

SUPERMARKETS AS A NATURAL OLIGOPOLY

PAUL B. ELLICKSON*

This paper proposes and tests a model of supermarket competition based upon an endogenous fixed cost (EFC) framework (Sutton, J. Sunk Cost and Market Structure: Price Competition, Advertising, and the Evolution of Concentration. Cambridge: MIT Press, 1991.). The relevance of the EFC framework to supermarket competition stems from the industry's surprisingly uniform competitive structure: irrespective of the size of the local market, a small number of firms (between three and six) capture the majority of sales. As markets grow, local rivalry drives firms to expand their fixed investments, limiting the number of firms that can profitably enter even the largest markets. Although markets stay concentrated, competition remains fierce, reflecting the inherently rivalrous nature of the underlying competitive mechanism. The goal of this paper is to identify the strategic focus of this rivalry, namely the drive to provide an ever greater variety of consumer products, and to eliminate alternative explanations for the observed structure by highlighting the unique form of firm conduct that characterizes this industry. (JEL D21, D43, L11, L13, L22, L81)

I. INTRODUCTION

This paper proposes and tests a model of the supermarket industry based upon endogenous fixed cost (EFC) framework (Sutton 1991). The relevance of the EFC framework to supermarket competition stems from the industry's surprisingly uniform competitive structure: irrespective of the size of the local market, a small number of firms (between three and six) capture the majority of sales. As markets grow, local rivalry drives firms to expand their fixed investments, limiting the number of firms that can profitably enter even the largest markets. Although markets stay concentrated, competition remains fierce, reflecting the inherently rivalrous nature of the underlying competitive mechanism. The goal of this paper is to identify the strategic focus of this rivalry, namely the drive to provide an ever greater variety of consumer products, and to eliminate alternative explanations for the observed structure by highlighting the

unique form of firm conduct that characterizes this industry.

This is the third in a series of three complementary papers that apply the EFC framework to supermarket competition. In Ellickson (2007), I develop a formal model of supermarket competition, based on Sutton (1991), in which firms compete for customers by offering a greater variety of products in every store. As markets grow in size, existing firms must incur higher costs if they are to remain in the industry, and this escalation in costs discourages entry by other firms. Consequently, markets both large and small are served by roughly the same small number of high quality firms. This "nonfragmentation" result is confirmed by the data: across all markets (defined by distinct distribution areas), the vast majority of sales are captured by 3–6 dominant chains and there is a sharp bound on the share of sales captured by the market leader. While the total number of firms does expand with the size of the market,

*This paper is an updated version of Chapters 3 and 4 of my 2000 MIT dissertation. I would like to thank Susan Athey, Bryan Ellickson, Richard Schmalensee, Scott Stern, various seminar participants, the journal editor, and two anonymous referees for many useful comments. All remaining errors and omissions are my own.

Ellickson: Simon School of Business Administration, University of Rochester, Rochester, NY 14627. Phone 585-273-1491, Fax 585-273-1140, E-mail paul.ellickson@simon.rochester.edu

ABBREVIATIONS

ACCRA: American Chamber of Commerce
 Researchers Association
 EFC: Endogenous Fixed Cost
 FEs: Fixed Effects
 MSA: Metropolitan Statistical Area

this expansion is reflected entirely in a fringe of low quality stores that do not compete with the natural oligopolists. In my earlier study (Ellickson 2006), I exploited the existence of this fringe to further extend the model to include two consumer segments, providing additional comparative statics and a sharper, structural test of the underlying theory. Taking these results as a jumping off point, the goal of the current paper is to complement these analyses by first establishing that the strategic focus of competition is indeed quality escalation and then further eliminating several alternative models by exploiting new comparative statics regarding the shape of the underlying reaction functions. In particular, I find that quality increases with market size, as the theory predicts. I further demonstrate that the dominant, oligopolistic firms compete head to head for their consumers at the local level, responding to quality increases by nearby rivals with increases of their own. These results are consistent with the EFC framework, but sharply contradict alternative explanations of industrial structure based on cost-reducing investment or product proliferation.

I evaluate the implications of the EFC model using a complete census of store level observations. Focusing first on competition at the market level, I find that the quality of stores indeed expands with the size of the market. Furthermore, this escalation of quality is exhibited only by firms investing in distribution technology, supporting the claim that store level quality is linked to firm-level investment. To demonstrate how the EFC framework can be further distinguished from alternative theories, I develop and test another even more restrictive implication of the EFC framework that sets it apart from rival explanations for the observed structure. While most models of strategic investment imply strategic substitution between rival firms (Athey and Schmutzler 2001; Bagwell and Staiger 1994), I show that in an EFC model, investments may be either substitutes or complements. In contrast, strategic complementarity is inconsistent with most standard models of capacity competition, horizontal product differentiation, cost-reducing investment, and product proliferation. Turning the focus to store-level investments, I find that quality is indeed a strategic complement, providing a second and more restrictive test of the EFC framework.

