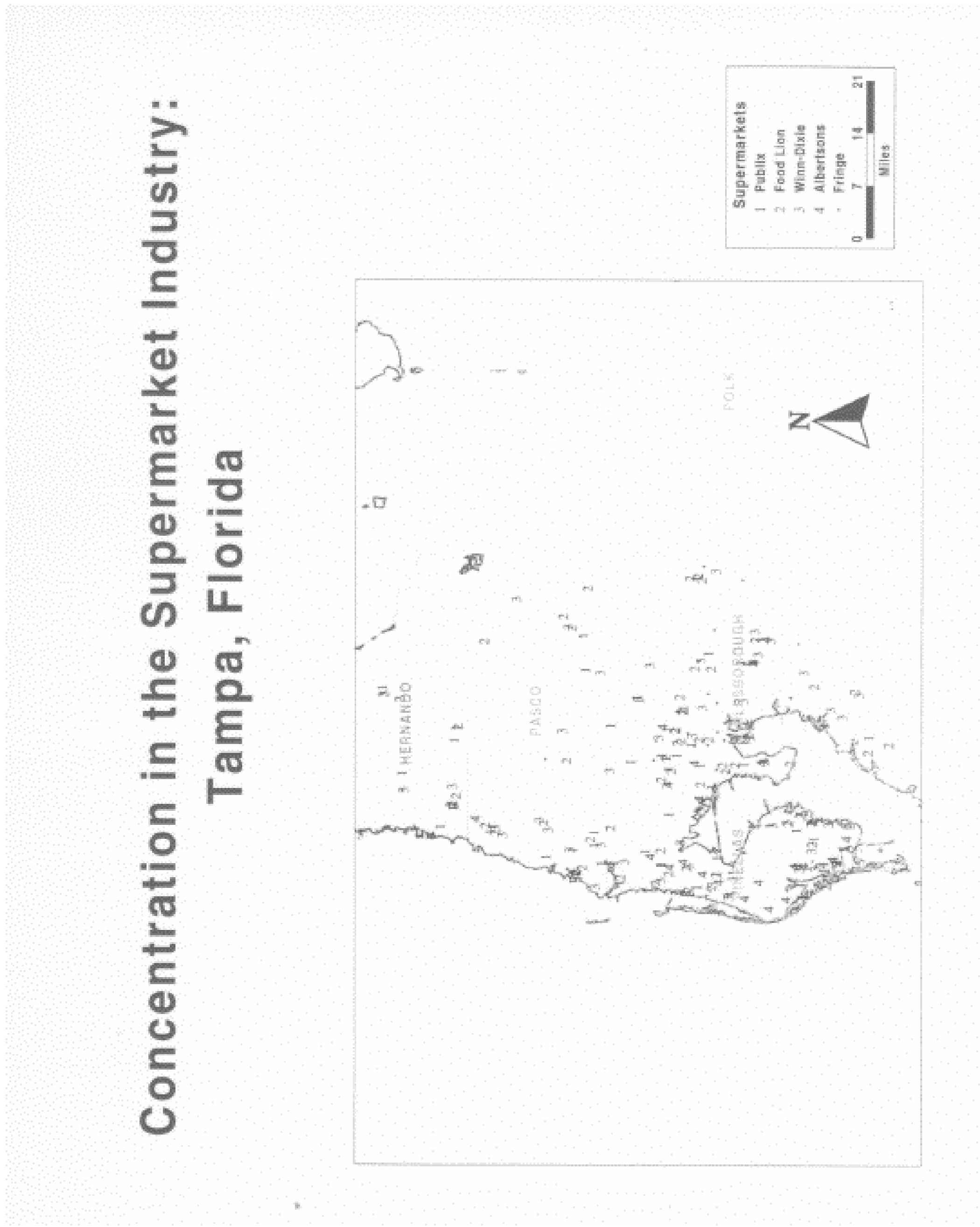

Figure 20: Map of Tampa, Florida

