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Firm-Level Competition in Price and Variety

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Consumer product manufacturers often compete in dynamic, multi-firm oligopolies using multiple strategic tools. While existing empirical models of strategic interaction typically consider only parts of the more general problem, this paper presents a more comprehensive alternative. Marketing decisions are dynamically optimal, consistent with optimal consumer choice, and responsive to rival decisions. Using a single-market case study that consists of five years of four-weekly data on ready-to-eat cereal sales, prices, and new brand introductions, we test several hypotheses regarding the nature of strategic interaction among several rival manufacturers. We find that cereal manufacturers price and introduce new brands cooperatively in the same period, but behave more competitively when dynamic reactions are included.

Key Words: cereal, differentiated products, dynamics, oligopoly, product line rivalry, strategic interaction

JEL Classifications: D43, L13, L66, M31, Q13

Introducing a new brand, or extending an existing brand, represents an important tool of strategic rivalry among consumer product manufacturers. In food products alone, manufacturers introduced 11,574 new brands in 2003 (Food Institute). A broader product line can increase firm profit by preventing potential entry by a rival (Brander and Eaton; Bayus and Putsis), allowing a firm to internalize consumer brand substitution within its own portfolio (Kadiyali, Vilcassim, and Chintagunta 1999; Nevo), or by helping to differentiate its products from those offered by rivals (Nevo). Product introduction may either intensify price competition as the number of substitute products rises (Hausman and Leonard), or soften competition in prices if a firm signals that it intends to compete in variety instead (Kadiyali, Vilcassim, and Chintagunta 1996). The incentive to introduce a new product, therefore, depends not only on its stand-alone profitability, but its indirect or strategic effect (Richards and Hamilton). Despite the relatively large amount of theoretical research on the demand for variety (Spence; Dixit and Stiglitz) and its strategic effects (Raubitschek), very few theoretical insights have been either empirically verified or refuted.

This lack of empirical research is perhaps due to the inherent complexity of the econometric problem: real-world marketing decisions are inherently multi-product, multi-firm, multi-tool and multi-period. Consequently, the objectives of this paper are both substantive and methodological. First, we seek to provide a better understanding of the strategic roles of price and product line decisions in the ready-

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to-eat cereal industry, using a single market as a case study. Second, we demonstrate the value of using an empirical approach that more nearly reflects the complexity of the relationships among firms in a concentrated industry—their use of multiple tools to compete with many others in a dynamic setting. Third, we illustrate the practical usefulness of this approach by simulating consumer surplus, value-added and operating profit outcomes under alternative behavioral assumptions.

The paper begins with a brief discussion of previous empirical research on pricing and product line competition. In the second section, we introduce an econometric model of multi-firm, multi-period and multi-tool strategic interaction. A third section describes the scanner data used as well as the estimation methods. In the fourth section, we present the results obtained from estimating the structural model, including a range of model specification tests and tests of our primary hypotheses. This section also includes a discussion of the results obtained from the simulation exercise and their implications for firm strategy. A final section offers some conclusions and suggestions for future research in this area.

Background on Price and Product Line Rivalry

The ready-to-eat (RTE) cereal industry provides a unique opportunity to study the interplay of pricing and product line decisions. Indeed, few industries are more active in developing new products and in using strategic new product introductions as a competitive tool (Liang; Hausman; Erickson; Nevo).[1] While pricing strategies for new products (Dockner and Jorgensen; Kadiyali, Vilcassim, and Chintagunta 1999) and the strategic motives for product line changes are relatively well understood, the interaction of product line and pricing decisions remains to be thoroughly studied.