The paper is organized as follows. Section II presents a formal model of supermarket competition. After deriving the natural oligopoly and

escalation results, I identify the conditions that yield strategic complementarity in investments. Section III describes the data set and explains how distribution networks can be used to identify distinct geographic markets. The empirical results are presented in Section IV. I first demonstrate that quality indeed increases with market size, but prices do not fall, suggesting that the relevant fixed investments are geared toward providing higher quality products, as opposed to lower prices. Switching the focus to the store level, I then establish that quality is a strategic complement, providing a sharper test of the EFC framework. Section V concludes.

II. AN EFC MODEL OF SUPERMARKETS

This section presents a theoretical model of supermarket competition based on Sutton's (1991) EFC framework. The model was developed in my earlier study (Ellickson 2007), but is reviewed in some detail here in order to (1) highlight the focal comparative static regarding quality escalation and (2) motivate several new results concerning the nature of strategic interaction. In particular, after establishing that Sutton's model implies that competing investments are strategic substitutes (and is equivalent to a model of cost-reducing investment), I introduce an alternative specification in which these investments are instead complements. This more restrictive implication is evaluated empirically in Section IV.C.

A. A Vertical Model of Competition

In this model of retail competition, supermarket chains are vertically differentiated, differing only in their level of quality z , which represents the "bandwidth" or variety provided in each of their stores. On the demand side, I assume that a wider choice set, prices held fixed, appeals to all consumers, allowing supermarkets to draw from a broader customer base. Utility is given by

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

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 of M identical consumers is endowed with Y units of good 1, a numeraire ($p_1 = 1$). Therefore, ignoring any distribution of profits, each consumer has wealth Y . I let $p(z)$ denote the price of a differentiated good of quality z .

Focusing on chain level investment, I assume there are N identical firms, where firm j uses input $F(z_j) + cq_j$ of the composite good x_1 to produce quantity q_j of the differentiated good x_2 of quality z_j . The fixed cost of quality $F(z)$ represents a firm-level sunk investment in distribution technology, such as the decision to build a dedicated distribution center or invest in advanced information technology systems (e.g., radio frequency identification). Competition is modeled as a three-stage game. In the first stage, firms choose whether or not to enter and incur a sunk entry cost σ , assumed to reflect the minimum efficient scale of a small chain of minimal quality. In the second stage, firms choose a level of quality z , requiring fixed cost $F(z)$. In the third and final stage, firms compete in the product market, which is modeled as Cournot.¹ Using this basic framework, I will now illustrate both the exogenous and EFC cases.

The Exogenous Fixed Cost Case. In the exogenous fixed cost case, quality is fixed but firms still pay the fixed cost of entry σ , determined exogenously by the industry's underlying technology. Without loss of generality, I assume all stores offer quality $z_j = 1$ and let $p(1) = p$. Maximizing profit at store j and solving the resulting symmetric first-order conditions yields equilibrium quantities and price

$$q = ((N-1)/N^2)(\alpha YM/c) \quad \text{and} \\ p = (N/(N-1))c.$$

Assuming entry will occur until profits are driven to zero, and ignoring the integer constraint on N , the equilibrium number of entrants is $N = \sqrt{\alpha YM/\sigma}$, which increases monotonically with the size of the market YM . As demonstrated in the study by Sutton (1991), this

fragmentation result is robust to several alternative assumptions regarding the impact of horizontal differentiation, the timing of entry, and the type of product market competition. However, the result is broken when the level of quality is determined endogenously.

The EFC Case. Letting quality z_j be a choice variable of the firm and proceeding via backward induction, I analyze the final product market competition stage first. Following Sutton (1991), I focus on a symmetric equilibrium. The equilibrium quantities and prices are identical to the exogenous fixed cost case, although they now hold irrespective of the level of z . To calculate the equilibrium level of quality, I proceed by assuming that a single firm deviates from this symmetric equilibrium to offer quality z_1 while the remaining $N-1$ firms offer quality z . Equilibrium quality is then determined by the following first-order condition

$$(2) \quad (\partial \pi(z_1))/\partial z_1 = 2\alpha YM(N-1)^2 \\ \times (((N-1)z_1) - ((N-2)z))/z / \\ \times [(N-1)z_1 + z]^3 - (F'(z_1)) = 0.$$

To solve for the equilibrium level of quality, I follow Sutton (1991) in specifying the following cost function $F(z)$

$$C_j(p_L, c, z_j, q_j) = \sigma + (p_L/\gamma)(z^\gamma - 1) + cq_j$$

which includes both the exogenous entry cost σ and a second term that depends on the level of quality chosen. p_L is assumed to be the cost of land, since increasing product variety invariably requires expanding the size of the store. To solve for the symmetric equilibrium in quality, I let $z_j = z$ and solve Equation (2) for z yielding

$$(3) \quad z = (2\alpha YM(N-1)^2/N^3 p_L)^{1/\gamma}.$$

Since both quality and fixed costs grow proportionately with market size YM (they are constant in the exogenous case), it is not surprising to find an equilibrium where the number of firms does not expand with the size of the market.² This *non-fragmentation result* is established by

1. It is important to emphasize that the natural oligopoly result does not depend on the assumption of Cournot competition: Shaked and Sutton (1983) derive a similar result under Bertrand conduct. Cournot competition is assumed here both for ease of exposition and because it yields a symmetric equilibrium in quality, a feature which accords well with the specifics of retail competition. The stores operated by Circuit City and Best Buy, Wal-Mart and K-Mart, Staples and Office Depot, and the dominant supermarket chains are often difficult to distinguish and are frequently located in close proximity to their rivals. In contrast, static Bertrand models typically yield asymmetric equilibria: firms either differentiate themselves in quality or geographic space to dampen the effect of price competition (Shaked and Sutton 1983; Ronnen 1991).