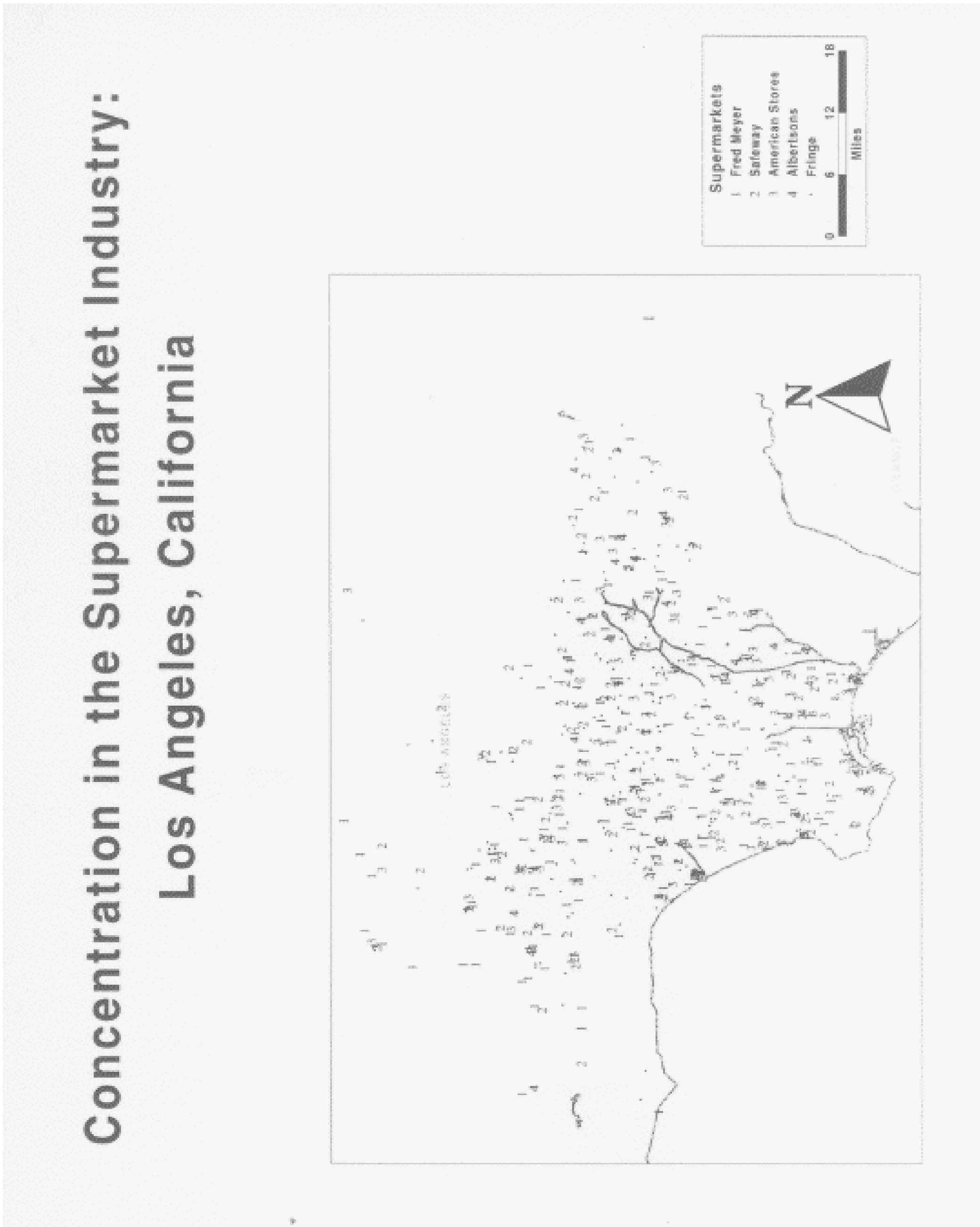

Figure 21: Map of Los Angeles, California

