Quality Competition in Retailing
A Structural Analysis*

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September 19, 2005

Abstract

This paper presents empirical evidence that endogenous fixed costs play a central role in determining the equilibrium structure of the retail food industry. Using the framework developed in Sutton (1991), I construct a structural model of retail competition in which escalating investment in firm level distribution systems yields a natural oligopoly of high quality supermarkets, while a low quality fringe of grocery stores serves consumers who do not value quality. Using a full census of the retail food industry to evaluate the model, I construct a structural prediction for the limiting number of supermarket firms and identify the quality escalation mechanism that sustains this oligopoly. Apart from the specific setting analyzed here, this model can help explain why certain retail industries remain highly concentrated as markets grow, while others quickly fragment.

Keywords: endogenous sunk costs, vertical product differentiation, oligopoly, retail, submarket, stochastic growth.
JEL Nos: L13, L22, L81

*I would like to express my gratitude to the editor, Patrick Bajari, and an anonymous associate editor for their extremely helpful comments. I also thank Arie Beresteanu, Bryan Ellickson, and Christopher Timmins for many useful suggestions. All remaining errors and omissions are my own.

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1 Introduction

In many retail industries, the most successful firms are the ones that offer the widest selection. For example, Wal-Mart rose to the top of the Fortune 500 by offering consumers a vast array of products at very competitive prices. The emphasis on product variety is particularly strong in the supermarket industry, where the introduction of computerized logistical and inventory management systems in the 1980s allowed firms to stock an ever expanding array of products. The explosion in both product variety and store size in the supermarket industry is striking. According to the Food Marketing Institute, the number of products offered per store increased from about 14,000 in 1980 to over 30,000 by 2004. To accommodate the greater selection, store size has increased an average of 1,000 square feet per year for the past three decades. Maintaining this variety requires substantial firm level investments. Every major supermarket firm invests in proprietary information technology and logistical systems aimed at increasing variety while minimizing storage and transportation costs. The emphasis on variety and the requisite fixed investments yield tightly contested markets among a handful of rival chains, a pattern that is repeated throughout much of retail.

This is the second of two complementary papers that explain the industrial structure of the supermarket industry using an endogenous fixed cost (EFC) model of vertical product differentiation (VPD). The unifying theme of both papers is that escalating investments in variety enhancing distribution systems yield a natural oligopoly of high quality firms. The explanation for why we observe a natural oligopoly among supermarkets is based on Shaked and Sutton's (1987) claim that "entry in certain industries is limited to a small number of firms, not because fixed costs are so high relative to the size of the market, but rather because the possibility exists, primarily through incurring additional fixed costs, of shifting the technological frontier constantly forward towards more sophisticated products." The tendency for larger markets to have better products instead of more firms reflects the dominance of vertical over horizontal differentiation; failure to match a rival's quality carries a severe penalty.

To establish the relevance of the EFC mechanism to the market for groceries, my earlier paper adapted Sutton's (1991) model of advertising to account for some specific features of supermarket competition. In my version of Sutton's model, supermarkets compete for customers by offering a greater variety of products in every store, requiring a fixed investment in distribution. Serving a larger share of the market requires building more stores. Expanding variety requires building larger stores and more advanced distribution systems. Because variety is a purely vertical form of product differentiation, firms that fail to match the quality increases of their rivals cannot survive. Therefore, as markets grow, existing firms must incur higher costs if they are to remain in the industry, and this escalation in costs discourages entry by additional firms. Consequently, markets both large and small are served by roughly the same small number of high quality chains.

As I demonstrate in Ellickson (2002), this simple model does not match what is observed in the data exactly: larger markets do have more firms. However, the expansion of firms is limited to a fringe of low quality stores that do not vertically integrate into distribution. In particular, there are two distinct tiers of firms in the food industry, supermarkets and grocery stores, but only one (supermarkets) is subject to endogenous investment. The current paper extends my earlier analysis by proposing and estimating a structural model of retailing in which each firm serves only one of these two submarkets, operating either supermarkets or grocery stores.

This framework easily generalizes beyond the specific setting analyzed here. In particular, several retail industries such as book stores, video rental outlets, and pharmacies feature two distinct tiers of firms: large regional (or national) chains and local "mom and pop" stores. While the dominant chains build large stores (or exploit the advantages of the internet), stock a vast array of products, and invest heavily in distribution and advertising, firms in the fringe offer a narrower, more specialized selection and build smaller stores that require little or no investment in distribution or advertising. The central claim of this paper is that retail industries can be viewed as containing two distinct submarkets, only one of which (the chain store segment) is subject to endogenous investment. Moreover, the equilibrium market structures that characterize these two submarket are polar opposites: one fragments while the other remains concentrated indefinitely. By estimating a structural model of competition, I am able to test these implications directly.

The main empirical challenge to applying the EFC model to any two-tiered retail industry lies in determining which firms belong in each tier. While it is clearly possible to rely on trade publications or personal judgment, a formal model that can be applied to several settings is clearly preferred. Therefore, to distinguish the submarkets, I propose a formal mechanism for predicting the size of the fringe, based on Sutton's (1998) stochastic growth model for firms that do not invest in endogenous fixed costs. Having identified these two submarkets, I empirically estimate a structural model for each industry, using a full census of both supermarkets and grocery stores. Consistent with the implications of the EFC framework, I find that the number of grocery firms expands with the size of the market, while the supermarket industry is served by an oligopoly whose size is largely independent of market size. I also find that supermarket quality expands with the market, validating the mechanism that sustains this supermarket oligopoly.

This paper contributes to a growing literature that applies Sutton's framework to retail competition. While my earlier paper was the first study to use an EFC model to explain the structure of a retail industry, subsequent authors have adopted a similar approach in a number of settings. In particular, Dick (2003) applies the EFC framework to the banking industry, Berry and Waldfogel (2003) to the newspaper and restaurant industries, and Latcovich and Smith (2001) to the market for online books. However, this is the first paper to propose a structural model of EFC competition and directly estimate the parameters governing the asymptotic number of firms. It is also the first study to directly establish the quality escalation mechanism that sustains this natural oligopoly. In addition, I provide empirical evidence that supermarkets do not differentiate themselves spatially, reflecting the primacy of the vertical dimension in driving market structure.