2. However, since quality also *decreases* monotonically with the cost of land, it is clearly important to control for the price of land when empirically evaluating the model. This is particularly relevant for distinguishing the EFC hypothesis from an alternative hypothesis in which *exogenous* fixed costs (i.e., land prices) simply expand with the size of the market. Without controlling for the price of land, these two hypotheses cannot be distinguished.

imposing a zero profit condition and solving for the equilibrium number of firms.

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

$$(4) \quad ((p_L - \gamma\sigma)/\alpha YM) N^3 - 2N^2 + (4 + \gamma)N - 2 = 0.$$

The fact that the number of firms will not increase indefinitely with the size of the market follows immediately from Equation (4). In the limit, as market size YM increases to infinity,³ the lead term drops out, leaving a quadratic polynomial with root⁴

$$(5) \quad N = 1 + 1/4\gamma + 1/4\sqrt{8\gamma + \gamma^2}$$

which depends only on γ and is finite for all finite γ . Since the maximum number of entrants is finite, this equilibrium is referred to as natural oligopoly (Shaked and Sutton 1983). From this simple framework, I have now identified a robust testable implication (natural oligopoly) as well as the mechanism that sustains it (escalation in quality).

B. The Nature of Strategic Investment

Before turning to the empirical analysis, I present two modifications of Sutton's standard model. The first result establishes that the vertical model of quality investment can be reformulated to emphasize cost reduction. The second shows that the model can be modified so that firm investment decisions become strategic complements.

A Model of Cost-Reducing Investment. Cost-reducing investments in distribution drove the diffusion of chain grocery stores in the 1920s (Ellickson 2011). The current emphasis on information technology is likely to yield cost efficiencies in addition to expanding the number of products carried. The EFC model should be able to accommodate either case. This is in fact true. As the following proposition demonstrates, Sutton's vertical model can be reformulated as a model of cost-reducing investment

3. For finite values of YM , the solution to the zero profit condition (4) 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 $p_L - \gamma\sigma$ is positive or negative.

4. The second root is always less than 1.

where quality does not enter consumers' utility functions at all.⁵ The following proposition establishes that all of the equilibrium properties of the standard model continue to hold in this setting.

PROPOSITION 1. *The standard version of Sutton's EFC model is equivalent to a model of cost reduction.*

Proof. Assume the M identical consumers each have Utility

$$(6) \quad u(x_1, x_2) = (1 - \alpha) \ln(x_1) + \alpha \ln(x_2)$$

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 $F(z_j) = \sigma + (c/z_j)q_j$ 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 the fraction $1/z_j$.⁶ 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

$$\pi_j = \left(\left(\alpha YM / \sum_{j=1}^N q_j \right) q_j \right) - ((c/z_j)q_j) - F.$$

Evaluating the associated first-order conditions yields equilibrium quantities and price

$$q = ((N - 1)/N^2) (\alpha YM z/c) \quad \text{and}$$

$$p = (N/(N - 1)) (c/z),$$

which now depend on the level of z determined in the second stage. In particular, we find that price falls monotonically as z increases. Since z still expands with the size of the market, larger markets will have lower prices.

5. In the quality-enhancing model, quality and price enter the indirect utility function as a ratio. Since consumers do not 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 as a result of a decrease in the "price of quality," the central insight of Spence (1976) applies: quality increases are equivalent to price reductions from the viewpoint of both buyer and seller.

6. 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.

Solving for the symmetric level of z yields the first-order condition

$$(7) \quad (\partial \pi(z_1))/\partial z_1 = 2\alpha Y M(N-1)^2 \\ [(N-1)z_1 - (N-2)z]z / \\ [(N-1)z_1 + z]^3 - F'(z_1) = 0,$$

which is identical to the quality-enhancing case. In all other respects, the results are identical to the standard model. ■

Clearly, whether the quality or cost interpretation will be more appropriate depends on the specific institutional setting. In some applications, such as the semiconductor industry where cost per bit is a decreasing function of the size/cost of the fabrication plant, the choice is obvious. In the case of supermarkets, the distinction is less clear. One way to distinguish between these cases is to focus on their consequences: falling prices or escalating quality. Another is to identify the form of strategic interaction. The empirical exercises presented below will do both, but first I will present two additional results concerning strategic interaction in the EFC framework.

Complements versus Substitutes. Since escalation in fixed investments drives the natural oligopoly result, it is tempting to conclude that these investments should always be strategic complements. However, this turns out not to be the case. The following result establishes that strategic substitution holds in Sutton's standard EFC formulation.

