Morrison School of Agribusiness and Resource Management

Faculty Working Paper Series

Price and Product-Line Rivalry Among Supermarket Retailers

Timothy J. Richards

July 2004

ASU
ARIZONA STATE UNIVERSITY
POLYTECHNIC CAMPUS

Price and Product-Line Rivalry Among Supermarket Retailers

Timothy J. Richards[*]

First Draft: July 2004

Price and Product-Line Rivalry Among Supermarket Retailers

Abstract:

Product-line length, or variety, is a key competitive tool used by retailers to differentiate themselves from rivals. Theoretical models of price and variety competition suggest that both store and product heterogeneity are key determinants of price and variety strategies, but none test this hypothesis in a rigorous way. This study provides the first empirical evidence on supermarket retailers' combined price and variety strategies using a nested CES modeling framework. Unlike other discrete-choice models of product differentiation, the NCES model is sufficiently general to admit both corner and interior solutions in both store and product choice. The model is estimated using store-level scanner data for all grocery chains in a major West Coast market and finds that retailers do indeed use both price and product-line strategies to compete for market share, but tend to follow moderately cooperative pricing strategies and price and more cooperative strategies in variety.

Key words: game theory, nested CES, price competition, retailing, variety.

JEL Code:

Price and Product-Line Rivalry Among Supermarket Retailers

Introduction

Many believe that retailers operate in what are often described as "local monopolies" (Slade; Besanko, Gupta and Jain; Dhar). However, there is an increasing amount of evidence that this is not strictly true (Chintagunta; Chintagunta, Dube and Singh; Richards and Patterson 2003, 2004). Indeed, a cursory analysis of the recent financial performance of U.S. supermarket chains suggests that exactly the opposite is more likely – that groceries are sold in something nearly approximating perfect competition. While it may be the case that shoppers tend to compare prices among brands within the store rather than between stores (Slade) and often make their store-selection decision on the basis of location, cleanliness, service or variety (Walters and McKenzie), managers are nonetheless responsible for the price-competitiveness of their store and often set prices for individual products on the basis of rival prices (McLaughlin). Nonetheless, retailers have long realized that by differentiating themselves horizontally they are able to obtain some measure of market power. As with other types of firms, retailers may use various forms of non-price competition to differentiate themselves from others.

Of these non-price tools, this paper focuses on the use of product-line, or variety, strategies among supermarket retailers. Retailers typically offer a number of products in order to differentiate themselves either vertically or horizontally. While vertical differentiation (offering hamburger and filet mignon, for example) represents a means by which retailers price discriminate to extract more surplus, horizontal differentiation (offering five different types of lettuce) is a way in which retailers can attract a larger number of customers, build market share

and gain market power through the "portfolio effect" (Nevo). Among theoretical models of

variety competition, Dixit and Stiglitz and Spence were among the first to develop formal models

of equilibrium product proliferation, showing that firms face a fundamental tradeoff between the

cost of developing additional products versus the benefits of greater market share and pricing

power with longer product lines. More recently, Raubitschek.uses the constant elasticity of

substitution (CES) model of Dixit and Stiglitz to show that the number of products offered by a

given firm in equilibrium will be lower, the fewer firms in the industry. Recognizing that

differentiation often results in the selection of only one store or product, Anderson and de Palma

develop a model of price and variety competition in which consumers select among stores, and

then products within stores, according to a nested-logit framework. In equilibrium, they argue,

greater heterogeneity among stores leads to less variety, while heterogeneity among products

within each store leads to greater variety. While conveniently parameterizing store and product

heterogeneity with the extreme-value scale parameters, it is well understood that the nested logit

model, while more general than a simple logit, implies unrealistic substitution patterns among

products within each nest. Further, it implies that only corner solutions exist at each choice

level. de Palma *et al.* apply this approach to explain spatial competition among video store

owners in which firms choose price and variety, but the authors do not formally test the theory.[1]

Watson, on the other hand, endogenizes location choice and formally tests a variety and price

game, finding that variety is a concave function of the number of local competitors. Strategic

product proliferation is important in a non-spatial sense as well. Brander and Eaton develop a

---

[1] The authors address a specific example, but do not formally test the hypotheses that follow from their model.

model of strategic preemption in which producers of substitutable products are likely to monopolize a particular market segment in order to prevent a rival from entering. Hamilton synthesizes two branches of the modeling literature by combining a discrete store-choice model with a CES model of product choice to show that variety is the key strategic variable among oligopolistic retailers, while pricing decisions reflect product heterogeneity only. While Hamilton agrees with Anderson and de Palma on the effect of product heterogeneity on variety, he shows that greater store differentiation, in fact, leads to more variety, not less. This study provides an empirical test of the implications of Hamilton's hypothesis.

Despite the extensive theoretical research on product proliferation, there has been comparatively few empirical tests. Previous empirical research concerning the competitive aspects of product variety is nearly all directed at the level of the manufacturer, where a "product line" may consist of only a small set of related brands and competitors are very few (Bayus and Putsis; Kadiyali, Vilcassim and Chintagunta, 1996, 1999; Dobson and Kalish; Oren, Smith and Wilson). Roberts and Samuelson design and estimate a repeated two-period non-cooperative oligopoly model among U.S. cigarette manufacturers in which "number of brands" is a key determinant of demand, but not a strategic variable. In this research, models of product-line competition are typically specified at the level of the individual brand and product-level conduct parameters are estimated while the proliferation decision itself is treated as either exogenous (Kadiyali, Vilcassim and Chintagunta (KVC) 1996, 1999) or without any basis in a structural model of competition (Bayus and Putsis). Nonetheless, KVC show that yogurt makers are able to gain a measure of market power through the "portfolio effect" of offering a greater array of products, effectively reducing the elasticity of demand for their whole product line. Draganska

and Jain, on the other hand, recognize the strategic importance of product-line length in estimating a model in which the number of flavors offered per product line and the price of the product line are endogenous to retail demand. Further, they follow Berry, Berry, Levinsohn and Pakes, and Nevo (2000, 2001) in specifying a logit demand model in which product differentiation is reflected in discrete consumer choices. Although the decision to introduce new products is presumably to attract new customers by providing a better match to their preferred set of characteristics, none of these studies explicitly considers the effect of product differentiation on the nature of competition in a market.

This study presents an empirical framework this is designed to test the nature of price and variety competition among multi-product retailers using a structural game-theoretic approach. Unlike previous models where retailers compete only in prices, we argue that retailers likely compete in the number of products offered as well, or the variety of selection. We test this hypothesis in a nested framework in which consumer demand at both a store and product level follow from a single, representative utility maximization problem and in which the endogeneity of price and variety strategies is explicitly accounted for. Our data represent two years of weekly sales of several different items within the fresh fruit category. Unlike other studies, we believe that using unbranded commodity data is necessary to test retail behavior because consumer packaged good sales are driven largely by manufacturer incentives and category management programs. Fresh produce, therefore, represents the only means of testing retailer strategies in an independent, uncontaminated way.[2] With these data, our primary contribution consists of an

---

[2] Studies by Choi and more recently, Sudhir, formally model the nature of manufacturer-retailer interactions but assume a highly simplified retail market.

empirical test of whether grocery retailers compete in prices, variety, both prices and variety or neither. Further, if they do compete in either of these tools, we can also shed light on the precise nature of the game that is being played.