This paper also contributes to a smaller literature focusing specifically on supermarket competition. Most closely related to my analysis is the work of Smith (2005a&b), who analyzes supermarket competition in the United Kingdom using a differentiated products discrete choice framework. While his focus is mainly on demand estimation and the impact of potential mergers, he also finds that the U.K. market is split between the "top 5" chains and a fringe of "high street emporiums" who build much smaller stores. Consistent with what I will argue here, he finds that consumers who switch from a top 5 firm are most likely to switch to another top 5 firm rather than a firm in the fringe, and that the characteristic that most influences their decision over where to shop is the size of the store.

The paper is organized as follows. Section 2 presents a brief description of the retail food industry, highlighting the role of distribution networks in defining local markets. Section 3 contains a theoretical model that adapts the EFC framework to the retail food industry, providing a structural model of equilibrium quality choice in two distinct submarkets. Section 4 documents the existence of the two submarkets, and proposes a formal mechanism for distinguishing them. Using the two sets of firms, the structural model of competition is estimated in section 5 using a market level census. Section 6 addresses the role of spatial differentiation and section 7 concludes.

2 Competition in the Retail Food Industry

The retail food industry is composed of two relatively distinct submarkets: supermarkets and grocery stores. Although chain grocery stores date back to the early 1900s, the supermarket format was not introduced until the 1950s, when the rise of nationally branded products and the diffusion of the automobile created a natural incentive to build larger, less centrally located stores. Situated in the suburbs to economize on land costs, supermarkets were 5 times larger than their rival grocery stores, carried far more products, and advertised heavily (Tedlow, 1990). Distinguished by the variety of products they carried, supermarkets and grocery stores were vertically differentiated: if they charged the same prices, consumers would choose the store with a wider selection. While supermarkets quickly captured the bulk of sales, grocery firms maintained a foothold by serving the remote locations and niche consumer markets that the supermarket firms ignored.

By the 1980s, supermarket firms realized that maximizing product variety meant building their own distribution networks. While grocery firms were mostly supplied by independent wholesalers, supermarket firms vertically integrated into distribution. The computerized logistical and inventory management systems introduced by mass-merchandisers like Wal-Mart required a degree of coordination, both in terms of scheduling and technology adoption, that was difficult to achieve through an arm's length contract. For example, even getting independent grocers to implement a standardized scanner system proved to be a major hurdle for third party wholesalers (Schiano, 1996). By 1998, 49 of the top 50 supermarket firms were vertically integrated into distribution, operating state of the art, climate controlled warehouses and specialized trucking fleets. The savings from integration are significant: according to a 1997 report by the Food Marketing Institute (FMI), operating costs are 25 to 60 percent lower for self-distributing chains. Although grocery firms (and third-party wholesalers) continue to capture around 25% of overall food sales, they do not compete directly with the dominant supermarket chains, focusing instead on smaller niches like ethnic foods and rural towns. Consistent with the EFC framework, they continue to carry less than half the products of supermarkets.

Apart from variety, there are clearly other dimensions of quality along which food stores compete, such as offering deli bars, fresh produce, and shorter check-out lines. As I will demonstrate later, the firms with the widest selection tend to dominate in these areas as well. An obvious exception are gourmet chains like Whole Foods that operate small stores and emphasize organic products. However, "quality" in the EFC framework is an attribute that 1) increases the willingness to pay of all consumers and 2) is increased primarily through fixed rather than marginal costs. These conditions apply quite cleanly to product variety: consumers should always prefer more choices to less and the costs associated with increasing store size and expanding logistical systems are mostly fixed. Gourmet "quality" is quite different. Tailoring products to high-end consumers involves marginal investments such as hiring more clerks and stocking more expensive products. Furthermore, consumers do not universally prefer organic produce, specialty cheeses, or free-range chicken. Consequently, the high end gourmet stores are more appropriately treated as part of the fringe, which is not subject to endogenous investments.

The central theme of this paper is that supermarkets compete in a natural oligopoly, sustained by competitive investment in quality enhancing distribution systems. It is these fixed costs, rather than the number of firms, that increase with the scale of the market. Instead of having more firms, larger markets have stores with greater variety. Testing these predictions empirically requires identifying a set of reasonably independent markets that vary in size. Fortunately, the fixed costs most relevant to supermarket competition, namely investments in distribution and store size, are relatively localized geographically. By exploiting the physical constraints of distribution systems, we can construct a reasonable number of relatively independent submarkets. This is the method employed by Trade Dimensions, the leading commercial data source for the supermarket industry, in constructing the 52 distribution areas reported in their *Marketing Guidebook*. My own analysis produced only modest changes, yielding the same total number of markets.[1]

Due to the historical importance of rail transport and the short distances over which perishable goods can be shipped, supermarket distribution areas are relatively distinct and well defined. Most firms cluster their warehouses in 50 major cities (near a rail head) and serve surrounding markets via overlapping hub and spoke networks. For example, all of the major Southern California supermarket chains operate warehouses in East Los Angeles, serving markets as far away as San Diego and Las Vegas from the same cluster of facilities. The appropriate market definition is clearly larger than a Metropolitan Statistical Area (MSA): the top four Southern California firms serve stores in the San Diego, Riverside, Ventura, and Orange County MSAs from their East L.A. distribution centers. It is also smaller than a state or region. Although the largest chains operate hundreds of stores in multiple markets, there are a significant number of strong local chains, many operating in only a single distribution area. While there is clearly some cost sharing that occurs across markets, the existence of several successful chains in the 50 to 150 store range makes it highly unlikely that the returns to scale extend beyond a single distribution area.[2] In particular, the firm that *Consumer Reports* ranked second best in the U.S. in 2002 (Wegman's), supports all 68 of its upstate New York stores from a single distribution center in Rochester. While there are certainly larger chains, if the efficient scale for a chain extended beyond the distribution market or was truly national, most chains would operate 500 or more stores. This is not the case. Instead, within each distribution area, firms make strategic investments in distribution and store size that allow them to stock the widest array of products at the lowest possible prices. The following model is motivated by the importance of these investments.

3 A Vertical Model of Retailing

This section extends the endogenous fixed cost (EFC) model of supermarket competition proposed in Ellickson (2002) to include two distinct submarkets (supermarkets and grocery stores) which differ in the types of consumer they target. While supermarkets provide a wide variety of products to consumers who value breadth, grocery stores target a distinct subset of consumers who shop purely on the basis

[1] A detailed description of these 52 markets is provided in Ellickson (2002) and a map is included in a separate (online) appendix.