In one notable exception, Draganska and Jain estimate a logit model of price and product line length rivalry using a structural approach similar to the one used in this study, but with two significant differences. First, Draganska and Jain assume Bertrand-Nash rivalry, and so are unable to estimate the extent of collusion or competition among firms. Second, because they do not allow for dynamic price or product line responses, their model is not likely to capture the full effect of introducing new products on the state of competition. Due to the time lag between the development and introduction of a new product, and the nature of strategic responses, estimating the strategic effects of product introduction requires an econometric approach that reflects the dynamic nature of price and product line interaction. In fact, prior research shows that allowing for dynamic responses among rival firms is likely to produce significantly different conclusions compared to a static alternative (Roberts and Samuelson; Kadiyali, Vilcassim, and Chintagunta 1996). Therefore, we extend the variety-competition logic of Draganska and Jain by allowing for more general Nash rivalry and recognizing that strategic interaction is likely to be inherently dynamic.

We also focus on firm-level outcomes of price and product line decisions, rather than the brand-level focus employed in much of the recent research in this area (Besanko, Gupta, and Jain; Kadiyali, Vilcassim, and Chintagunta 1999; Nevo; Dhar et al.). While these studies provide very general, important insights into the source and nature of market power, brand-level analysis with multiple firms suffers from the curse of dimensionality, meaning that there are simply too many brands to derive any meaningful results for reactions among any subset of them. Nevo addresses this problem by estimating a mixed-logit model of demand in which brand substitution is driven by proximity in characteristic space (nutritional and sensory) rather than market share. However, the price-markup equations in this model are able to infer only extremes along the continuum of market power from perfect competition to monopoly, not oligopolistic interaction in which rivals make marketing decisions in response to expectations of

[1] Over the 1999–2003 period, RTE cereal companies introduced an average of 98.6 new products each year (Food Institute).

rival behaviors. Reimer and Connor attempt to remedy this weakness by estimating a more general brand-level price response model using Nevo's demand parameters, but they do not incorporate the intertemporal aspect of marketing rivalry.

Research in both marketing and industrial organization has long recognized the fact that strategic marketing decisions of all sorts (price, advertising, product introduction) are inherently dynamic. Villas-Boas (2004) provides a recent example in which consumer learning about goods gives manufacturers an incentive to reduce prices now in order to develop a larger loyal market segment for the future. However, there is little consensus regarding how to represent marketing dynamics in an empirical model of oligopolistic rivalry (Feichtinger, Hartl, and Sethi). In fact, there are two broad model types: (1) Nerlove-Arrow, or "goodwill" models; and (2) Lanchester, or "market share" models. Nerlove and Arrow maintain that marketing expenditures are in fact investments in long-lived capital assets they termed "goodwill." Because goodwill is both slow to develop and depreciates slowly over time once established, the impact of an investment made in one period can be felt for many periods into the future (see Slade for an example). On the other hand, Vidale and Wolfe and Kimball develop an alternative characterization, based on Lanchester's models of battlefield strategy, that assumes marketing tools act directly on the rate of change of sales or, more precisely, on the evolution of a firm's market share (see Chintagunta and Rao for an example). While Lanchester-type models produce important insights into dynamic marketing behavior, their mathematical complexity necessitates a number of simplifying structural assumptions. Namely, models of this type generally assume that the industry consists of two firms (duopolists) who compete using only two marketing tools over a fixed market size, and perhaps most importantly, are constrained by equations of motion governing market share that are not grounded in any model of consumer optimization. For these reasons, we assume price and product line changes have an effect on demand through the accumulation of goodwill so that prices and brand numbers constitute state variables in a general, dynamic game.

One drawback of this approach, however, is the computational burden of ensuring that the optimal solution paths to a closed-loop, or Markov-perfect game, are in fact internally consistent among the players. Because of this inherent complexity, empirical applications often involve very simple structural models—often including only one or two state variables (Pakes and McGuire; Slade). We, however, follow Roberts and Samuelson and Vilcassim, Kadiyali, and Chintagunta in specifying and estimating a game in which each firm is assumed to solve an infinite series of two-period repeated games. The resulting solution to this game provides dynamic reaction functions that show how each firm's price and product line decisions respond to decisions taken by their rivals in a dynamic way.[2] While this approach is a simplification, it yields an empirical model that describes a highly complex strategic environment in a tractable and powerful way.