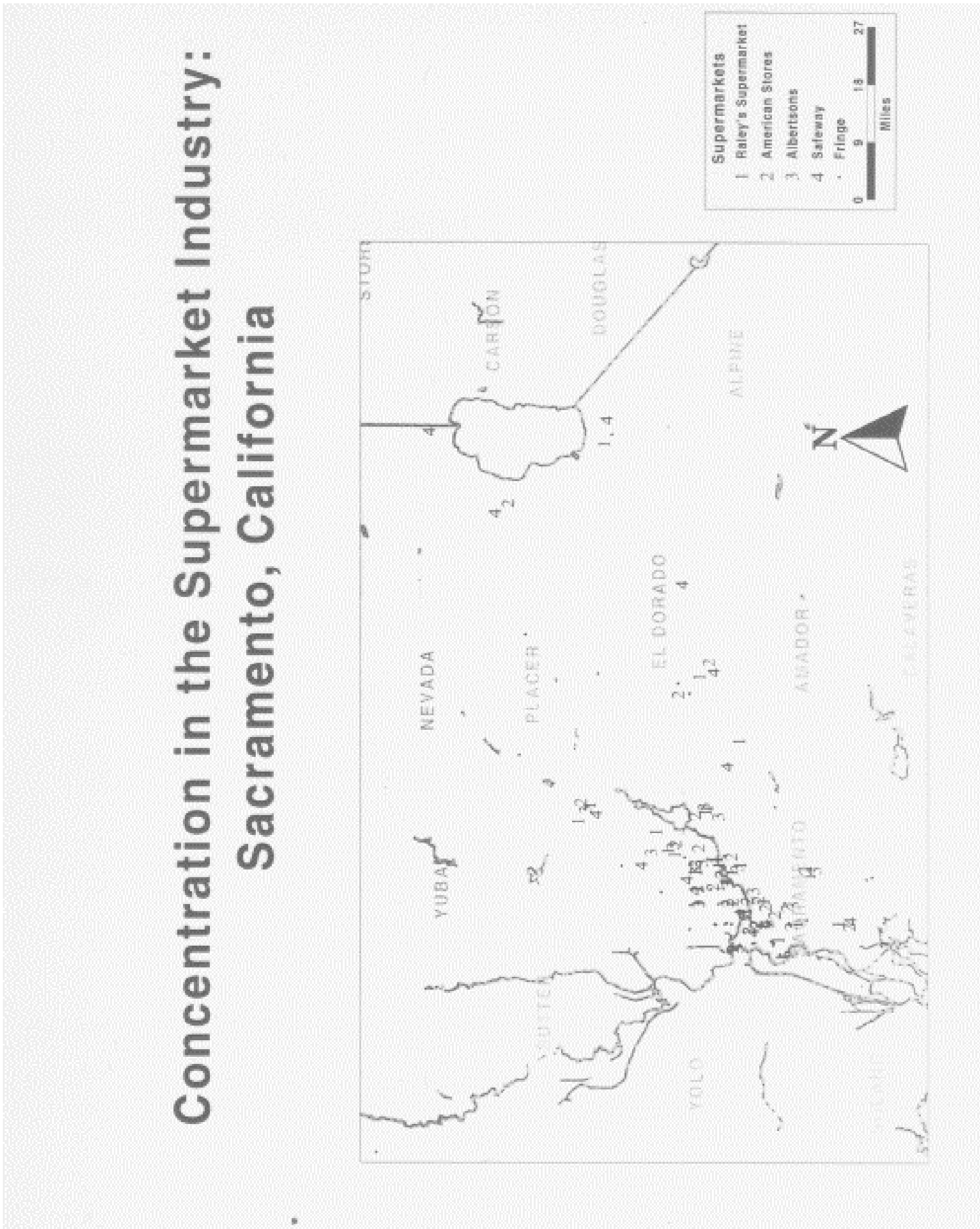

Figure 22: Map of Sacramento, California