[2] The median supermarket chain operates fewer stores (62) than would fit into the smallest distribution areas. However, two-thirds of the 331 MSAs hold 60 or fewer stores. See Elickson (2002) for additional empirical evidence concerning the size distribution of firms and markets.

of price. In this framework, based on Sutton (1991), supermarket firms compete for a distinct segment (θ) of the population (that values variety) by offering more products in every store. As market size expands, supermarket firms choose higher levels of variety (quality) and their escalating investment in endogenous fixed costs makes further entry into the market unprofitable, yielding a natural oligopoly in the supermarket segment. Grocery stores, on the other hand, do not invest in variety, but instead target the remaining fraction $(1-\theta)$ of consumers who care only about price. Since fixed costs in the grocery segment are determined exogenously, the number of grocery firms expands monotonically with the size of the market.[3]

In deriving the comparative statics of the theoretical model, I follow Sutton (1991) in treating these two submarkets as fully independent.[4] This is a natural assumption for supermarkets, which compete mostly amongst themselves. However, grocery stores clearly need to differentiate themselves horizontally to remain profitable. Unfortunately, models with both vertical and horizontal differentiation are notoriously complex. Since the primary focus of this paper is competition among supermarkets, I will maintain the assumptions of independent submarkets and purely vertical differentiation throughout the analysis.

3.1 Utility Framework

Competition in both submarkets can be described using the same basic utility framework, with the supermarket case nesting the grocery subcase. Since the focus of this paper is chain level competition between retailers, both supermarket and grocery firms are assumed to produce a single, purely vertically differentiated product: a chain of stores. Within each geographic market, firms differ only in their level of quality z, which represents the brandwidth or variety provided in each of their stores. All stores owned by a given firm provide the same level of quality, with grocery stores supplying the minimum. I assume that $z \geq 1$, with $z = 1$ representing the minimum level of quality, and that higher quality, prices held fixed, appeals to all consumers in the supermarket segment. There are M identical consumers with income Y and utility

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

where x_1 is the quantity of the composite commodity and x_2 is the quantity of groceries with quality

[3] The model is easily modified to one in which consumers have the same preferences, but allocate a portion (θ) of their food purchases to supermarkets and the remaining fraction $(1-\theta)$ to grocery stores. Such shopping behavior is widely noted in both the academic marketing literature and the industry's trade journals.

[4] In particular, Sutton (1991, pp. 64-66) establishes that there exists a critical market size, beyond which the market will endogenously split into two distinct groups of firms, with consumers strictly self selecting by type. For market sizes between the point at which some firms begin to invest in quality and the two submarkets become independent, the price charged by the high quality firms (supermarkets) will be constrained by the low quality firms (grocery stores), and the only equilibria may involve the use of mixed strategies. In the empirical exercises presented below, I will assume that we observe markets that are strictly larger than this critical value.

z. Let x_1 be numeraire and $p(z)$ denote the price of groceries.

3.2 Competition Among Supermarkets

Supermarkets serve the fraction θ of the M consumers who value quality. A firm producing quantity q_j of quality z_j has cost function

$$C_j = p_L \sigma_s + \frac{p_L}{\gamma}(z_j^\gamma - 1) + c q_j \tag{2}$$

where p_L is the price of land and c is marginal cost. The parameter σ_s is strictly positive and $\gamma > 1$. Marginal cost (c) is given by

$$c = \phi_1 w + \phi_2 p_g + \phi_3 p_L \tag{3}$$

where the parameters $\phi_i > 0$, w is the wage, and p_g is the cost of goods sold. Applying Shephard's Lemma to the cost function, the demand for land by a firm producing quantity q_j of quality z_j is

$$h_L = \sigma_s + \frac{1}{\gamma}(z_j^\gamma - 1) + \phi_3 q_j \tag{4}$$

Holding quality z_j fixed, the demand for land increases linearly in q_j since serving additional consumers requires building more stores. However, as the firm improves quality, fixed costs escalate and the demand for land increases as the size (rather than the number) of stores expands. As shown below in equation (6), equilibrium quality z depends inversely on the price of land, so high land prices can dampen quality improvement if the required expansion of store size is too expensive.

Competition is modeled as a three-stage game. In the first stage, firm j chooses whether or not to enter the market, incurring entry cost $p_L \sigma_s$. In the second stage, each firm chooses a level of quality z_j, incurring the additional fixed cost $\frac{p_L}{\gamma}(z_j^\gamma - 1)$. In the third and final stage, firms compete in the product market, which is modeled as Cournot. Following Sutton, I assume that the parameter γ is large enough to guarantee a symmetric equilibrium in both quantity and quality.[5] Solving the game by backwards induction yields equilibrium quantity and price

$$q = \left(\frac{N_s - 1}{N_s^2}\right)\frac{S_s}{c} \quad \& \quad p(z) = \left(\frac{N_s}{N_s - 1}\right) c \tag{5}$$

and equilibrium quality

$$z = \left(\frac{2S_s(N_s - 1)^2}{N_s^3 p_L}\right)^{\frac{1}{\gamma}} \tag{6}$$

where $S_s \equiv \alpha\theta Y M$ is the size of the market (total supermarket revenue) and N_s is the number of supermarket firms who have entered at stage one. Equation (6) demonstrates that quality will expand with market size, although the increase can be constrained by the price of land. Nonetheless, as shown in

[5] In this version of his model, Sutton's condition for a symmetric equilibrium becomes $\gamma > \max\left\{1, \frac{2}{3}\frac{p_L}{\sigma_s}\right\}$.

equation (2), fixed costs clearly expand with market size, both through land prices and the equilibrium level of quality.

Since fixed costs grow as market size (S_s) increases, it is not surprising to find an equilibrium where the number of firms does not expand with the market. In particular, since entry in the first stage will drive profits to zero, ignoring integer constraints on the number of firms, the zero-profit condition is then given by

$$\left(\frac{p_L - \gamma p_L \sigma_s}{S_s}\right) N_s^3 - 2N_s^2 + (4+\gamma)N_s - 2 = 0 \tag{7}$$

The fact that the number of firms does not increase indefinitely as market size increases follows immediately from equation (7). In the limit, as market size S_s goes to infinity, the lead term drops out, leaving a quadratic polynomial with root

$$N_s^{\infty} = 1 + \frac{\gamma}{4} + \frac{1}{4}\sqrt{8\gamma + \gamma^2} \tag{8}$$

which depends only on γ and is finite for all finite γ.[6] Since the maximum number of entrants is finite, this equilibrium is referred to as a *natural oligopoly* (Shaked and Sutton, 1983) and N_s^{∞} is the asymptotic number of firms characterizing this *non-fragmentation* result. By estimating equation (6) and recovering γ, I will construct a prediction for the maximal number of firms from (8) that closely matches what is observed in the data and verify the escalation mechanism that sustains this equilibrium.