An Empirical Model of Price and Product Line Rivalry

In this paper, firms are assumed to compete for market share by choosing prices and product variety, as measured by the number of brands or the length of their product line. Ultimately, however, market share is determined by consumer response to the choices made by each firm. Therefore, the empirical model consists of a system of demand equations (one for each firm) and a block of supply equations that consists of one equation for each price and product line decision. Although many recent empirical industrial organization studies (e.g., Dhar et al.) use flexible demand systems to impose as few restrictions as possible on the nature of consumer response (Genesove and Mullin), we use a discrete choice model of differentiated products due to its parsimony

[2] Dockner shows that the steady-state solution to this closed-loop strategic game is identical to a static conjectural-variations equilibrium while capturing the state-dependent nature of the underlying game.

and the plausibility of logit elasticity estimates (Chintagunta, Dube, and Singh). The random utility function on which the discrete choice model is based reflects the essential arguments of the "demand for variety" literature in both economics (Dixit and Stiglitz; Spence) and marketing (Watson; Kim, Allenby, and Rossi; Draganska and Jain). Namely, consumers derive value from variety and are willing to pay more for a greater selection of products. Draganska and Jain estimate a similar structural model of price and product line rivalry based on a random utility framework, but assume Bertrand-Nash rivalry in both price and product line. Although this simplifies their model considerably, it also ignores the possibility that firms may behave strategically in setting both price and product line policies. Therefore, we extend their approach by allowing for more general Nash behavior, both in the current period and over time.

The discrete choice model of demand is specified by assuming household h obtains utility from consuming cereal characterized by a unique set of attributes. By choosing the cereal that provides the highest utility among all alternatives, the outcome is inherently discrete. Further, utility depends on habits, experience, and other learned behaviors and so is inherently dynamic, meaning that utility in the current period is a function of cereal choices made in previous periods. Following Draganska and Jain, utility is defined over all brands offered by each manufacturer (product lines), rather than over each individual brand. As such, utility is written as[3]

$$(1) \quad u_{hjt} = \beta_{0j} - \alpha p_{jt} + \lambda S_{hj,t-1} + \sum_k \beta_{1k} x_{jkt} + b(n_{jt}) + \xi_{jt} + \varepsilon_{hjt}.$$

where β_{0j} is the maximum willingness to pay for the brands of firm j, p_{jt} is the price of products offered by firm j in period t, $S_{hj,t-1}$ is the market (volume) share of firm j products for household h in the previous period, $\boldsymbol{x}_{jt}$ is a vector of k attributes describing the products offered by firm j, n_{jt} is the number of different variants or brands sold by firm j in period t, $b(n_{jt})$ is the utility obtained from n_{jt} brands sold by j, ξ_{jt} is an unobservable (to the econometrician) error term and ε_{hjt} is a random error, assumed to be iid extreme value distributed. Elements of the vector $\boldsymbol{x}_{jt}$ include a set of firm-specific preference variables and a measure of the intensity of manufacturer promotion during each period.

The utility function in Equation (1) includes one of the two ways in which we incorporate cereal demand, pricing and variety dynamics. First, Equation (1) describes household-level dynamic effects by including a lagged value of the share of each brand. Whether measuring habit formation among consumers, an aggregate learning effect, inventory stockpiling, brand loyalty, or goodwill decay, Equation (1) forms the core of a common dynamic model of consumer utility (Erdem, Imai, and Keane). Second, as described in greater detail below, we follow Roberts and Samuelson by explicitly including dynamic firm reactions, or "intertemporal conjectures." Thus, price and product line dynamics emanate not only from fundamental consumer behavior, but directly from strategic firm interactions as well.