PROPOSITION 2. *In the standard version of Sutton's EFC model, quality choices by rival firms are always (locally) strategic substitutes.*

Proof. Although the model does not yield an analytical solution for a firm's best response function, by the implicit function theorem it has the same sign as the cross partial derivative of the profit function:

$$(8) \quad (\partial^2 \pi(z_1))/\partial z_1 \partial z = 2\alpha Y M(N-1)^2 \\ \times [(N-1)^2 z_1^2 - 2(N-1)^2 z_1 z + (N-2)z^2] / \\ \times [(N-1)z_1 + z]^4,$$

where z_1 represents the quality choice of the deviating firm. Evaluated at $z_1 = z$, the right-

hand side of Equation (8) reduces to

$$(9) \quad (2\alpha Y M(N-1)^2/N^4 z^2)(-N^2 + 3N - 3),$$

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

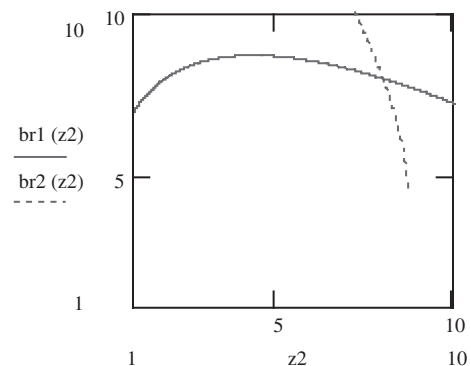
Away from equilibrium, quality choices may be either substitutes or complements, as the following example illustrates. Choosing parameters $\alpha = 1/2$, $p_L = 1$, $\sigma = 1$, $YM = 512$, and $\gamma = 2$, yields equilibrium quality $z = 8$ and 2 entrants. Solving for firm 1's best response as a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

$$br_1(z_2) = 8\sqrt[3]{z_2} - z_2.$$

Figure 1 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. 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 1 far to the left),⁷ but they cannot be complements for both. ■

In fact, this substitution result holds across most standard models of cost-reducing investment: Bagwell and Staiger (1994) demonstrate

FIGURE 1
Best Response Functions



7. This outcome resembles the Bulow, Geanakoplos, and Klemperer (1985) 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.

that investments in cost-reducing or quality-enhancing R&D are strategic substitutes under quite general conditions. Athey and Schmutzler (2001) 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), horizontal product differentiation on the line (d'Aspremont, Gabszewicz, and Thisse 1979) or the circle (Salop 1979) with quadratic transportation costs, and the vertical product differentiation model of Shaked and Sutton (1983). Nevertheless, strategic complements seem more consistent with the escalation mechanism sustaining oligopoly in the EFC framework. Fortunately, it is easy to modify the EFC model to yield complementarity.

PROPOSITION 3. *When the relationship between quality and price is non-linear, Sutton's EFC model is consistent with strategic complementarity.*

Proof. Replacing the utility function (1) by

$$(10) \quad u(x, z) = (1 - \alpha) \ln x_1 + \alpha z \ln x_2,$$

we obtain equilibrium quantities and price

$$(11) \quad q(z) = ((N - 1)/N^2) (\alpha z / (1 - \alpha + \alpha z)) \\ (YM)/c \quad \text{and} \quad p = (N/(N - 1)) c,$$

where quantity now depends on the choice of z determined in the previous stage.

Evaluated at $z_1 = z$, the cross-partial derivative of the profit function reduces to

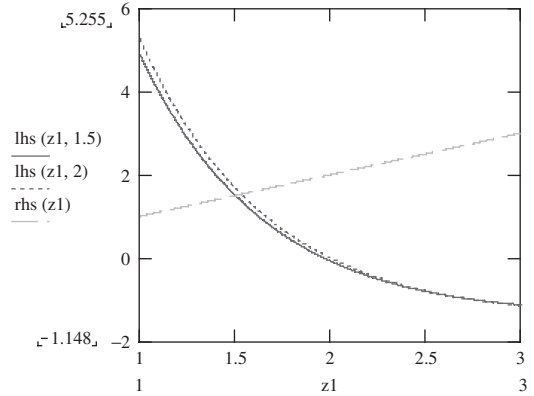
$$(12) \quad (2\alpha YM(N - 1)^2) / ((1 - \alpha + \alpha z)^2 N^3) (\phi'(z)) / \\ (\phi(z)) [-(1 - \alpha z) + ((2N - 3)/N) \\ (1 - \alpha)(1 - z)],$$

where

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

(compare Equation [9]). 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 income and substitution effects. The following example demonstrates a case in which the effect of the first term outweighs the second. Choosing parameters $\alpha = 1/2$, $p_L = 1$, $\sigma = 85/8$, $YM = 75$, and

FIGURE 2
An Example of Strategic Complementarity



$\gamma = 2$, yields 2 equilibrium entrants ($N = 2$) and equilibrium quality $z = 1.5$. Figure 2 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 now positive. Consequently, the optimal response to a rival's quality increase is to increase own quality. Unlike the model of cost-reducing investment presented above, investment by rival firms actually increases the return to own investment, resulting in strategic complementarity. ■