Empirical Model of Variety Competition

The primary implication of Hamilton's model is that, although retailers choose both variety and price, pricing decisions reflect only product heterogeneity and acquisition cost and not the intensity of competition among stores. On the other hand, the number of different products offered by a store – variety – depends not only on product differentiation, but differences among stores as well. In order to test the core hypothesis of this research, we develop an econometric model that includes structural equations for: (1) equilibrium prices, (2) equilibrium variety (number of products per store), and (3) the market share of each store. Rivalry in either price or variety will, in turn, be largely determined by the degree of differentiation between stores, the extent of product differentiation, differences in marginal cost (wholesale price), and differences in fixed retailing costs. Both the degree of product differentiation and store differentiation are, however, unobserved to the econometrician. Therefore, the econometric procedure estimates both product and store differentiation as unknown parameters.

In the majority of cases, this is due to the fact that the extent of differentiation is unobserved to the econometrician, or is a latent variable influencing both competition and demand. Berry; Berry, Levinsohn and Pakes; Ackerberg and Rysman, and Nevo (2000, 2001), among others, explicitly account for unobserved product differentiation within a discrete choice framework. By estimating structural supply and demand models with consumer utility a function

of both observed and unobserved product characteristics, these studies are able to identify the extent of differentiation in imperfectly competitive markets. This approach, however, focuses on differentiation inherent in the product itself – or that created by manufacturers – and necessarily assumes away any further differentiation created by other channel members. Dhar and Cotterill, on the other hand, argue that products purchased in retail supermarkets are differentiated in two dimensions: (1) from other products in the same store according to their embodied attributes, and (2) from similar products in other stores on the basis of store characteristics. This implies that a two-stage model of store and product choice is required to estimate the degree of substitutability both among stores and among products within stores.

There are several ways to represent the two-stage choice process, depending on whether each stage is regarded as discrete (one alternative is chosen) or continuous (several can be chosen). Many argue that real-world choices are more usually discrete than continuous. Deaton and Muellbauer (1980) describe the general conditions under which well-defined preferences will generate discrete choices. Namely, if the utility function is of the general form:

$u(q) = u(\sum_i \psi_i(x) q_i, z)$ where ψ_i is an index of quality, increasing in the vector of attributes x,

then consumers will choose the commodity for which the quality-adjusted price is the lowest. Hanemann (1984) develops an econometric framework based on this logic that integrates the discrete choice among brands and the continuous choice of quantity in one maximum utility problem. Based on the indirect utility functions he defines, Vaage (2000) describes an application to Norwegian appliance and power demand, while Chiang (1991), Chintagunta (1993), Richards (1998) and van Oest, Paap, and Franses (2003) consider discrete choices among

brands and continuous quantity purchases. Although this approach has a definite advantage in theoretical consistency, it has a number of limitations in empirical application, however. First, substitution among brands is driven entirely by their market share and not by fundamental attributes of the choice itself (Nevo). Second, the price-response parameter in the brand-choice model is constrained to -1.0 so estimates of brand-choice elasticity are necessarily unrealistic. Third, this approach makes the somewhat unrealistic assumption (true of all random utility models) that consumers do indeed make a discrete choice among brands. For most products that consist of multiple flavors or sizes, purchases are more typically described as "multiple-discrete" where observed demand consists of a mixture of interior and corner solutions.

A logical and intuitive alternative to the discrete / continuous approach followed by the studies above is a nested logit similar to Anderson and de Palma or de Palma *et al.* However, retail grocery shoppers do indeed make a discrete choice among stores, but the subsequent choice among products, and the quantities of each, are more logically considered to be continuous. While many authors model similar problems using a nested logit approach, there are many practical problems with this approach in studying retail demand for quality-differentiated foods. First, consumers typically buy many different types of product from within a single category on each shopping trip. Such multiple discreteness as described above is not appropriate for a nested-logit framework. Second, while a nested logit model offers more general substitution relationships than a simple logit model, it nonetheless imposes unrealistic restrictions on substitution between products in separate branches of the model. Third, nested logit models imply linear utility in price and other product attributes – hardly a realistic or theoretically sound description of utility. Consequently, we adopt a different approach here that offers both a more

general treatment of substitutability among products, while retaining the nested-decision logic inherent in shoppers' decisions between quality differentiated stores and products within stores.

A number of recent studies consider more general forms of the discrete / continuous problem addressed by Hanemann. Hendel (1999) develops an explanation based on the heterogeneity of needs among computer users within a large corporation. Building on this basic framework, Dube (2004) uses the logic that "multiple discreteness" likely reflects the fact that purchase and consumption are not the same event. Rather, consumers buy goods in anticipation that their taste may vary from one consumption event to another between shopping trips. For example, within the fruit category, a consumer may anticipate consuming a banana for breakfast, an apple for lunch and perhaps strawberries with dinner. Moreover, there are typically several individuals involved in each consumption event, with the shopper anticipates not only a preference for variety over different events, but also tastes that vary among individuals. Kim, Allenby and Rossi (2002), on the other hand, specify a translated, additive utility function that relies on quality-adjusted prices to drive discrete outcomes in a manner similar to Hanemann. Unlike Hanemann, however, their approach allows for declining marginal utility and the possibility of some interior utility maximization solutions. However, the models developed by Kim, Allenby and Rossi and Dube are more appropriate for household-level data where true corner solutions are observed.

For the aggregate, store-level data used here, we adopt a more general model that allows for both corner solutions and continuous substitution at both a store and product-level – the nested CES (NCES). Perhaps not surprising given the nature of the available data, research into the demand for recreational visits (ie., fishing, skiing, camping, etc.) has developed a number of

useful ways of approaching the discrete / continuous demand problem. Building on the NCES

model of Sato (1967) as applied to demand analysis by Brown and Heien (1972), Morey *et al.*

(2001) build a model of fishing-trip demand that allows for general substitution relationships

among alternatives, is parsimonious in parameter space, allows for complementarity, has the

potential to be flexible and, finally, appears to perform well in empirical application.[3] Although

they develop models based on both expenditure-share and trip-occasion share, for retail food

demand, clearly expenditure share is the appropriate specification. von Haefen and Phaneuf

(2003) subsequently reestimate the NCES of Morey *et al.* using a Possion, rather than a

multinomial distribution for trips over time. In the case of retail grocery stores, however, we are

not interested in individual household's allocation of trips over time.