3.3 Competition Among Grocery Stores

Recall that grocery stores serve the remaining fraction $(1-\theta)$ of the M consumers who do not value quality, providing grocery services of quality $z \equiv 1$ at price $p(1)$. Applying the same functional form for costs (2) as above, at the minimal level of quality ($z_j = 1$), the middle term of the cost function drops out, leaving

$$C_j = p_L \sigma_g + c q_j$$

where $p_L \sigma_g$ represents the fixed cost of entry into the grocery business. Assuming entry will occur until profits are driven to zero, and ignoring the integer constraint on the number of firms, the equilibrium number of entrants to the grocery submarket is

$$N_g = \sqrt{\frac{\alpha\,(1-\theta)\,YM}{p_L \sigma_g}} \tag{9}$$

which increases monotonically with market size. This prediction will be empirically verified in section 5, along with the stronger natural oligopoly result for supermarkets. However, before proceeding to

[6] The second root of equation (8) is always less than 1. For finite values of S_s, the solution to the zero profit condition (7) depends on the sign of the lead term. In particular, whether the equilibrium number of entrants approaches the limit from above or below depends on whether $1 - \gamma\sigma_s$ is positive or negative. See Ellickson (2002) for a more detailed discussion of these comparative statics.

these empirical exercises, I must first identify the firms that serve each submarket and the fraction θ of consumers who value quality. Since firms do not self-identify as either supermarkets or grocery stores, I propose a formal method for distinguishing the submarket in which each firm actually competes.

4 Distinguishing the Submarkets

The data for the retail food industry are drawn from Trade Dimension's Retail Tenant Database for September 1999. Trade Dimensions collects store level data from every retail food store operating 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 are also sold to marketing firms and food manufacturers for marketing purposes. Information on average weekly volume, store size, number of checkouts, physical location, and overall store format (e.g. supercenter, warehouse, limited assortment) is gathered through quarterly surveys sent to store managers. These surveys are then compared with similar surveys given to the principal food broker assigned to each store, which are then verified through repeated phone calls.

The two tiered structure of the food industry is easily illustrated using the empirical distribution of market shares across all 52 distribution markets. In particular, I constructed Lorenz curves for each market by first ranking firms according to market share and then plotting the cumulative share of sales against the cumulative share of firms. The first three panels of Figure 1 contain Lorenz curves for three individual markets: Spokane (WA), Denver (CO), and Baltimore/Washington (MD/DC). Although the markets contain roughly 1.3, 4.7, and 9.8 million people respectively, the size distribution of firms is remarkably similar across the three. In each market, 5 or 6 firms account for the majority of sales. The remainder is split among a fringe of very small firms. The main difference between these markets is the size of this fringe, which clearly expands with the market. The lower right panel of Figure 1 contains Lorenz curves for the full set of markets. The pattern is remarkably similar across all of the markets: 4 to 6 firms capture the majority of sales, while the residual is spread across an expanding fringe of much smaller firms. Furthermore, as documented in Ellickson (2002) and repeated below in Table 1, the top firms in each market operate significantly larger and higher quality stores than the firms in the fringe, consistent with the existence of two submarkets distinguished by quality.

Estimating the theoretical model of retail competition requires splitting the firms by type. While one simple option is to split the firms according to whether they are vertically integrated into distribution, this has several significant drawbacks. First, firms that are in the process of constructing a distribution facility will be incorrectly classified as belonging to the grocery submarket. Second, there are a few large firms that have formed alliances with suppliers that appear to replicate the advantages of vertical

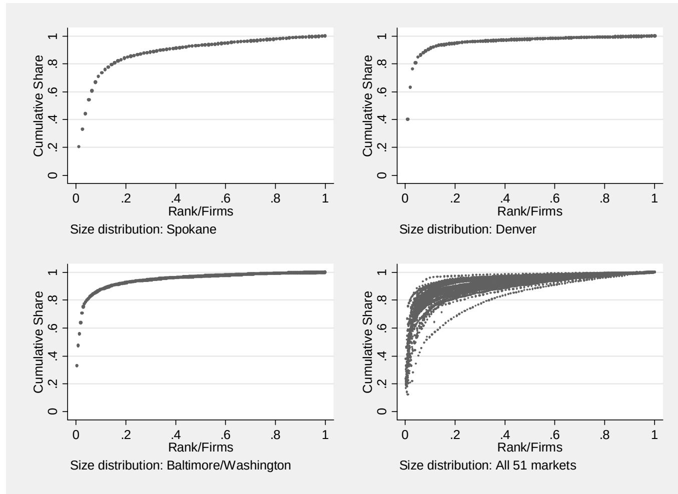

Figure 1: Lorenz Curves (Size Distribution of Firms)

integration. To the extent that these firms have made joint investments, they should be classified as supermarkets. Finally, there are several examples of small chains of limited assortment and club stores that *do* operate their own distribution facilities, but *do not* operate stores that compete substantially with full line supermarkets (e.g. Trader Joe's, Aldi, and Sam's Club). Since the number of supermarket firms is likely to be quite small (on the order of 2 to 5 per market), incorrectly classifying these firms as supermarkets could have a substantial impact on the overall count. Therefore, although the integration distinction is useful as a robustness check, I instead introduce a procedure for distinguishing the submarkets that applies Sutton's (1998) stochastic growth model to the firms in the fringe.

Sutton (1998) proposes a model for the size distribution of firms in an industry that is *not* subject to endogenous fixed costs. In this framework, based on Simon's stochastic growth model (Simon, 1955; Simon and Bonnini, 1958; Gibrat, 1931), a discrete set of independent investment opportunities (locations) becomes available to firms over time.[7] Each location is filled by exactly one firm. Firm size is then measured by the number of locations served by firm i at time t. To characterize the distribution of firm sizes, we must first quantify the advantage of being an incumbent firm and specify how often new entry occurs. Since Sutton's goal is to characterize the *least* skewed distribution, he imposes the following conditions:

- **Condition 1:** The probability that the next location is filled by an active firm is independent of firm size.

[7] The connection between retail competition and Sutton's stylized model is suprisingly clean: the total number of food stores (both supermarkets and grocery stores) increases linearly with population at a rate of about 1 store per 11,000 people. Thus, a new store location (i.e. suburb) can be viewed as a discrete investment opportunity.

- **Condition 2:** The probability (π) that the next location is filled by an entrant is constant over time.