The example underlying Proposition 3 modifies the standard model so that consumers are willing to pay more for groceries if they are offered greater variety. As a result, increases in quality induce consumers to devote a larger fraction of their income to the quality-differentiated good, substituting away from the outside good which, in the context of groceries, is a competitive fringe of low-quality stores.⁸ Consequently, firms are no longer splitting a fixed pie—both consumption and the level of quality are determined endogenously and the strategic

8. Supermarkets have always used a wider selection to induce consumers to substitute away from the corner grocer. More recently, responding to increased competition from take-out restaurants, supermarkets have begun investing in prepared food counters targeting consumers who do not have time to cook. In both cases, the investments are geared toward inducing substitution from an "outside" good.

interaction shifts to complementarity. Moreover, the complementarity result is not confined to the specific example presented here. Analogous findings employing the Shaked and Sutton (1983) Bertrand framework are developed in studies by Ronnen (1991) and Lehmann-Grube (1997). In Ronnen's model, 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. Ronnen's 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. Lehmann-Grube presents results similar to Ronnen's in a model with sequential entry. However, because complementarity in investment arises so rarely outside of the EFC setting, it provides the opportunity for a strong empirical test of the model. This exercise will be the focus of section IV.C.

III. DATA AND MARKET DEFINITION

The data for the supermarket industry are drawn from Trade Dimension's *Retail Tenant Database* for 1998. Trade Dimensions collects store level data from every supermarket operating in the United States 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 direct marketing purposes. The (establishment level) definition of a supermarket used by Trade Dimensions is the government and industry standard: a store selling a full line of food products and generating at least \$2 million in yearly revenues. Foodstores with less than \$2 million in revenues are classified as small convenience stores and are not included in the data set. Firms in this segment operate very small stores and compete only with the smallest supermarkets (Ellickson 2007; Smith 2004).

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 (e.g., ATM, check cashing) 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. Market demographics are taken from the decennial Census of the United States and price data from the ACCRA *Cost of Living Index*.

Testing the EFC framework requires a set of reasonably independent markets that vary significantly in size. Since it is escalating fixed investment that renders further entry into each market unprofitable, it is essential that these costs not spill across markets. Retail industries, which are clearly spatially differentiated, provide a natural setting in which this is arguably the case. The supermarket industry is almost ideal because perishable goods can be shipped short distances. Of course, defining markets accurately requires identifying both the relevant costs and how far they can be spread.⁹ The EFC model suggests focusing on distribution networks, because these facilities constitute a primary (and observable) firm-level investment.

The task of defining distribution markets is simplified by the fact that supermarket firms cluster their distribution centers in major cities (typically near a railroad spur) and serve surrounding areas from these facilities. For example, all of the major chains operating in Southern California operate warehouses in east Los Angeles. While the radius of operation of a typical distribution center varies geographically, the patterns are remarkably consistent across firms within regions, so that constructing markets simply involves plotting distribution networks and drawing boundaries around them. This is the method used by Trade Dimensions in constructing the 52 marketing areas reported in their *Marketing Guidebook*. My own analysis produced only four changes, resulting in a total of 51 distribution markets.¹⁰ These markets are much larger than MSAs, more closely resembling mid-sized states, and contain an average of over five million people and 593 stores.

9. Previous studies of this industry (Chevalier 1995; Cotterill and Haller 1992) and the Federal Trade Commission have focused on the metropolitan statistical area (MSA) as the relevant geographic market, mainly because supermarket chains distribute advertising circulars at the MSA level. However, advertising is only one of the investments that firms make at the chain level and, with the growth of store level promotions (e.g., club cards), its importance has declined in recent years.

10. The specific details of how these markets were constructed are described in my earlier study (Ellickson 2007), which also establishes the high degree of independence between these markets by matching each store to its primary distribution center and measuring the degree of spillover across markets. In particular, I find that stores supplied by an out-of-market distribution facility owned by the parent firm account for, on average, less than 10% of total sales. This spillover is uncorrelated with the size of the market.

IV. QUALITY COMPETITION IN THE SUPERMARKET INDUSTRY

This section provides an empirical test of the quality escalation mechanism emphasized above and then identifies the shape of the underlying reaction functions that determine equilibrium quality levels. To do so, I rely on prior empirical results presented in two previous papers. In my earlier study (Ellickson 2007), I empirically established the relevance of natural oligopoly at the market level. In particular, I demonstrated that, across the full set of distribution markets, between four and six firms capture 60–70% of sales. Although larger markets do have more firms, the expansion is limited to a fringe of small stores, while the number and realized share of the oligopolists remains stable. Moreover, I found that these oligopolists provide a distinct, higher quality product than the fringe, operating stores more than twice as large and offering far more services. They are also much more likely to operate their own distribution centers. Both this “quality wedge” and the importance of firm-level investment are consistent with a more general “two-tiered” model, which was formally developed and tested in my earlier study (Ellickson 2006). Both papers provided strong evidence that the “dominant” firms constitute a well-defined class of players: they compete in relative isolation from the fringe of low quality “mom & pop’s” and can be easily distinguished based on observable characteristics. Treating these results as a jumping off point for the current analysis, I now turn my attention to the strategic choice of quality faced by the dominant firms.