Focusing on the choice among grocery stores on a single shopping occasion basis, we

assume that a household maximizes utility from the current occasion only. Further, we assume

that the consumer first chooses among the products she wishes to buy, and then decides from

which store she wants to purchase the entire bundle, based on considerations of both cost and

inherent quality of the store. Using a two-level NCES specification, the indirect utility function

for this problem is written:

$$V(p_{ij}, y) = \left[\sum_{i=1}^{N} \left[\sum_{j=1}^{N_i} \hat{p}_{ij}^{1-\sigma_i} \right]^{(1-\sigma)/(1-\sigma_i)} \right]^{1/(1-\sigma)} y, \tag{1}$$

---

[3] Brown and Heien call their NCES model the S-branch utility tree. This specification was, however, later criticized by Blackorby, Boyce and Russell (1978) because it implies preferences are affine homothetic. They reject this attribute of the S-branch model by specifying a more general Gorman Polar Form model that nests the S-branch as a special case.

where σ_i is the elasticity of substitution among j products in store i, and σ is the elasticity of substitution among j stores (and the outside option) in a given market. Analogous to the nested logit model of price and variety competition of Anderson and de Palma, in this case σ_i represents the degree of heterogeneity among products within a given store (*intrastore* heterogeneity) and σ represents the degree of heterogeneity among stores (*interstore* heterogeneity). As they discuss, and clarify in a footnote, for retailers who sell many highly substitutable products with little heterogeneity (a seller of submarine sandwiches, for example) σ_i is likely to be high relative to σ. However, for retail formats that sell products meeting many different and diverse needs, the critical node of competition is likely to be between stores rather than within each store. Supermarkets fall logically within this second category. Given this key parameter, Anderson and de Palma argue that formats with a high degree of intrastore heterogeneity are likely to be characterized by few stores offering many different products, while a high degree of interstore heterogeneity is more conducive to many stores with limited offerings. Although our model to this point is not able to comment on the number of stores, we will be able to test their hypotheses regarding the number of products offered within each store. Further, note that prices are adjusted for the inherent "quality" of each product and store in a manner similar to that suggested by Deaton and Muellbauer and Hanemann, namely by multiplying observed prices by a strictly positive function:

$$\psi_{ij} \; = \; (\exp(\beta_{1ij} + \beta_{2ij}z_{ij} + \beta_{3ij}zp_{ij} + \beta_{4ij}N_i + \beta_{5ij}m_1 + \beta_{6ij}m_2 + \beta_{7ij}m_3))^{\sigma_i/(1-\sigma_i)}, \qquad (2)$$

where γ_{ij} is an idiosyncratic preference parameter, z_{ij} is a binary variable indicating whether or not the product was on a promotion during the week, zp_{ij} is an interaction term between the

promotion dummy and shelf price, N_i is the number of products offered by store i, and $\boldsymbol{m}$ is a vector of seasonal dummy variables. Multiplying ψ by the price provides a quality adjusted price so that $\hat{p}_{ij} = \psi_{ij} p_{ij}$ for each $j = 1, 2, 3, \ldots N_i$ products per store and $i = 1, 2, 3 \ldots N$ stores.

Concavity requires $\sigma_k \in [0, \infty)$ and, to allow for the possibility that the quantity of some products is zero, $\sigma > 1$. Applying Roy's Identity to (1) and simplifying provides the share equations for each choice of store and product:

$$\theta_{ij} = \left(\frac{\hat{p}_{ij}^{1-\sigma_i}}{\displaystyle\sum_{j=1}^{N_i} \hat{p}_{ij}^{1-\sigma_i}} \right) \left(\frac{P_i^{1-\sigma}}{\displaystyle\sum_{i=1}^{N} P_i^{1-\sigma}} \right), \tag{3}$$

where $P_i = (\displaystyle\sum_{j=1}^{N_i} \hat{p}_{ij}^{1-\sigma_i})^{1/(1-\sigma_i)}$ is the price-aggregator function, or price index, for store i. In our application of the NCES to store and product choice, we include an "outside option" along with the four included retail stores to allow for the fact that shoppers can buy fresh fruit from places other than the major retail chains described by our data. Consequently, share expansion can indeed represent category growth for any and all of the stores we consider here. An estimable form of (3) is created by expressing each share in logs and adding an iid error term, μ_{1ij}:

$$\log(\theta_{ij}) - (1-\sigma_i)\log(\hat{p}_{ij}) + \log\left(\sum_{j=1}^{N_i} \hat{p}_{ij}^{1-\sigma_i} \right) - (1-\sigma)P_i + \log\left(\sum_{i=1}^{N} P_i^{1-\sigma} \right) = \mu_{1ij}, \tag{4}$$

for $i = 1, 2, \ldots 4$ and $j = 1, 2, \ldots 5$. However, modeling the demand side is not sufficient to

understand how these stores interact in price and variety space.

Rather, we follow the structural industrial organization literature by formally modeling the supply side of the retail sector as well. Prices and variety in the NCES retail model are clearly endogenous. Even if neither are strategic variables for retailers, which they may indeed be, they are likely to be endogenous for the more subtle reasons cited by Villas-Boas. Both prices and the number of product-types offered for sale are set by retail managers who are able to observe many factors that can influence store-level demand, but are not observable to the researcher. Display alignment, in-store specials, supplier concerns and many other considerations are taken into account in making marketing decisions that may not be observable to an outside analyst and are most certainly not independent from price and variety outcomes. In order to model strategic interaction among retailers in prices and variety and to address these more subtle price-endogeneity issues, the demand system is estimated simultaneously with the first order conditions for retail profit maximization (Bresnahan 1989; Berry, Levinsohn and Pakes 1995; Besanko, Gupta and Jain 1998; Nevo 2001, among many others). In this way, we also estimate both price and variety-response elasticities for each retail chain in our sample data. Although the first order conditions for the NCES system are highly non-linear, we follow Dhar, *et al.* in deriving general first order conditions in terms of elasticities only.[4] Draganska and Jain also derive the supply side for firms that choose both price and product-line length in a similar, general notation, but assume Bertrand-Nash behavior with respect to both variables. We do, however, follow a similar approach in estimating behavior at the store, rather than the individual

---

[4] Dhar, *et al.* extend the general notation for the first-order conditions of a profit maximizing multi-product firm presented by Nevo (2001) by demonstrating that the estimation of conduct parameters requires only elasticities from the demand system, along with measures of cost and other supply shifters as required.

product level. Focusing on store-level strategies has both logical and practical appeal. First, retail store managers do not compare prices with rivals' on an individual product level, but rather category by category (McLaughlin). Second, variety is more meaningful on a store-level than with respect to individual product lines, particularly in the fresh produce data used in this study. Third, estimating the entire four-store and five-product model would create an unreasonably high number of parameters to estimate, particularly given that we include both price and variety reactions. Therefore, the profit equation for firm i is written as:

$$\pi_i = M \sum_{j \in N_i} \theta_{ij}(p_{ij} - c_{ij}) - g_i(N_i) = M\theta_i(P_i - C_i) - g_i(N_i), \tag{5}$$

assuming non-jointness of production. In (4), M is total market size, and c_{ij}, the marginal cost of retailing, is separable between wholesaling and a Generalized Leontief retail unit-cost function so that total product costs are written:

$$c_{ij} = m_{ij} + \sum_k \tau_k v_k + \sum_k \sum_l \tau_{kl}(v_k v_l)^{1/2} + \mu_{4ij}, \tag{6}$$

where m_{ij} is the wholesale (FOB) price of product j, v_k is a vector of input prices that includes retail labor costs, marketing costs and FIRE (finance, insurance and real estate) costs and μ_4 is an iid random error term. Firm profit also includes certain fixed costs of variety, which encompass the costs of either developing and marketing private labels, or introducing and shelving external brands. Draganska and Jain argue that these costs are convex as greater variety imposes higher costs on the firm. To capture this effect, we model variety costs in terms of a simple quadratic function: $g_i(N_i) = \delta_{i1}N_i + 0.5\delta_{i2}N_i^2$, which, of course, implies linear marginal costs of variety.