The specification of utility is also unique in that we explicitly allow for variety effects. Whereas Draganska and Jain define n_{jt} as the number of flavors of a particular brand, when analyzing product line strategy at the firm-level, it is more appropriate to define n_{jt} as the number of brands offered by one firm in a particular category. Brands of cereal are assumed to be analogous to flavors of other food products because offering a variety of brands is the primary way in which cereal manufac-

[3] Whereas introducing variety into a representative *consumer* utility function in this way would be implausible, this approach follows Hendel in recognizing that at each purchase occasion, a *household* typically chooses several specific types of cereal at one time. Choosing a product line reflects utility functions that differ among family members, or alternatively, members of the household who choose to vary their consumption choices from meal to meal. Either way, utility rises in variety. From this perspective, individual cereals offered by a particular manufacturer are akin to flavors of a particular type of product.

turers appeal to consumers with differing tastes.[4] Further, defining variety in this way is not only consistent with how product managers view variety decisions, but also approximates more closely the familiar notion of "brand proliferation." Moreover, our definition is consistent with previous research on product variety. Bayus and Putsis define variety as the number of distinct types of computer offered by a single manufacturer, while Watson uses a simple count of the number of eyeglass frames. More generally, Chong, Ho, and Tang conduct an empirical analysis in which they show that a flavor-definition of variety outperforms simply SKU counts in explaining consumer choice. Draganska and Jain also offer a rigorous justification for a particular structure of $b(n_{jt})$, the utility a household obtains from additional brands within the same product category. Assuming an additive utility structure over multiple varieties of the same product category, Kim, Allenby, and Rossi show that utility rises in the number of brands offered.

Consequently, we assume that (1) all brands provide the same utility to a representative household, (2) that all brands are offered with the same probability, and (3) that the cost of searching for a particular brand rises with the number of brands being offered. As a result, the total utility from a line of length n_{jt} is given by

$$(2)\qquad b(n_{jt}) = \gamma_0 + \gamma_1 n_{jt} + (1/2)\gamma_2 n_{jt}^2,$$

where $\gamma_0 > 0$, $\gamma_1 > 0$ and $\gamma_2 < 0$ reflects the fundamental concavity of utility in the variety offered by a particular manufacturer.

Combining all of the demand-side assumptions described, and assuming ε_{ijt} is iid extreme-value distributed, the random utility in (1) implies share functions for each $j = 1, 2, \ldots, J$ firm of:

$$(3)\qquad S_{jt} = \left\{\exp\left[\beta_{0j} + \sum_k \beta_k x_{kjt} - \alpha p_{jt} + \lambda S_{j,t-1} + \gamma_1 n_{jt} + \left(\frac{1}{2}\right)\gamma_2 n_{jt}^2 + \xi_{jt}\right]\right\} \div \left\{1 + \sum_{i=1}^{J} \exp\left[\beta_{0i} + \sum_k \beta_k x_{kit} - \alpha p_{it} + \lambda S_{i,t-1} + \gamma_1 n_{it} + \left(\frac{1}{2}\right)\gamma_2 n_{it}^2 + \xi_{it}\right]\right\},$$

where S_{jt} is the market share of firm j. While the logit demand model is both intuitively plausible and empirically tractable, it suffers from the well-known "independence of irrelevant alternatives" (IIA), or proportionate draw problem. Simply, IIA implies that the likelihood of switching between two alternatives depends only on their share and not on the price of another. IIA is circumvented with the use of a nested or mixed logit model (Berry; Nevo), but at the cost of imposing unacceptable simplifications on structural (demand and supply) modeling of the form presented below. Further, whereas the mixed logit cannot be simplified further and must be estimated using simulated likelihood methods, the fixed-coefficient MNL version used here is more conveniently expressed by taking logs and subtracting the share of the outside good (S_0) from both sides to produce a demand equation that is estimated with nonlinear least squares in the usual way:

$$(4)\qquad \ln(S_j) - \ln(S_0) = \beta_{0j} + \sum_k \beta_k x_{kj} - \alpha p_j + \lambda S_{j,t-1} + \gamma_1 n_j + (1/2)\gamma_2 n_j^2 + \xi_j.$$

Estimating a MNL model of demand is also beneficial as it permits the simultaneous estimation of demand and the first order conditions for profit maximization—the supply side of our model of competition in prices and product line length. Using a structural model of market-level rivalry also allows a traditional instrumental variables method to account for the likely endogeneity of prices and prod-

[4] Note that brand extensions are considered separate brands with this definition. For example, Honey Nut Cheerios and Cheerios are considered two brands.

uct line length in Equation (4). In fact, Besanko, Gupta, and Jain outline a number of reasons why the error term ξ_j is likely to be correlated with prices and product line length, namely that demand depends on advertising, shelf space, supply availability, and a number of other in-store factors that are observable to the retailer and consumer, but not the econometrician.