A. Escalation in Quality

Ellickson (2007) established that the oligopolists build larger stores on average than do firms in the fringe, and also offer higher levels of several alternative measures of store quality. However, the EFC model has a stronger implication: quality provided by the natural oligopolists should increase with the size of the market. If the EFC mechanism were not in play, we would expect firms to build smaller stores, reflecting the high price of land in large urban markets. I find, however, that store size increases, but only among the dominant firms, providing empirical support for the theoretical model.

Table 1 presents several regressions relating average store size (the measure of quality most closely connected to product variety) in

each distribution market to population. The remaining exogenous variables in Equation (3) are included as controls. Focusing first on the dominant firms, I find that average store size increases with market size. The first column of Table 1 contains the results of a regression of $\ln(\text{Store Size})$ for the top six firms¹¹ on the three exogenous variables in Equation (3) ($\ln(\text{Population})$, $\ln(\text{Income})$, and $\ln(\text{LandPrice})$), as well as four regional fixed effects (FEs) (West, South, Midwest/North, East/Atlantic coast). Average housing cost per bedroom proxies for the cost of land.¹² The coefficient on population is positive and significant at the 1% level. The inclusion of market specific demographics in column 2 weakens the result somewhat, although the coefficient on $\ln(\text{Population})$ remains positive and significant at the 5% level.

The existence of the fringe also provides a natural control: if the escalation result only applies to firms that invest in distribution, it should not impact firms that do not. Columns 3 and 4 of Table 1 report regression results for non-vertically integrated firms (i.e., those that do not operate their own distribution networks). The coefficients on $\ln(\text{Population})$ are insignificantly different from zero in both specifications (the point estimate is actually *negative* in the second regression). Columns 5 and 6 report similar results for firms that are classified as independent (meaning that they operate less than 11 stores) and likely belong to the fringe. Taken together, these results provide strong evidence of the quality escalation mechanism and empirical support for the EFC framework. The next subsection considers the role of cost reduction.

B. Does Distribution Lower Costs?

As I have noted, the standard EFC model of quality enhancement can be reinterpreted as a model of cost reduction. In that case, we should observe declining prices rather than escalating quality. I have already demonstrated that quality (store size) increases as markets expand in size. Now I will show that prices do not decline.

11. *Store Size* is constructed as the average store size across all of the stores operated by the top six firms in each market, yielding 51 market level observations. The results are robust to several alternative definitions for the set of “dominant firms” and the resulting quality measures.

12. This is the closest available proxy to the cost per square foot in each store. Cost per bedroom is averaged over all the zip codes that contain a supermarket, weighted by the share of stores in each zip code.

TABLE 1
Quality Regressions

Firm Type	Top		Not VI		Independent	
ln (<i>Population</i>)	0.061 (0.021)	0.041 (0.019)	0.023 (0.367)	−0.020 (0.051)	0.018 (0.025)	−0.023 (0.036)
ln (<i>MedIncome</i>)	0.483 (0.200)	0.699 (0.213)	0.226 (0.305)	0.721 (0.360)	0.076 (0.241)	0.574 (0.291)
ln (<i>LandPrice</i>)	−0.266 (0.048)	−0.231 (0.048)	−0.099 (0.102)	−0.032 (0.079)	−0.033 (0.092)	0.006 (0.073)
% Under 18		4.68 (1.41)		7.85 (2.04)		7.74 (1.83)
% Over 64		2.21 (1.20)		3.97 (2.16)		4.00 (1.70)
Constant		−2.84 (1.94)		−5.87 (3.26)		−4.90 (2.72)
Region FEs	Inc		Inc		Inc	
Adjusted R^2	0.24	0.34	0.28	0.17	0.30	0.20
Observations			51			

Notes: Dependent variable: ln(Mean Store Size). Robust standard errors in parentheses.

To evaluate the cost-reduction hypothesis, price data from the same quarter as the store census were drawn from the American Chamber of Commerce Researchers Association (ACCRA) *Cost of Living Index*. The data are collected from surveys conducted by local chambers of commerce under ACCRA's guidance. The data set includes prices for 27 specific grocery products, reported as MSA averages. I have converted these to distribution market averages by weighting the MSA averages in each distribution market by population. Prices are available for 48 of the 51 distribution markets.

The ACCRA provides an index of supermarket prices composed of a weighted basket of grocery products. I constructed an alternative "distribution index," using the same weights, but including only those products which are typically delivered to stores from the firm's own distribution centers.¹³ These "distribution products" are the most likely to reveal the impact of supply chain IT investment.