Unlike Draganska and Jain, however, we allow for price and variety behavior that is more general than Bertrand-Nash by introducing conduct parameters, or conjectural elasticities, within both prices and varieties. Further, firms are assumed to form expectations of others' reactions to changes in both price and product line. In other words, we estimate cross-tool conduct parameters similar to Kadiyali, Vilcassim and Chintagunta so that we may test for whether firms respond to changes in price with changes in product line and vice versa. In this way, we reflect the nested logic of the NCES model in that each store's prices and product lines are determined by decisions made within other firms as well as for internal considerations. Taking this into account, the first-order condition with respect to the price index of retailer i becomes:

$$\frac{\partial \pi_i}{\partial P_i} = \theta_i M + \sum_k (P_i - C_i) \frac{\partial \theta_i}{\partial P_k} \frac{\partial P_k}{\partial P_i} M + \sum_k (P_i - C_i) \frac{\partial \theta_i}{\partial N_k} \frac{\partial N_k}{\partial P_i} M = 0, \quad k = 1,2,3,4. \tag{7}$$

Similarly, the first order condition with respect to variety, or product-line length for retailer i is given by:

$$\frac{\partial \pi_i}{\partial N_i} = \sum_k (P_i - C_i) \frac{\partial \theta_i}{\partial N_k} \frac{\partial N_k}{\partial N_i} M + \sum_k (P_i - C_i) \frac{\partial \theta_i}{\partial P_k} \frac{\partial P_k}{\partial N_i} M - \delta_{1i} - \delta_{2i} N_i = 0, \quad k = 1,2,3,4. \tag{8}$$

where P_i and C_i are retail and wholesale CES price indices, respectively, and the terms $\partial P_k/\partial P_i$, $\partial N_k/\partial P_i$, $\partial N_k/\partial N_i$, $\partial P_k/\partial N_i$, represent firm i's expectation of firm k's response to changes in its storewide "average" price and the variety of products on offer. These equations can be simplified by writing each in terms of demand and response elasticities, and measures of total

category cost (e_i) and revenue (r_i), producing an estimable system of price:

$$r_i + \sum_k (r_i - e_i)\epsilon_{ik}\phi_{ik} + \sum_k (r_i - e_i)\eta_{ik}\lambda_{ik} = \mu_{2i}, \quad k = 1,2,3,4, \qquad (9)$$

and variety equations:

$$\delta_{1i}N_i - \delta_{2i}N_i^2 - (r_i - e_i)(\eta_{ii} + \sum_k \eta_{ik}\alpha_{ik} + \sum_k \epsilon_{ik}\gamma_{ik}) = \mu_{3i}, \quad k = 1,2,3,4, \qquad (10)$$

where ϵ_{ik} is the price elasticity of demand of product i with respect to the price of product k, η_{ik} is the "variety elasticity" of demand of product i with respect to the number of k products offered, ϕ_{ik} is the conjectural elasticity of firm k's price with respect to a change in firm i's price, λ_{ik} is the conjectural elasticity of firm k's product-line length with respect to firm i's price, α_{ik} is the elasticity of firm k's variety response to an increase in offerings by firm i, while γ_{ik} is the conjectural elasticity of firm k's price with respect to a change in firm i variety and μ_{2i}, and μ_{3i} are econometric error terms. As a result, the entire system consists of three blocks of equations, with 20 equations in the demand block (four stores of five products each) and 4 equations in each of the price and variety response blocks. While estimation of the entire system together would be preferable, the size of this problem requires that each be estimated sequentially, while imposing the cross-equation restrictions implied by the previous stage. All of these estimates are obtained, therefore, by FIML within each independent block of equations.

Data and Estimation Methods

In order to provide a sample that is both of sufficient detail and depth to study the above

problems yet is tractable in an econometric sense, the data for the proposed study consist of retail

scanner data across multiple products within a single grocery category for all supermarket

retailers located in a single retail market. We use data from the fresh fruit category because retail

sales of unbranded commodities represent the only opportunity to study retail competition that is

not driven by manufacturer promotion programs, category management, or obligations created

under slotting or pay-to-stay fee agreements. Store-specific data are required to identify

competitive interactions among stores, while product-specific data provide the measure of

heterogeneity among products within each store. Further, because individual stores are subject to

significant individual variation, we aggregate all stores in a given chain to represent a common,

representative "store." At the product-level, the data consist of price, quantity and total

expenditures on a weekly basis from January 1998 through December 1999, for a total of 104

weekly observations. Because there are a number of unique items per product definition,

depending upon whether it is bagged or bulk, small or large, or a particular variety, we aggregate

over individual price-look-up (PLU) codes to the product-level for red delicious apples, granny

smith apples, fuji apples, bananas, and grapes. Our measure of variety consists of a simple PLU

count for each aggregate product. All data were obtained from FreshLook Marketing, Inc. (FLM)

of Chicago, IL.

Los Angeles represents an ideal case-study because there are a small number of retailers

who dominate the retail market, each retailer follows a HI-LO as opposed to an EDLP strategy

and the Bureau of Labor Statistics reports wholesale product price data for major regional

centers, so our wholesale price series is likely to represent true purchase costs. Issues of variety,

price and store-differentiation are best studied with single-category data due to the variety of

factors consumers regard as important in choosing a store (Arnold, Oum and Tigert; Supermarket News), the potential for heterogeneous price and product strategies across categories in a given store, and the necessity of pooling data over cross-sectional and time-series observations. Obtaining product SKU (stock-keeping unit) counts by product is important because different stores may emphasize one product over another. While one store may stock many different varieties of apple, for example, the same store may limit the number of available brands of peach in order to emphasize its higher margin offerings. Moreover, if the analysis were to consider other categories such as beverage, cereals or ice cream, the number of SKUs is often influenced by considerations such as manufacturer incentives, slotting fees, or promotional allowances (Chintagunta 2002). To identify a pure strategic variety choice, therefore, this analysis requires data from a single, important category for each chain.

Data for the other variables are from various secondary sources. Wholesale prices for the sample of fruits represented here are from the Economic Research Service of USDA (grapes), the Washington Growers' Clearing House (apples), or the Ecuador Minister of Agriculture (bananas) and represent shipping-point FOB prices. Retailing costs are measured by indices of wages in retail and wholesale trade, business services, advertising, finance, insurance and real estate (FIRE), transportation and utilities as well as a food store employment cost index, and an index of hourly wages among food store workers, all from the Bureau of Labor Statistics (BLS).

In order to capture retail competition at the store-level, all prices represent per-product, per-store averages and all quantities are expressed on a per-store basis. Therefore, each grocery chain is essentially regarded as one firm with multiple locations. Store characteristics include the number of stores in the LA metro region. Further, the "outside option" is calculated in a manner

similar to Nevo (2001). Specifically, LA residents are assumed to consume each fresh fruit at the national average rate. US per capital fruit consumption values are then multiplied by the population of LA county (the market area of the sample stores) to obtain a total market consumption value for each fruit. The outside option is then the difference between total LA consumption and that represented by the sample stores. Any error can be due to differences between LA and national consumption rates, or to fruit purchased outside of the retail channel represented here. If these errors are random, then the parameter estimates remain valid.