Condition 1 imposes an equal treatment property on the active firms: existing firms have an equal chance of capturing new opportunities. Condition 2 forces entry conditions to be constant over time. Provided that conditions 1 and 2 are satisfied, the size distribution of active firms tends to a geometric distribution with parameter π, which can be approximated (treating the size of the firm as a continuous variable) by an exponential distribution with parameter π. This distribution can then be used to determine the relationship between the number of firms in the market and the k-firm concentration ratio C_k (the sales of the k largest firms divided by the sales of the full set of firms).

In particular, if N_g is the total number of grocery firms, C_k tends toward:

$$\frac{k}{N_g} \cdot \left(1 - \ln\left(\frac{k}{N_g}\right)\right) \tag{10}$$

which is independent of the probability π but depends on the number of entrants. This yields a Lorenz curve which is bowed well above the diagonal, but well below the curve originally proposed by Simon. When the full set of both supermarket and grocery firms is analyzed, the empirical Lorenz curves are bowed far away from the predicted bound (see the top left panel of Figure 2), suggesting that Condition 1 does not hold for the full set of firms. In particular, Condition 1 implies the absence of scale economies, or more precisely, the absence of scale economies that impact different firms differently. This is clearly violated when one set of firms operate distribution networks while the other does not. However, the goal here is not to characterize the distribution of all firms, but rather to predict the size distribution of *grocery firms alone*. Because these firms do not invest in distribution or advertising, and since the third party wholesale channel is available to everyone, the equal treatment condition seems appropriate for grocery firms. A similar argument applies to the independence assumption, since grocery firms are quite small on average relative to the market. Note that firms are free to grow over time. The model only requires that entry in this segment be constant over time and that all firms have an equal chance of growing, conditions that seem reasonable for grocery firms. With this in mind, the model yields a prediction for the share of the largest grocery firm in a market, conditional on the number of such firms that have entered. This limit provides a cutoff for dividing firms by type.

While equation (10) predicts the cumulative share of the top k grocery firms conditional on the number of firms that enter this market, I am interested only in the share of the largest firm. If the supermarket and grocery industries differ sharply in scale, the largest grocery firm should still be much smaller than even the smallest supermarket firm. Starting with the full set of firms of both types in each geographic market, I use equation (10) to predict the share of the largest grocery firm in each

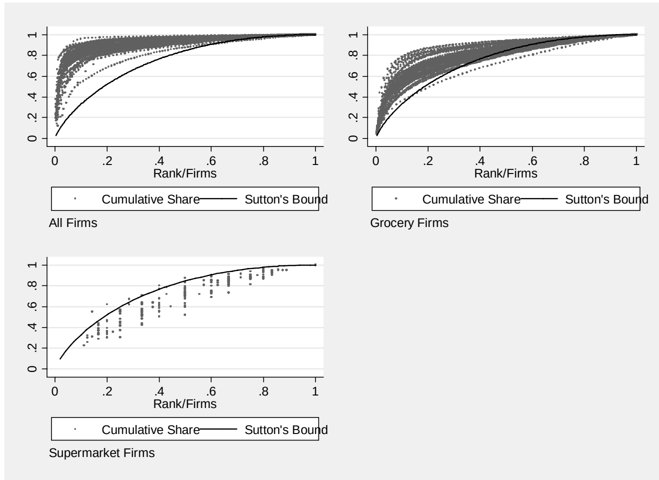

Figure 2: Distinguising the Submarkets

market (C_1). The firms whose shares are less than this cutoff provide my first estimate of N_g. I then repeat this process using the new estimate of N_g, iterating until the estimate no longer changes. I performed this procedure using two alternative measures of firm size, share of sales and share of stores, with similar results. I will focus on the share of sales method since it incorporates more information about the relative size of firms.

The top right and bottom left panels of Figure 2 contain Lorenz curves for the grocery and supermarket industries respectively, along with Sutton's bound (equation 10). As expected, the Lorenz curves for grocery firms lie much closer to the predicted bound, but mostly above it as Sutton's model predicts. The Lorenz curves for supermarket firms violate the bound in all but one market. Again, this should not be surprising since Sutton assumes that opportunities within a market are independent, which is clearly not the case for supermarkets. More importantly, the figure illustrates the relatively high degree of symmetry among supermarket firms. In the majority of the markets, the empirical distribution lies much closer to the 45 degree line than Sutton's bound, providing some empirical justification for the symmetric equilibrium emphasized in the vertical model of supermarket competition.

Characteristics for the two submarkets are presented in Table 1, along with corresponding statistics for two alternative methods of dividing the firms. The overall dataset includes 7,781 firm/market level observations. As a robustness check, I first divide the dataset based on whether each firm is among the top 6 competitors in each of the 52 distribution markets. Focusing on the first two columns, we see that the top 6 firms build stores that are twice the size of firms in the fringe. They also offer significantly higher levels of several additional dimensions of quality.[8] Furthermore, the top 6 firms operate a far greater number of stores, serve a much larger fraction of each market, and are far more likely to be vertically integrated into distribution. The next two columns split the firms on the basis of vertical integration. That method identifies 558 "dominant" firms and 7223 "fringe" firms. The store and firm characteristics resemble the differences found for the top 6 division, although the differences between the tiers are not as large. Dividing using the Sutton-based method yields 247 (96 unique) supermarkets and 7534 grocery firms. Their characteristics, contained in the last two columns of Table 1, are much closer to those found for the top 6 division than the VI division. However, 83% of these firm/market level observations are vertically integrated, 7% more than in the top 6 division. Since the Sutton growth model approach is more theoretically grounded than the VI division and appears to produce a more reasonable set of firms, I will focus on this method in the empirical results that follow.

Table 1: Store Characteristics by Firm Type

	Firm Type					
Characteristic	Top 6	Fringe	VI	Not VI	Supermarket	Grocery
Size	39.1	16.5	32.2	16.3	39.0	16.7
	(13.5)	(10.1)	(15.6)	(9.84)	(11.7)	(10.4)
Checkouts	12.6	5.69	10.5	5.62	12.3	5.76
	(6.53)	(3.21)	(6.42)	(3.09)	(5.88)	(3.38)
Features	2.51	1.57	2.12	1.57	2.52	1.58
	(.76)	(.97)	(1.06)	(.96)	(.70)	(.97)
Technology	1.59	1.15	1.37	1.15	1.58	1.15
	(.32)	(.68)	(.53)	(.68)	(.30)	(.68)
Stores	52.6	1.88	31.3	1.77	63.3	1.94
	(55.5)	(3.47)	(47.6)	(3.82)	(57.6)	(3.65)
Market Share	.118	.002	.064	.002	.138	.002
	(.101)	(.004)	(.094)	(.007)	(.104)	(.006)
% VI	.760	.043	1	0	.830	.047
	(.424)	(.202)			(.376)	(.211)
Observations	312	7469	558	7223	247	7534

Standard Deviations in parentheses.