The first three columns of Table 2 contain regressions of this price index on the same covariates employed in the quality regressions. While the point estimate of the coefficient on ln (*Population*) is negative, it is insignificantly different from zero in all three specifications. To

control for unobserved heterogeneity in costs, I use the prices of four "reference products" reported in the same ACCRA survey to create "price deflators." The reference products are drawn from industries which I believe to be unlikely to invest in cost reduction (newspapers, dry cleaners, movie theaters, and pizza parlors) and their prices are included as divisors of the dependent variable. After including the reference price controls, the point estimates for the coefficient on ln (*Population*) are all *positive*, and in two cases, significant.¹⁴ Taken together, these results suggest that marginal cost reduction is not the primary mechanism through which fixed costs escalate. I now turn to the final, most restrictive test of the EFC framework.

C. The Nature of Local Conduct

Clearly, the EFC framework is not the only approach to explaining the dominance by large, "category-killing" chains that has arisen throughout much of retail. Recent models of capacity competition explain the high degree of concentration in retail markets by using a combination of cost-reducing investment and costly consumer search (Bagwell and Ramey 1994;

13. Some products, like Coca-Cola, are delivered directly to stores by the manufacturer, while other products, like produce and milk, are purchased locally. Since they don't pass through the firm's own distribution network, these direct store-delivered products are unlikely to reflect chain-specific, distribution level efficiencies.

14. Regressions with the reference prices included as regressors, rather than as deflators of the dependent variable, yield similar results. Moreover, regressions of each "distribution" product deflated by the (direct store-delivered) price of Coca-Cola produced coefficients on ln (*Population*) which were uniformly positive (and frequently significant).

TABLE 2
Price Regressions

Deflator	None	None	None	Newspaper	Dry Cleaner	Movie	Pizza
$\ln(\text{Population})$	-0.013 (0.015)	-0.012 (0.014)	-0.007 (0.017)	0.011 (0.040)	0.091 (0.016)	0.007 (0.015)	0.032 (0.017)
$\ln(\text{Income})$	-0.129 (0.101)	-0.138 (0.120)	-0.309 (0.138)	-0.376 (0.362)	-0.769 (0.195)	-0.116 (0.146)	-0.337 (0.153)
$\ln(\text{Land Price})$	0.194 (0.046)	0.190 (0.050)	0.205 (0.048)	0.041 (0.101)	0.070 (0.077)	-0.064 (0.056)	0.111 (0.059)
% Under 18		-0.184 (0.745)	-0.464 (0.849)	-2.69 (2.85)	-4.15 (1.27)	-0.599 (1.19)	-1.56 (1.05)
% Over 64		-0.314 (0.605)	-0.883 (0.667)	-3.04 (1.87)	-3.70 (1.01)	-0.627 (0.681)	-1.48 (0.722)
Constant	-0.895 (0.657)	-0.698 (0.995)					
Region FEs			Inc	Inc	Inc	Inc	Inc
Adjusted R^2	0.44	0.45	0.47	0.07	0.15	0.18	0.24
Observations				48			

Notes: Dependent variable: $\ln(\text{Price Index/Deflator})$. Robust standard errors in parentheses.

Bagwell, Ramey, and Spulber 1997). In this case, vigorous price competition leads to the emergence of a dominant low-cost, low-price leader, rather than oligopoly. Moreover, in cost-reduction models of this type, as well as the cost-reducing version of the EFC framework, investments are strategic substitutes. However, as I found earlier, the EFC framework is one of the few settings in which these investments can be complements. Therefore, if it holds in the data, complementarity provides a powerful mechanism for distinguishing EFC from these alternative models of competitive structure.

To identify the form of strategic interaction, I focus on the zip code as a local market,¹⁵ and take quality choice (store size) to be the dependent variable. Starting from the data set of store level observations in all 51 markets, I once again select out only those stores operated by firms which are in the top six in each distribution market.¹⁶ Fringe firms are assumed to be strategically independent from the top six. A top six firm may then face between one and five other top six firms in a given zip code market.

To quantify the strategic interaction between firms, I estimate the reaction functions of

competing firms using the following regression:

$$(13) \quad \ln(\text{Size}_{ij}) = \alpha_1 \cdot \ln(\text{Avgsize}_{\setminus i}) + \alpha_2 \cdot \ln(\text{Avgsize}_i) + \sum \alpha_3 \cdot \text{Market}_j + \sum \alpha_4 \cdot \text{County} + \varepsilon_{ij},$$

where Size_{ij} is the size of store i in zip code j , $\text{Avgsize}_{\setminus i}$ is the average size of store i 's competitors in zip code j , and Avgsize_i is the average size of the stores of the firm that owns store i , outside of zip code j . Market_j is a set of (logged) zip code-level demographic and market characteristic variables, County a full set of county-level FEs, and ε_{ij} is an error term. The local demographic and market variables include population, median household income, median age, median home value, and the percent of the population that is urban or Hispanic. Because newer markets undoubtedly contain larger stores, I include a store index code¹⁷ to control for the age of the market and store.

Since the store sizes chosen by rival firms are clearly endogenous (owing to the simultaneity of firms' actions), Equation (13) cannot be consistently estimated using ordinary least squares. Moreover, unobserved factors such as

15. I will also present results for two larger local market definitions, 3 and 4 digit zip codes.

16. As above, the results are robust to several alternative classifications for the dominant firms.

17. The store index codes were entered sequentially by Trade Dimensions as stores were opened, providing a rough timeline. The codes also contain gaps reflecting the entries for establishments from other retail industries which gives the index some cardinal as well as ordinal properties.