Although estimating equations (4), (9) and (10) together is preferred on efficiency grounds, the size of the estimation problem required sequential estimation of the demand and supply blocks. Elasticity estimates from the system of equations described by (4), therefore, are included in equations (9) and (10) in order to recover the conjectural elasticity estimates. In both systems, however, prices and variety are clearly endogenous, so an instrumental variable procedure is used for each block of equations. For the demand system, the set of instruments includes the set of wholesale fresh fruit prices, the supermarket cost indices described above and lagged values of each product's retail price and market share. Because of the large number of parameters in the demand system, however, this set of instruments is still not sufficient to obtain unique estimates of each. Consequently, we follow Draganska and Jain and interact these dummies with a set of product and store binary indicator variables. These instruments are also used to estimate the supply block. Both sets of equations are estimated using full information maximum likelihood.

Results and Discussion

Although tests of the price and variety response hypotheses are conducted using the supply-side results, there is also considerable interest in the validity of the CES demand system and the insights it provides. If the elasticity of substitution among stores is equal to 1.0, then there is no need to consider a nested system as all stores are regarded as perfect substitutes. Similarly at the product level, an elasticity of substitution of 1.0 implies that all products are perfect substitutes. Based on the results in table 1, a Wald chi-square statistic for the hypothesis that $\sigma = 1.0$ is 17.50, while the critical value at one degree of freedom at a 5% level is 3.84. Therefore, we clearly reject the null hypothesis, which suggests that a two-level nested system is preferred. Among the product-level elasticities of substitution, we again reject the null hypothesis that $\sigma_i = 1.0$ in each case so different types of fruit are indeed imperfect substitutes for one another.[5] In fact, Anderson and de Palma raise the issue of whether we should expect greater differentiation (less substitutability) within a particular store or among different stores. In the supermarket example, consumers choose many types of goods to fill fundamentally differing needs, but each store sells roughly similar types of products. Therefore, we expect greater differentiation within each store than across stores. The results in table 1 support this expectation as the product-level substitution elasticities are significantly lower than the store-level estimate. Interpreted as measures of heterogeneity, these estimates also mean that the degree of product-level heterogeneity is far greater than the level of heterogeneity among stores. Although four point-estimates of the product-level substitution elasticities do not permit a formal test of the hypothesis that greater product-heterogeneity leads to more variety, or longer product-lines, the

---

[5] The test statistic for the null hypothesis that $\sigma_1 = 1.0$ is 303.689, for $\sigma_2 = 1.0$ is 147.053, for $\sigma_3 = 1.0$ is 219.775, and for $\sigma_4 = 1.0$ is 119.046. In each case, the test statistic is chi-square distributed with one degree of freedom.

estimates in table 1 provide some evidence contrary to this idea. Whereas store 1 has a substitution elasticity of 0.040 and offers only 52.6 products on average, store 4 offers 77.33 products and has a substitution elasticity among products of 0.202 – the highest of all our sample stores. Anderson's argument maintains that if products are not readily substitutable for one another, a firm can introduce more brands without fear of cannibalizing existing sales. However, this must be weighed against the fact that retailers can span the characteristics space preferred by customers with fewer, more distinct products. In this case, the latter effect dominates.

The remaining parameters in the demand system comprise the product-level quality functions, ψ_{ij}. Whereas Morey *et al.* assume common quality parameters among each of their primary-level choices, this alternative was rejected in the LA retail data in favor of product- and store-specific parameters. In each case, a positive parameter estimate suggests that the perceived "quality" or underlying demand for the product rises in the associated variable or, in the case of the intercept term, the inherent preference for the good in question is higher than average. In this respect, the results in table 1 indicate that consumers in three of the four stores express a preference for red delicious apples, while consumers in all stores tend to favor fuji apples. Perhaps surprising given the importance of bananas to fresh produce retailing, consumers in three of four stores tend to show a negative preference for bananas. Retailers are perhaps more interested, however, in the effectiveness of price-promotion programs among fresh fruit. For virtually all products and stores, the promotion variable represents a strongly significant influence on demand. A positive value for the binary sales indicator means that demand increases during a sale, while a negative interaction term means that demand also becomes less elastic. Both of these outcomes are desirable from the retailer's point of view.

[table 1 in here]

While it is not the primary objective of this paper, it would be possible to calculate the profit implications of a sale in each case with the CES demand estimates. Finally, the β_{ik4} parameter shows the effect on the demand for product k in store i of increasing the number of variants in a particular product line. Consumers may value a variety of choices in fresh fruit if they are easily satiated in either the taste or nutritional attributes they desire when consuming fruit (McAlister and Pesemier; Chintagunta 1998), they seek a hedge against future changes in taste (Walsh) or desire more attributes than one item can provide (Farquhar and Rao). Product variants in this case may mean different sizes of apple, package forms, or different colors of grape, for example. Although Draganska and Jain provide arguments, and show empirical support, for a concave effect of variety on market share, here we maintain a linear relationship to keep the model as parsimonious as possible. In general, the results tend to be broadly positive, particularly in the case of fresh grapes, where many would argue that variety not only appeals to consumers' nutritional needs for diversity, but is also visually appealing as well. These results are similar to Draganska and Jain or Bayus and Putsis in personal computers.

While it is a relatively simple matter to calculate price elasticities for individual products, because the focus of this paper is on store-level strategies, table 2 presents estimates of "fresh fruit" price elasticities for each store. Consistent with common notions of the competitiveness of the supermarket sector, the price elasticity of demand for each store is near unity, except for the fourth. As expected, the stores are substitutes for each other and, in general, strong substitutes both in an economic and statistical sense. With respect to variety elasticities, all of the own-elasticities are positive and significant, while the cross-elasticities are negative and significant.

These elasticities provide some potentially valuable information. For example, the fact that the second and fourth stores both face price-inelastic demand, and relatively high variety elasticities suggests that these stores may benefit from higher prices and longer product lines among their fresh fruit. However, greater insight into the strategic value of these changes is provided by the supply-side estimates of each firm's price and variety response.

[table 2 in here]

These estimates are shown in table 3. As in Vilcassim, Kadiyali and Chintagunta, each structural equation allows for firm-specific "multiple interactions" or expected price and variety responses by rivals to a change in variety, or to a change in price. Given that these responses are derived in a Nash equilibrium framework, all are assumed to be optimal given the choices made by other firms. By assuming general Nash behavior on the part of all stores, we offer a more comprehensive analysis of product-line decisions than Draganska and Jain, who assume Bertrand-Nash (zero conduct parameters) in both prices and variety. With respect to price behavior, the conjectural elasticity estimates presented in the top panel show how rivals are anticipated to react to changes in the price of store i. If the estimate is greater than zero, rival firms are expected to raise their prices in response to a rise in firm i's price in a cooperative way. Clearly, the results in table 3 indicate that the retailers are far from competitive ($\phi_{ik} = 0$). Rather, the estimates in each case suggest a range from mildly cooperative (firm 2 with respect to firm 4) to strongly cooperative (firm 2 with respect to firm 3). These results also suggest that price and variety are strategic complements as each firm expects its rivals to increase the number of products they offer in response to an increase in the firm's own price. When one firm raises its price, others' market shares will rise, thereby leaving them more consumer surplus to extract

-22-

either directly through higher prices, or through a combination of even higher prices and longer product lines. Allowing for non-zero conjectural elasticities in this way provides perhaps greater insight into the variety choice problem than Anderson and de Palma as it recognizes that pricing decisions among rival firms also depend on product line decisions, and *vice versa*. Based on the pricing-equation estimates, therefore, retail supermarkets appear to behave cooperatively in their pricing decisions, both in response to rival price and product-line choices.