5 Natural Oligopoly with a Competitive Fringe

Having identified two distinct sets of firms, I am now in a position to evaluate the empirical implications of the structural model. Beginning with the grocery submarket, equation (9)

$$N_g = \sqrt{\frac{\alpha(1-\theta)YM}{p_L\sigma_g}}$$

[8] The optimal measure of quality would combine variety with store size, since providing brandwidth requires stocking more products and building larger stores (wide aisles and easily accessible products consistently rate highly in consumer surveys (Progressive Grocer)). Since Trade Dimensions does not record the number of products carried by each store, I use store size (in 1000s of square feet) alone as a proxy for variety. As a robustness check, I present three alternative measures of quality constructed from store characteristics: the number of checkouts (cash registers), the number of features present in a store (0-4 among an in-store bakery, restaurant, pharmacy, and deli) and a similar measure for scanning registers and ATM machines (technology).

provides the basis for an estimation equation governing the equilibrium number of entrants. Taking logs of both sides of this equation yields

$$\ln N_g = \frac{1}{2}\ln YM + \frac{1}{2}\ln(1-\theta) - \frac{1}{2}\ln p_L - \frac{1}{2}\ln\sigma_g + \frac{1}{2}\ln\alpha \tag{11}$$

where N_g is the total number of grocery firms, $(1-\theta)$ is the share of consumers that shop only at grocery stores, Y is individual income, M is the number of consumers (population size), p_L is the price of land, σ_g is the cost of constructing a single store, and α is the share of income spent on groceries. The results of the previous section yield measures of both N_g and $(1-\theta)$. The measure of N_g is taken directly from the results of the previous section, while $(1-\theta)$ is constructed from the ratio of total revenue in the grocery submarket to total revenue in both submarkets.[9] Population (M) is measured using total population and income (Y) is measured using average personal income, both taken from the 2000 Census. The price of land p_L is measured using average housing cost per bedroom (a proxy for land cost per square foot).[10] The parameters α and σ_g, which represent the share of income spent on groceries and set-up costs respectively, will be treated as unobservables, although region fixed effects will be used to mitigate any potential correlation with the included regressors. The results from several specifications are presented in Table 2.[11]

Table 2: Grocery Firm Regressions

	$\ln(N_g)$				
$\ln(YM)$	.505 (.075)	.519 (.061)	.647 (.052)	.782 (.074)	
$\ln(1-\theta)$				.592 (.133)	
$\ln(p_L)$			$-.591$ (.150)	$-.645$ (.148)	
$\ln\left(\frac{(1-\theta)YM}{p_L}\right)$					.778 (.086)
Constant	-7.74 (1.87)				
Region FE	No	Yes	Yes	Yes	Yes
Adj-R^2	.48	.59	.70	.80	.78
Observations	52	52	52	52	52

Robust Standard Errors in parentheses.

Column 1 contains a baseline regression that includes only market size (YM). The coefficient is almost exactly .5, the value implied by the theoretical model. Adding fixed effects for seven geographic

[9] Recall that total revenue is $\alpha(1-\theta)YM$ for grocery firms and $\alpha\theta YM$ for supermakets, yielding a combined total revenue of αYM. Since we observe the revenue of every firm in both submarkets, θ is trivial to construct.

[10] The ideal measure would clearly be the cost per square foot of land used for commercial purposes. Unfortunately, detailed data on these prices at the level of disaggregation required here is not available.

[11] I will use the same market definition for both supermarkets and grocery stores, even through grocery firms do not invest in distribution. Using a smaller market definition for grocery stores (e.g. MSAs) does not substantially alter the results.

regions increases the coefficient estimate slightly, although it is still indistinguishable from .5. Column 3 adds the price of land (p_L), leading to an increase in the coefficient on market size to a level that is significantly larger than .5. However, as the model predicts, the coefficients themselves are close in magnitude and opposite in sign. The fourth column introduces the share of consumers who shop at grocery stores $(1-\theta)$. The coefficient on $\ln(YM)$ increases again, but remains close in magnitude to the others. Finally, imposing equality of coefficients yields a single estimate close to the coefficient on $\ln(YM)$ in column 4, and significantly larger than .5. An estimate above .5 means that the number of entrants increases faster than predicted, suggesting that the conduct assumption (Cournot) is insufficiently collusive. Since each market can accommodate more entrants than predicted, margins must be falling at a slower rate than the Cournot assumption implies. This may reflect the omission of horizontal differentiation from the analysis, which would provide some additional insulation from competition. Nonetheless, this stylized model of competition seems to fit the data remarkably well. While a more complex model of the fringe might explain how these small grocery firms are able to survive in the presence of the dominant supermarket chains, the focus of this paper is on the supermarket industry.

Having established that the number of grocery firms indeed expands monotonically with the size of the market, I now turn to the central empirical exercise of the paper: establishing a natural oligopoly among supermarkets. Recall, from section 3, that the equilibrium choice of quality is determined by equation (6):

$$z = \left(\frac{2\alpha\theta YM(N_s-1)^2}{N_s^3 p_L}\right)^{\frac{1}{\gamma}}$$

where z is store level quality, Y is individual income, M is the number of consumers, α is the share of income spent on groceries, N_s is the number of firms (calculated using the mechanism above), and θ is the fraction of consumers who shop at supermarkets. The remaining parameters (γ and p_L) characterize the cost function

$$C_j = p_L\sigma_s + \frac{p_L}{\gamma}(z_j^\gamma - 1) + cq_j$$

where the parameter γ determines how quickly fixed costs increase with quality z. Equation (6) can be rewritten as

$$\ln z = \frac{1}{\gamma}\ln(YM) + \frac{1}{\gamma}\ln(\theta) + \frac{1}{\gamma}\ln\left(\frac{(N_s-1)^2}{N_s^3}\right) - \frac{1}{\gamma}\ln(p_L) + \frac{1}{\gamma}\ln(2\alpha) \tag{12}$$

or, by imposing the equality restriction on the parameter $\frac{1}{\gamma}$, as

$$\ln z = \frac{1}{\gamma}\ln\left(\frac{\theta YM(N_s-1)^2}{N_s^3 p_L}\right) + \frac{1}{\gamma}\ln(2\alpha) \tag{13}$$

As market size goes to infinity, the equilibrium number of firms is a function of γ alone, given by equation (8):

$$N_s^{\infty} = 1 + \frac{\gamma}{4} + \frac{1}{4}\sqrt{8\gamma + \gamma^2}$$

Therefore, an estimate of γ provides a structural prediction for the asymptotic number of firms.