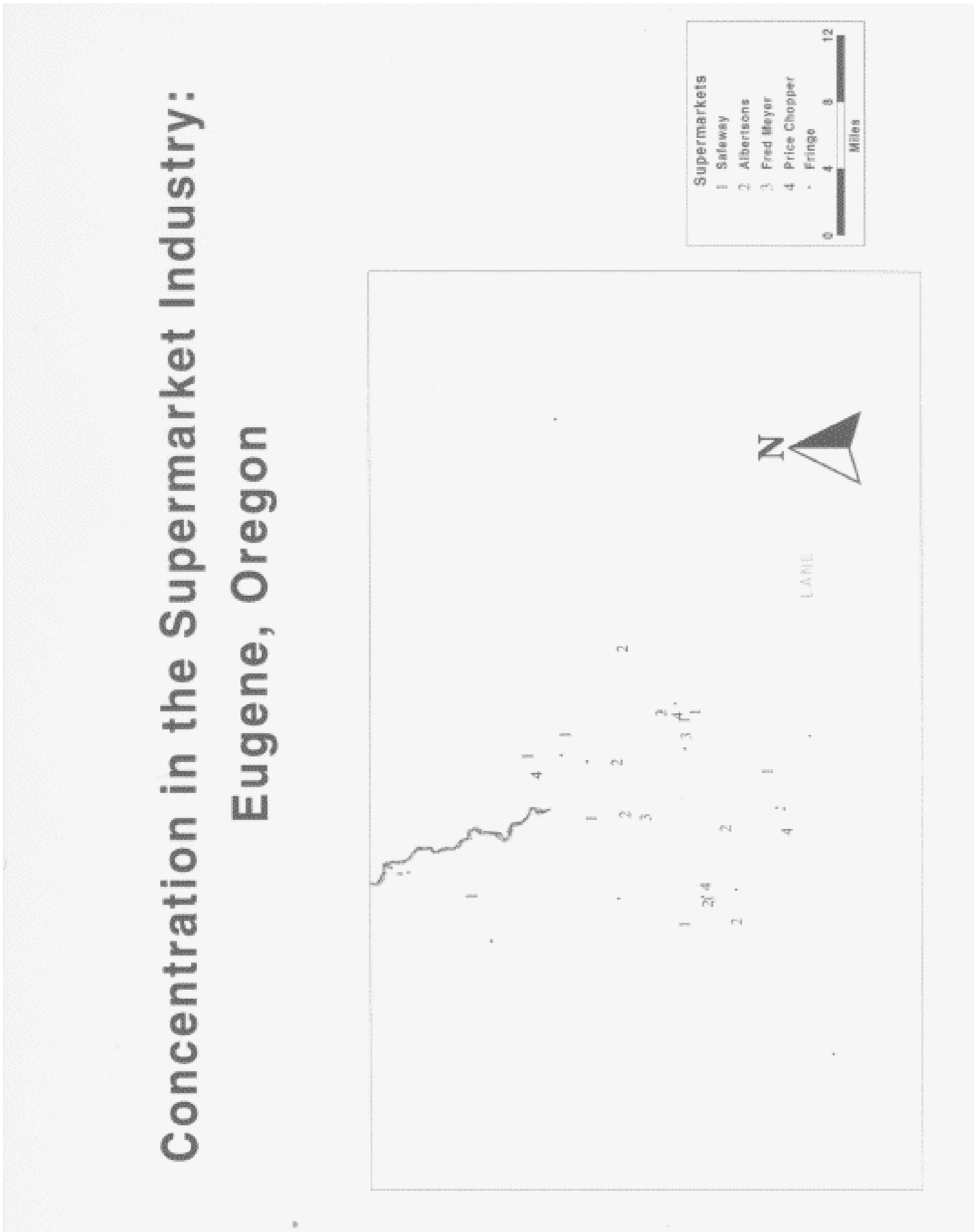

Figure 23: Map of Eugene, Oregon