[table 3 in here]

On the other hand, the bottom panel shows that variety decisions are less uniform with respect to their implications for retailer strategy. First, the γ_{ik} parameters show the conjectural elasticity of firm k's variety with respect to that offered by firm i. A positive elasticity, therefore, suggests that product lines are strategic complements – if one firm lengthens its product line, it will be able to raise its price, thus leaving more of the market for the other firms. As in the case of a simple price increase described above, with more market share the other firm can raise its price to extract more surplus (as suggested by the positive α_{ik} elasticities in table 3), or may either shrink their product lines to reduce cost, or lengthen them to build more pricing power. In table 3, firm 1 apparently makes product line decisions on the expectation that firm 2 will not follow, as is the case for firm two with respect to firms 1 and 4. Each firm, however, expects firm 3 to capitulate in any product line expansion (or contraction) in a relatively vigorous way. With respect to the expected price-response of rivals to changes in variety, firms 1 and 2 expect very strong cooperation in nearly all cases, but firms 3 and 4 expect firm 2 to counter any changes they may make. This lack of uniformity may be due to the fact that changes in product line are not generally as transparent as prices. Supermarkets tend not to advertise many of the minor

products they offer, but typically publish as many prices as possible on a weekly basis. Nonetheless, we can make a general conclusion that retailers, on average, tend to cooperate in both price and product-line decisions.

Further, because price elasticities in the CES model depend upon the elasticity of substitution among products, the results in table 3 can also be interpreted as indirect tests of the store-heterogeneity hypothesis outlined in the introduction. In the lower block of results shown in table 3, a positive conjectural elasticity estimate (α_{ik}) suggests that firm i will offer more products for sale the higher the cross-price elasticity of demand, or the less heterogeneous it perceives the market to be. Unlike the product-heterogeneity case, this finding is consistent with the theoretical predictions of both Hamilton and Anderson and de Palma. Anderson and de Palma explain this result in the following, indirect way: greater store-heterogeneity, holding the number of firms fixed, allows each to raise its price, thus inducing entry and the range of products offered per store to fall. In our model, however, the effect is much more direct. Specifically, if stores are largely seen as homogeneous, then each will seek to differentiate themselves by offering a greater range of products. If doing so causes other stores to raise their prices in response to the overall increase in demand, then they each have further incentive to offer more variety. Clearly, this process is limited by the rising cost of variety (note the convexity of each of the variety cost functions in table 3), but can perhaps explain in part the rise of supercenters and other "big box" retailers in markets such as children's toys, consumer electronics and books.

Conclusions and Implications

This study provides some empirical evidence on the strategic interaction of pricing and product-line decisions by supermarket retailers. Theoretical models of price and variety competition suggest that *interfirm* heterogeneity reduces variety, or the length of a firm's product line, while *intrafirm* heterogeneity increases equilibrium variety. While other studies investigate this question using restrictive, nested-logit based models, this is the first to empirical test the variety / heterogeneity relationship using a flexible, nested CES model.

The data used in this study consists of two years of weekly scanner data for four major retail chains in the Los Angeles market. We use data from an unbranded, fresh product category in order to minimize the influence of manufacturer interference in retail sales decisions and to gain access to accurate and relevant wholesale price data. These data are used to estimate a fully structural system of fresh fruit demand and first-order conditions with respect to store-level prices and product numbers. With this approach, the estimated conjectural elasticities represent retailers' response to store heterogeneity in price and variety strategies.

Estimates of the demand system provide a number of interesting results. First, we find a lower elasticity of substitution among products within each store than among stores, as expected given the similarity of product offerings among supermarkets. Second, we find considerable support for research among consumer product goods retailing (Chintagunta 2002) that finds price promotion to be highly effective in increasing product-level market share. Third, variety does indeed have a strongly positive impact on sales volume in a particular product line. Fourth, we find that sales at the store level are nearly approximately unit elastic with respect to price, and uniformly positively related to store-level measures of variety.

Using the demand system estimates, we then estimate price and variety response

equations that allow for that allow for multiple strategic interactions between rival store's price and variety decisions. Of primary interest among these estimates, we find that each store tends to follow a "cooperative" or complementary variety strategy with respect to certain of its rivals, but not all. Following different variety strategies with respect to some rivals is likely driven by perceived proximities in other respects, such as location, price levels or private label strategies. Further, we use these estimates to test Anderson and de Palma's hypothesis that greater store-level heterogeneity is likely to lead to a smaller assortment of products offered per firm. We find support for this hypothesis, but not for their corollary that greater product-level heterogeneity leads to longer product lines. Moreover, the mechanism driving our result is fundamentally different as ours is strategic in nature while theirs derives from the type of equilibrium assumed.

While this research provides many implications for what we know about competitive interactions among supermarket retailers, perhaps the most important concerns the consequences for how the supermarket industry is likely to evolve. Driven by factors outside their immediate market niche, namely competition from other store formats, traditional supermarkets of the type we study here have been reducing retail prices in real terms in a number of categories. Consequently, if they follow cooperative pricing strategies, each will undercut the other until something nearly competitive arises. At the same time, however, variety is expected to respond in the same direction, leading to smaller product assortments and shorter product lines. In fact, this is precisely what is occurring now. Through "efficient assortment" and category management programs, supermarkets are reducing SKU counts throughout the store in order to save inventory and handling costs as well as to allow the introduction of their own store brands.

References

Ackerberg, D. and Rysman. Paper presented at the 5th Biennial Conference on Industrial Organization in the Food Industry. INRA-IDEI, Toulouse, France. June 2002.

Anderson, S. P. and de Palma, A. "Multiproduct Firms: A Nested Logit Approach." Journal of Industrial Economics 40(September 1992): 261-275.

Arnold, S., T. Oum, and D. Tigert. "Determinant Attributes in Retail Patronage: Seasonal, Temporal, Regional and International Comparisons." *Journal of Marketing Research* 20(1983): 149-157.

Bayus, B. L. and W. P. Putsis, Jr. "Product Proliferation: An Empirical Analysis of Product Line Determinants and Market Outcomes." *Marketing Science* 18(1999): 137-153.

Berry, S. "Estimating Discrete Choice Models of Product Differentiation." *RAND Journal of Economics* 1994

Berry, S., J. Levinsohn, and A. Pakes. "Automobile Prices in Market Equilibrium." *Econometrica* 63(1995): 841-890.

Brander, J. A. and J. Eaton. "Product Line Rivalry." *American Economic Review* 74(June 1984): 323-334.

Chiang, J. "A Simultaneous Approach to the Whether, What, and How Much to Buy Questions" *Marketing Science* 10(1991): 297-315.

Chintagunta, P. K. "Investigating Purchase Incidence, Brand Choice and Purchase Quantity Decisions of Households." *Marketing Science* 12(1993): 184-208.

Chintagunta, P. K. "Inertia and Variety Seeking in a Model of Brand-Purchase Timing." *Marketing Science* 17(1998): 253-270.

Chintagunta, P. K. "Investigating Category Pricing Behavior at a Retail Chain." *Journal of Marketing Research* 39(2002): 141-154.

Chintagunta, P. K., Dube, J. P. and V. Singh. "Market Structure Across Stores: An Application of a Random Coefficients Logit Model with Store Level Data." *Econometric Models in Marketing* 16(2002): 191-221.