The first step in estimating either equation (12) or (13) is selecting the relevant unit of analysis. Given that the theoretical model assumes that firms are symmetric and operate identical stores, it does not make sense to estimate it at the firm or store level since any heterogeneity that exists at these levels cannot be explained by the model. Therefore, the unit of analysis is taken to be a market. Quality (z) is measured using average store size across all of the supermarkets that operate in the market, yielding 52 market level observations. Population (M) and income (Y) are measured as before and p_L is again measured using average housing cost per bedroom. Since both equations (12) and (13) are linear in the parameters, estimation is straightforward. The only complication is that N_s is endogenous, determined by the stage 1 zero profit condition

$$\left(\frac{p_L - \gamma p_L \sigma_s}{\alpha \theta Y M}\right) N_s^3 - 2N_s^2 + (4+\gamma)N_s - 2 = 0$$

While both (12) and (13) can be estimated using OLS if we are willing to assume that the only disturbance is pure multiplicative measurement error, this is not a particularly attractive assumption. Instead, I will exploit the exclusion of σ_s from equation (13) and use proxies for σ_s as instruments for N_s, allowing the unobserved α to vary across markets. I propose two instruments for N_s: the total geographic size of the market in square miles and a measure of how clustered stores are within markets.[12] Clustering is measured as the average great circle distance (calculated using the Haversine formula) over all of the stores in each market from the market center, taken to be the centroid of the zip code where the majority of the distribution centers are located (or if the locations are more than a few miles apart, the central zip code of the central city).[13]

The results from an instrumental variables (IV) regression of the unrestricted model are presented in Table 3. The first column includes all variables except θ (the share of consumers who frequent supermarkets), while the second uses the full set of regressors. Both specifications include region fixed effects and are estimated via two-step efficient GMM. Focusing on column 2, the coefficients all have the expected signs and are insignificantly different in magnitude from each other, as the model predicts.

[12] Both instruments are proxies for σ_s, aimed at capturing market specific entry costs that do not vary with quality. A more clustered set of locations requires less costly deliveries (since driving distances are shorter), fewer trucks, and fewer full time drivers, which applies to stores of every size. Total area of the market measures geographic variation in the nature of clustering (e.g. several separate clusters as in most West Coast markets versus a single cluster as in many East Coast markets).

[13] Distribution center locations are unlikely to be endogenous since they are almost always located in a greater warehouse district alongside a railroad spur. However, using the central zip of the central city exclusively does not substantially alter the results. While store location are chosen endogenously by the firms, they are mainly driven by population density, which is exogenous. Again, the results do not change substantially if population clustering is used instead of store clustering.

The coefficient on $\ln\left[\frac{(N_s-1)^2}{N_s^3}\right]$ is larger in magnitude, but imprecisely estimated in both specifications.[14] However, every coefficient does have the expected sign, the estimates are relatively stable across both specifications, and the magnitudes of the precisely estimated coefficients are quite similar. As expected, land prices do constrain the size of stores, but not so much that quality remains fixed. For example, if market size were to double, as it does from the 25^{th} to 75^{th} percentile of our sample, average store size is expected to increase by about 4.7%. The resulting increase in land price would reduce the increase by 1.1% to about 3.6%. Evaluated at the average store size, this amounts to an increase of 1330 square feet, which is about 10% of the size of a typical grocery store. Larger markets do indeed have better products.

Table 3: Quality Regressions

	$\ln(Store\ Size)$	
$\ln(YM)$	.095 (.035)	.066 (.032)
$\ln(p_L)$	$-.106$ (.041)	$-.082$ (.040)
$\ln(\theta)$		.210 (.088)
$\ln\left[\frac{(N_s-1)^2}{N_s^3}\right]$	.345 (.278)	.443 (.268)
Region FE	Included	
J-Statistic	.89	.15
Observations	52	

Robust Standard Errors in parentheses.

The parameter estimates from the restricted model are presented in Table 4. Again, column 1 excludes the variable θ while column 2 includes it. The parameter $\frac{1}{\gamma}$ is estimated using two-step efficient GMM with region fixed effects. The Hansen J-statistic based test of over-identifying restrictions yields p-values of .32 and .71, respectively, consistent with instrument exogeneity. The F-statistics from the first stage (9.62 and 9.22, respectively) suggest a relatively high degree of strength. Both estimates of $\frac{1}{\gamma}$ are consistent with the coefficients on the first three regressors in Table 3, yielding estimates for γ of 8.26 and 9.61 respectively. Since γ governs how quickly costs expand with market size, these parameter estimates imply that quality is very costly to produce, explaining why there are relatively few entrants to the supermarket industry. Moreover, Sutton argues that large values of γ (well above 1) lead to symmetric equilibria even when entry is sequential (see pp. 66-69 of Sutton (1991)). This might explain why there are no regional monopolies in the supermarket industry, despite a wide range of entry conditions. It also suggests that local markets are likely to remain stable oligopolies, rather

[14] The magnitude and imprecision of the coefficient on $\ln\left[\frac{(N_s-1)^2}{N_s^3}\right]$ is likely due to a combination of the restrictiveness of the conduct assumption (Cournot) and possible mismeasurement of N_s.

than becoming increasingly monopolized by dominant firms.

The estimates of $\frac{1}{\gamma}$ also have a clear structural interpretation, yielding specific predictions for the asymptotic number of firms. Using equation (8)

$$N_s^\infty = 1 + \frac{\gamma}{4} + \frac{1}{4}\sqrt{8\gamma + \gamma^2}$$

the estimates of $\frac{1}{\gamma}$ from Table 4 can be used to estimate N_s^∞. The estimates of $\frac{1}{\gamma}$ from column's 1 and 2 yield predicted values for N_s^∞ of 5.96 and 6.71, respectively. Both estimates are consistent with the data presented in the Lorenz curves in section 4, where 4 to 6 firms capture the majority of sales in every market. Moreover, these results illustrate how quickly the limiting number of firms is reached. Although these 52 markets vary in size by more than an order of magnitude, they are all served by roughly the same number of firms.