TABLE 3
IV Estimates of Reaction Functions

Market Definition	Zip Codes			4 Digit Zip	3 Digit Zip
ln (Competitors' size)		0.176 (0.029)	0.205 (0.046)	0.155 (0.046)	0.282 (0.047)
ln (Own size)	0.796 (0.019)	0.786 (0.019)	0.803 (0.026)	0.722 (0.026)	0.744 (0.023)
ln (Population)				0.057 (0.012)	0.002 (0.009)
ln (Median income)				0.049 (0.043)	0.124 (0.060)
ln (Median home value)				-0.055 (0.033)	-0.113 (0.044)
ln (Store index)				0.111 (0.004)	0.112 (0.003)
Constant	0.689 (0.070)	0.097 (0.118)			
Market level controls			Included	Included	Included
County FEs			Included	Included	Included
Observations	8,636	8,636	8,636	11,436	12,953

Notes: Dependent variable: ln(store size). Robust standard errors in parentheses.

an advantageous location in a shopping district, a disproportionate share of commuters, or 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, county FEs, or the store age index, creating the possibility of a reflection problem (Manski 1993). The importance of unobserved heterogeneity and correlated unobservables is not unique to this setting, arising as well in the contexts of peer effects, locational sorting, and entry games (e.g., Bajari et al. 2010; Bayer and Timmins 2007; Ellickson and Misra 2008). Following this literature, I proceed by identifying a suitable instrument for competitor's size.

Specifically, I propose instrumenting competitors' store size with their average store size outside of the distribution market.¹⁸ This is a similar approach to the strategy used to handle price endogeneity in both Hausman (1997) and Nevo (2001). There are at least two reasons why a firm's size decisions should be correlated across markets. First, I have already established that the scale economies associated with providing a broad selection of products involve investments in distribution that are shared across

stores. Second, the benefits of maintaining a reputation for high quality may extend across markets, as will the returns from advertising. Identification therefore requires that the tendency to provide larger stores in general be unrelated to the idiosyncratic forces driving store size to be large in any particular local market. In the context of peer effects, Bajari et al. (2010) demonstrate that instrument validity hinges on finding a covariate of an agent's action that does directly impact the actions of other agents. In the case of supermarkets, it seems reasonable to assume that the reactions of a single store to its competitor's actions in that market only depend on the competitor's actions outside that market through its actions in that market. In other words, an individual store should only care about the size portfolio of its competitor's stores through that portfolio's impact on that competitor's store size in that particular market.

Having constructed an appropriate instrument, the first column of Table 3 can be viewed as the first stage of a two-stage regression. The remaining columns present several alternative specifications for Equation (13), estimated using two-stage least squares. The second column of Table 3 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 first county FEs and then zip code demographics. The coefficient

18. This instrument may be constructed in several ways, using a firm's average outside this zip code but within this market, across all stores outside this zip code (all markets), or across all stores outside this market. Since the results are robust to the choice of alternative, I will focus on the latter.

on competitor's size remains positive and significant at the 1% level in each specification. The coefficient on $\ln(\text{Population})$ is also positive and significant, showing that the escalation result holds at the local level as well. The fifth and sixth columns repeat the specification of column 4, using the larger 4 digit and 3 digit zip code market definitions to address issues of selection caused by focusing on markets with at least two top six firms. The size effects are bigger for the larger market definitions, which is not surprising. Again, 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 result is consistent with several models of EFC that emphasize the demand-expanding effect of quality enhancement, it casts significant doubt on a number of competing explanations of local market structure, particularly models of cost-reducing investment and product proliferation (Schmalensee 1978). Establishing that the EFC framework provides an accurate portrait of local competition helps justify its use in explaining firm-level competition as well. Clearly, a similar exercise using firm-level investment data would be very informative. However, this evidence on the actual shape of firm's reaction functions in local markets, together with the picture of the competitive structure of local competition presented in my earlier study (Ellickson 2007), suggests that the competitive, rivalrous emphasis of the EFC framework accords well with observed conduct in the supermarket industry.

V. CONCLUSIONS

This paper proposes and tests a model of the supermarket industry in which supermarket firms invest in EFCs to improve service quality. The model is consistent with a number of facts about this industry documented both here and in my earlier studies (Ellickson 2006, 2007). Regional markets of widely varying size are dominated by a small number of firms. This natural oligopoly of supermarket chains, each operating a large number of large stores, dominates a fringe of small firms, each operating a few small stores. The size of the stores operated by the oligopolistic chains expands with the extent of the market. The oligopolistic chains do not carve out separate turf, choosing instead to compete head to head with their rivals, with choice

of store size behaving as a strategic complement. No other theory seems capable of explaining these facts.

The same features seem to characterize modern retailing in many arenas, ranging from coffee shops to electronics stores. Whether this conjecture holds up remains an open question.

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