Chintagunta, P. K. and D. C. Jain. "Empirical Analysis of a Dynamic Duopoly Model of Competition," *Journal of Economics and Management Strategy,* 4(1995): 109-131.

Choi, S. C. "Price Competition in a Channel Structure with a Common Retailer." Marketing Science 10(Fall 1991): 271-296.

Cotterill, R. W. "Market Power in the Retail Food Industry: Evidence from Vermont." *Review of Economics and Statistics* 68(1986): 379-386.

Cotterill, R. W. and W. P. Putsis, Jr. "Market Share and Price Setting Behavior for Private Labels and National Brands," *Review of Industrial Organization*, 17(2000): 17-39.

de Palma, A., R. Lindsey, B. Von Hohenbalken, and D. S. West. "Spatial Price and Variety Competition in an Urban Retail Market: A Nested Logit Analysis." *International Journal of Industrial Organization* 12(1994): 331-357.

Dhar, T. P., J. -P. Chavas, R. W. Cotterill, and B. W. Gould. "An Econometric Analysis of Brand Level Strategic Pricing Between Coca Cola and Pepsi Inc." Working paper. Food Systems Research Group, University of Wisconsin Madison. June 2003.

Dhar, T. and R. W. Cotterill. 2003. "Oligopoly Pricing with Differentiated Products: The Boston Fluid Milk Market Channel," paper presented at AAEA annual meeting, Montreal, Canada. August.

Dixit, A. K. and J. E. Stiglitz. "Monopolistic Competition and Optimum Product Diversity." *American Economic Review* 67(1977): 297-308.

Dobson, G. and Kalish, S. "Positioning and Pricing a Product Line." *Marketing Science* 7(1988): 107-125.

Draganska, M. and D. Jain. "Product-Line Length as a Competitive Tool." Working paper, Stanford University Graduate School of Business, October 2003.

Dube, J. P. "Multiple Discreteness and the Demand for Carbonated Soft Drinks." *Management Science* forthcoming in 2004.

Ecuador Ministry of Agriculture. Agriculture Information System. (www.sica.gov. ec/ingles /cadenas/banano). June 2004.

Farquhar, P. and Rao, V. "A Balance Model for Evaluating Subsets of Multiattribute Items." *Management Science* 5(1976): 528–539.

Hamilton, S. "Variety Competition." Working paper, Department of Economics and Business, University of Central Florida, August 2003.

Hendel, I. "Estimating Multiple-Discrete Models: An Application to Computerization Returns."

Review of Economic Studies 66(1999): 423-446.

Kadiyali, V., P. Chintagunta, and N. Vilcassim. "Empirical Analysis of Competitive Product Line Pricing Decisions: Lead, Follow, or Move Together." *Journal of Business* 69(1996): 459-487.

Kadiyali, V., P. Chintagunta, and N. Vilcassim. "Product Line Extensions and Competitive Market Interactions: An Empirical Analysis," *Journal of Econometrics*, 89(1999): 339-363.

Kim, J., G. M. Allenby, and P. E. Rossi. "Modeling Consumer Demand for Variety." *Marketing Science* 21(Summer 2002): 229-250.

Lancaster, K. *Variety, Equity, and Efficiency* New York: Columbia University Press. 1979.

Liang, J. N. "Price Reaction Functions and Conjectural Variations: An Application to the Breakfast Cereal Industry," *Review of Industrial Organization*, 4(1986): 31-58.

McAlister, L. and E. Pesemier. "A Dynamic Attribute-Satiation Model for Choices Made Across Time." *Journal of Consumer Research* 9(1982): 141-150.

Morey, E. R., W. S. Breffle, and P. A. Greene. "Two Nested Constant-Elasticity-of-Substitution Models of Recreational Participation and Site Choice: An "Alternatives" Model and an "Expenditures" Model." *American Journal of Agricultural Economics*, 83(2001): 414-27.

Nevo, A. "A Practitioner's Guide to Estimation of Random-Coefficients Logit Models of Demand." *Journal of Economics and Management Strategy* 9(2000): 513-548.

Nevo, A. "Measuring Market Power in the Ready-to-Eat Cereal Industry," *Econometrica* 69(2001): 307-342.

Oren, S., S. Smith, and R. Wilson. "Pricing a Product Line." *Journal of Business* 57(1984): S73-S100.

Raubitschek, R. S. "A Model of Product Proliferation with Multiproduct Firms." Journal of Industrial Economics 35(March 1987): 269-279.

Slade, M. E. "Product Rivalry with Multiple Strategic Weapons: An Analysis of Price and Advertising Competition," *Journal of Economics and Management Strategy,* 4(1995): 445-476.

Sudhir, K. "Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer." Marketing Science 20(Summer 2001): 244-264.

United States Department of Labor, Bureau of Labor Statistics. *Employment and Earnings: State and Area*. 2004. http://stats.bls.gov:80/cgi-bin/dsrv?sa (June 6, 2004).

United States Department of Agriculture. Economic Research Service. *Fruit and Tree Nut Yearbook*. Washington, D.C. June 2004.

Vilcassim, N. J., V. Kadiyali and P. K. Chintagunta. "Investigating Dynamic Multifirm Market Interactions in Price and Advertising." *Management Science* 45(1999): 499- 518.

Villas-Boas, J. M. and R. S. Winer. "Endogeneity in Brand Choice Models." *Management Science* 445(October 1999): 1324-1338.

Villas-Boas, J. M. "Consumer Learning, Brand Loyalty, and Competition." *Marketing Science* 23(Winter 2004): 134-145.

von Haefen, R. H. and D. J. Phaneuf. "A Note on Estimating Nested Constant Elasticity of Substitution Preferences for Outdoor Recreation," *American Journal of Agricultural Economics* 85(2003): 406-413.

Walsh, J. "Flexibility in Consumer Purchasing for Uncertain Future Tastes." *Marketing Science* 14(1995): 148–165.

Walters, R. G. and S. B. McKenzie. "A Structural Equation Analysis of the Impact of Price Promotions on Store Performance." *Journal of Marketing Research* 25(1988): 51-63.

Washington Growers Clearing House. *Annual Report*. Wenatchee, WA. 1998-1999.

Watson, R. "Product Variety and Competition in the Retail Market for Eyeglasses." Working paper, Department of Economics, University of Texas at Austin, March 2004.

Wilkinson, J. B., J. B. Mason and C. H. Paksoy. "Assessing the Impact of Short-Term Supermarket Strategy Variables." *Journal of Marketing Research* 19(1982): 72-86.