This is the first paper to provide a structural test of Sutton's EFC framework and directly verify the quality escalation mechanism that drives natural oligopoly. Previous studies (including my own) have relied on reduced form bounds estimates to test the central prediction that markets do not fragment. This exercise can be repeated here as well. To provide a final robustness check, I compared these parameter estimates with a second estimation based on Sutton's (1991) bounds technique. His bounds estimator yields an estimate for γ of 9.09, near the midpoint of the two estimates presented here.[15] Therefore, two sharply different techniques yield the same conclusion: supermarkets are a natural oligopoly.

Table 4: Restricted Model

	$\ln(\textit{Store Size})$	
Restricted I $\left(\frac{1}{\gamma}\right)$	.121 (.050)	
Restricted II $\left(\frac{1}{\gamma}\right)$		.104 (.043)
Region FE	Included	
J-Statistic	.321	.133
Observations	52	

Robust Standard Errors in parentheses.

6 Robustness: How Important is Spatial Differentiation?

I have argued that the EFC framework provides a compelling model of natural oligopoly in the supermarket industry. Specifically, large regional markets are dominated by a small set of firms whose

[15] The details of the bounds estimation are provided in a separate online appendix available at http://www.econ.duke.edu/~paule/research.html.

quality expands with market size. I have also maintained the implicit assumption that the choice of spatial location is essentially non-strategic: vertical rather than horizontal differentiation drives market structure. Both arguments would be seriously undermined if, at a finer level of spatial disaggregation, supermarkets were local monopolists. Horizontal models suggest such a possibility. For example, in purely horizontal models that feature persistent concentration such as product-proliferation with sequential entry (e.g. Schmalensee (1978)), single firms (or several firms acting as a cartel) produce all the products along a continuous segment of product space, thereby softening competition.[16] Such behavior could explain the persistent concentration documented here. However, in horizontal models emphasizing price competition, firms typically isolate themselves to dampen its effect. In contrast, the EFC framework implies that firms will compete head to head. Since I have store level data, I am able to verify this prediction and rule out the other models.

Table 5: Head to Head Competition

Region	Stores	Firms	Observations	Population
New England	1.5	1.4	363	20869
Mid-Atlantic	1.7	1.5	1414	22163
South East	2.2	1.8	1969	21279
East Central	1.7	1.5	878	22892
West Central	1.8	1.5	1038	23731
South West	1.9	1.7	729	24480
Pacific	2.3	1.9	1513	30774
Total Zip Codes			7904	

Focusing on local competition between individual supermarket outlets, we turn our attention to zip codes. Table 5 presents the average number of supermarket *firms* per zip code alongside the average number of supermarket *stores*. Since zip codes vary considerably in size (they are much larger in western markets than elsewhere), the results are broken out by region. In each region, the average number of supermarket firms per zip code is over 1 and close in magnitude to the number of supermarket stores, suggesting that local monopoly is relatively rare. If a zip code is large enough to hold more than one store, it usually contains more than one firm. Table 6 verifies this pattern by conditioning on the number of stores operated by supermarket firms in each zip code. For zip codes containing two or more stores operated by supermarket firms, Table 6 presents the frequencies of each possible market configuration. Again we see that multi-store monopoly is an extremely rare occurrence; when zip codes contain more

[16] 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 horizontal models of differentiation where equilibria are concentrated.

than one supermarket *store*, they usually contain more than one supermarket *firm*.

Table 6: The Absence of Local Monopoly

	Number of Supermarket stores				
Configuration	2	3	4	5	6+
Monopoly	322	39	6	0	0
Duopoly	1744	525	143	41	15
3-opoly	-	488	251	108	64
4-opoly	-	-	118	75	72
5-opoly	-	-	-	9	19
6+	-	-	-	-	2
Total Markets			4041		

To provide a more formal test, I focus on the narrower question of whether the *top* supermarket firm in a market chooses store locations more spatially clustered than the industry as a whole. This hypothesis can be tested using the "dartboard" index of spatial agglomeration (Ellison and Glaeser, 1997). In this setting, what I mean by "agglomeration" is the concentration of stores by the top firm in relatively few locations. Specifically, for each distribution market I construct the following measure of concentration for the top firm's stores:

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

where s_i is the top supermarket firm's share of stores in zip code i, x_i is the share of distribution market population residing in zip code i, and N is the total number of stores in the distribution market. If firms succeed in dividing the market into local monopolies, the top firm should be more clustered than either the industry as a whole or the set of supermarket firms, resulting in a larger value of η.

Table 7 presents parameter estimates of η calculated for the top supermarket firm, all supermarket firms, and the food industry as a whole. I compute η for each set of firms using three submarket definitions: zip code, county, and MSA.[17] Focusing first on η calculated for the food industry as a whole (any store η), I find that η is very close to zero in all three submarkets. Since we expect retail firms to locate close to their consumers, this is not surprising.[18] For each definition of local submarket, the estimate of η for the lead supermarket firm (top supermarket η) is smaller than η for either the food industry as a whole (any store η) or the full set of supermarket firms (supermarket η), indicating that the store locations chosen by the top firm are less spatially clustered than either the overall

[17] The sample includes all markets in the dataset where η is defined. Any market which contains only one submarket must be dropped from the sample, so Alaska and Hawaii are not included in the results in column 3 (MSA submarkets).

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

industry or the full set of supermarket firms.[19] These results are clearly inconsistent with product proliferation. Overall, I find no evidence that firms succeed in differentiating themselves spatially from their competitors. Instead, they compete head to head, as the EFC framework implies. While the choice of location is undoubtedly important, it is the vertical dimension that appears to drive the overall structure.

Table 7: Concentration in Local Markets (The Dartboard)

	Submarket		
	Zip Code	County	MSA
Any Store η	-.002	-.002	.002
	(.002)	(.002)	(.016)
Supermarket η	-.005	-.005	.002
	(.004)	(.004)	(.020)
Top Supermarket η	-.015	-.014	-.009
	(.013)	(.014)	(.033)
Observations	52	52	50

7 Conclusion

Traditional models of retailing have focused on horizontal differentiation, a natural choice given the importance of spatial location as a determinant of where one shops. This paper stresses the role of vertical differentiation. Obviously, supermarkets and grocery stores are differentiated both horizontally and vertically. However, as this paper has demonstrated, it is the vertical dimension that is key to understanding why this industry is dominated at the regional level by a natural oligopoly, a set of firms that invest heavily in logistics and distribution to offer a much wider variety of products in larger stores at lower prices than do grocery stores. These features seem common to many forms of retailing.

[19] Because η is a parameter estimate, the standard deviations of η are much larger for the set of top supermarket stores, since fewer "darts" are being thrown. Restricting the sample by population to include only large markets improves the precision of the estimates considerably.

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