Table 1. Nested CES Parameter Estimates: Los Angeles Retail Fresh Fruit, 1998-1999

	Store 1		Store 2		Store 3		Store 4	
Coeff.	**Estimate**	**t-ratio**	**Estimate**	**t-ratio**	**Estimate**	**t-ratio**	**Estimate**	**t-ratio**
σ_i	0.040*	12.642	0.176*	31.381	0.123*	30.802	0.202*	29.866
β_{i11}	6.199*	6.060	3.620*	3.193	-0.948	-0.945	3.668*	3.593
β_{i12}	1.074	1.091	8.705*	8.910	9.082*	10.037	16.652*	17.320
β_{i13}	5.963*	5.922	-11.433*	-10.464	-6.524*	-6.397	-17.874*	-15.761
β_{i14}	0.096	0.367	0.298*	3.438	0.255*	2.159	0.532*	5.876
β_{i21}	-18.536*	-14.376	-0.533	-0.507	-2.050	-1.675	0.269	0.209
β_{i22}	-0.569	-0.592	9.526*	11.055	16.586*	13.850	4.580*	4.927
β_{i23}	2.351*	2.390	-10.341*	-10.079	-16.326*	-12.913	-4.375*	-4.263
β_{i24}	0.209	0.842	0.298*	3.489	0.229	1.941	0.532*	5.602
β_{i31}	23.458*	16.186	6.678*	5.656	15.514*	12.002	10.814*	8.076
β_{i32}	-0.807	-0.828	2.114*	1.985	0.926	1.042	5.891*	6.780
β_{i33}	4.151*	4.108	1.730	1.714	1.959*	2.002	-9.490*	-9.016
β_{i34}	0.499	1.956	0.378*	4.272	0.285*	2.493	0.519*	5.365
β_{i41}	-2.297*	-2.030	7.908*	7.397	-7.616*	-6.571	-4.535*	-3.662
β_{i42}	10.730*	10.377	22.073*	15.463	17.275*	15.751	10.838*	11.076
β_{i43}	-4.073*	-4.048	-23.600*	-16.468	-9.853*	-10.052	-9.316*	-9.627
β_{i44}	-0.353	-1.253	0.109	1.120	0.272*	2.339	0.557*	6.306
β_{i51}	1.541	1.538	-4.797*	-4.247	-2.413*	-2.332	11.474*	8.376
β_{i52}	15.491*	12.844	2.623*	2.572	3.772*	3.468	5.451*	5.855
β_{i53}	-5.175*	-5.885	-0.985	-1.524	-1.535*	-2.643	-2.470*	-4.789
β_{i54}	0.962*	4.081	0.512*	5.235	0.368*	2.882	0.571*	5.663
σ	0.870*	117.400						
LLF	-468.571							
χ^2	1,1214.79*							
N_i	52.606		73.663		70.529		77.328	

[a] In this table, parameter β_{ijk} refers to the demand-parameter estimate for store i, product j, variable k, where $j = 1$ is red delicious apples, $j = 2$ is granny smith apples, $j = 3$ is fuji apples, $j = 4$ is bananas, $j = 5$ is grapes, $k = 1$ is the product-store specific preference parameter, $k = 2$ is the direct promotion effect, $k = 3$ is the price*promotion interaction effect, and $k = 4$ is the variety effect. N_i is the average number of products offered per store over the sample period. A single asterisk indicates significance at a 5% level. The σ_i are elasticities of substitution among products within store i, while σ is the elasticity of substitution among stores. Seasonal indicator variables are suppressed to conserve space, but are all significantly different from zero. The χ^2 test statistic compares the estimated model to the "null model" with constant terms only. At 5% and 141 degrees of freedom, the critical chi-square value is 169.711.

Table 2. Store Price and Variety Elasticities

With respect to:[a]	Elasticity of:							
	Q_1		Q_2		Q_3		Q_4	
	ϵ_{1k}	t-ratio	ϵ_{2k}	t-ratio	ϵ_{3k}	t-ratio	ϵ_{4k}	t-ratio
P_1	-1.151	-106.326	0.146	13.485	0.146	13.485	0.224	8.157
P_2	0.321	6.632	-0.976	-20.157	0.321	6.632	0.353	8.631
P_3	0.207	10.098	0.207	10.098	-1.090	-53.037	0.176	8.244
P_4	0.624	8.657	0.623	8.631	0.623	8.644	-0.674	-9.527
	η_{1k}	t-ratio	η_{2k}	t-ratio	η_{3k}	t-ratio	η_{4k}	t-ratio
N_1	0.179	6.795	-0.022	-6.089	-0.022	-6.089	-0.022	-6.089
N_2	-0.022	-5.437	0.685	10.905	-0.226	-5.437	-0.226	-5.437
N_3	-0.071	-4.990	-0.071	-4.990	0.369	7.617	-0.071	-4.990
N_4	-0.032	-5.711	-0.129	-5.711	-0.063	-5.711	0.675	9.791

[a] In this table, all subscripts refer to store i, so Q_i is the volume of sales from store i, P_i is the price index for store i, and N_i is the number of products offered for sale by store i. All elasticities are calculated at sample means. A single asterisk indicates significance at a 5% level.

Table 3. LA Supermarket Price and Variety Response Elasticities, 1998-1999

	Firm 1		Firm 2		Firm 3		Firm 4	
	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio	Estimate	t-ratio
ϕ_{i1}	1.000	N.A.	0.403	17.777	0.455	13.463	0.232	45.481
ϕ_{i2}	0.458	22.897	1.000	N.A.	0.158	7.914	0.136	33.371
ϕ_{i3}	0.565	24.189	0.678	27.730	1.000	N.A.	0.127	29.757
ϕ_{i4}	0.326	22.351	0.072	4.388	0.239	13.671	1.000	N.A.
λ_{i1}	1.000	N.A.	0.126	50.124	1.210	24.750	0.211	39.071
λ_{i2}	0.425	17.735	1.000	N.A.	0.186	5.802	0.221	39.146
λ_{i3}	0.149	45.385	0.683	30.627	1.000	N.A.	0.053	1.297
λ_{i4}	0.134	11.933	0.030	2.240	0.139	11.526	1.000	N.A.
τ_{i1}	0.104	2.092	1.969	20.031	0.608	22.929	0.458	15.886
τ_{i3}	-0.407	-7.878	1.347	26.163	0.824	18.652	-0.102	-3.221
τ_{i13}	0.010	2.668	0.424	9.867	0.142	14.031	0.081	7.315
δ_{i1}	-2.826	-20.570	-1.540	-8.332	0.077	2.395	2.428	81.428
δ_{i2}	0.371	26.105	0.859	16.218	10.999	299.700	10.909	280.460
γ_{i1}	1.000	N.A.	-0.149	-1.856	0.082	8.854	0.052	4.717
γ_{i2}	-0.210	-3.798	1.000	N.A.	-0.058	-7.545	-0.043	-6.719
γ_{i3}	0.412	77.248	1.118	14.912	1.000	N.A.	0.017	2.476
γ_{i4}	0.160	2.866	-0.566	-7.456	-0.001	-0.538	1.000	N.A.
α_{i1}	1.000	N.A.	1.155	15.887	0.013	0.730	0.015	1.071
α_{i2}	0.146	25.191	1.000	N.A.	-0.035	-3.065	-0.018	-2.016
α_{i3}	1.058	148.070	1.306	17.642	1.000	N.A.	0.009	0.991
α_{i4}	0.380	8.288	-0.309	-5.647	0.002	-0.151	1.000	N.A.
LLF	4,094.223							

[a] In this table, ϕ_{ik} is the conjectural elasticity of firm k's price with respect to price changes by firm i, λ_{ik} is the conjectural elasticity of firm k's variety with respect to price changes by firm i, α_{ik} is the conjectural elasticity of firm k's variety with respect to the number of products offered by firm i, γ_{ik} is the conjectural elasticity of firm k's price with respect to the number of products offered by firm ii, and τ_{il} and δ_{im} are parameters of the retailing and variety cost functions, respectively. A single asterisk indicates significance at