Optimal price and product line decisions are derived under the assumption that RTE cereal firms play a general Nash game in prices and product line lengths.[5] Although much of the literature on product differentiation (Nevo, for example) assumes managers set prices for individual brands, previous research on cereal manufacturer conduct suggests that managers rather choose a pricing strategy for the entire product line and then position individual brands within an overall price location.[6] Further, we allow for the possibility that strategic interaction is a source of dynamic behavior independent of the various reasons for dynamic demand described above. Indeed, critics of the CV approach suggest that it is ill-conceived because it tries to capture in a static parameter behavior that can only logically occur over time—the notion of a "reaction" necessarily implies a passage of time after an impulse occurs. Therefore, we follow Roberts and Samuelson and Vilcassim, Kadiyali, and Chintagunta (1999) in specifying a simple two-period dynamic optimization model in order to capture the simple, inter-temporal dimension of inter-firm reactions in both price and product line decisions. Because strategic interaction as a source of dynamic supply behavior remains a testable hypothesis, however, we retain the possibility that reactions do occur in the current period (are *ex ante* rather than *ex post*) in order to test for the appropriate form of the game. In this way, we present a more general treatment of inter-firm price and product line rivalry.

Given the assumptions regarding the market-demand for cereal outlined here, the two-period profit function faced by firm j is

$$(5)\qquad \begin{aligned} V_{j0} &= (\pi_{jt} + \rho\pi_{j,t+1}) \\ &= (p_{jt} - c_{jt})S_{jt}M - g_j(n_{jt}) \\ &\quad + \rho[(p_{j,t+1} - c_{j,t+1})S_{j,t+1}M - g_j(n_{j,t+1})], \end{aligned}$$

where ρ is a discount factor, M is the size of the entire market, g_j is the cost of a product line of length n_j, and c_j is the marginal cost of production for firm j. The marginal cost of production is assumed to be derived from a Generalized Leontief (GL) unit–cost function, C_j. A GL cost specification is chosen because it is flexible (meaning that it is an approximation to an arbitrary functional form), it is inherently homogeneous in prices without normalization, it is affine in output without further restriction, and it imposes convexity in output, while concavity in prices, symmetry, and monotonicity can be maintained and tested. Total production and marketing costs are a function of the primary inputs to cereal production and marketing—grains, sugar, and food production labor—so the cost of producing one unit of output is

$$(6)\qquad c_j(\nu) = \sum_k \tau_{jk}\nu_k + \sum_k \sum_l \tau_{jkl}(\nu_k\nu_l)^{1/2} + \mu_j,$$

where ν_k is a vector of input prices and μ_j is an iid random error term. With this unit–cost function, the marginal cost of cereal production and marketing is also Generalized Leontief, so retains the attributes described previously. While production costs are almost certainly convex in output, product line cost can be either concave or convex in the number of brands. If there are economies of scope in producing multiple brands from the same process, then costs will rise at a decreasing rate.

[5] Our focus on manufacturer strategies requires that we maintain two assumptions throughout the study. First, as in Besanko, Gupta, and Jain and Slade, retailers are assumed to be monopolists over their own consumers so we do not explicitly consider retail price competition or product line competition. Slade describes survey data that support this assumption. Second, we assume competitive channel interactions between retailers and manufacturers so that any change in wholesale prices are directly reflected in retail prices and retailers stock entire product lines.

[6] This practice was most evident during "Grape Nuts Monday" when the maker of Grape Nuts (Post) reduced prices for all of their cereals by 20% across the board.

On the other hand, if forgone economies of scale or development costs dominate, then line length is likely to impose convex costs. To allow for either possibility, we specify the cost of line length as a quadratic and leave the particular structure of the cost function as an empirical question:

$$(7)\quad g(n_{jt}, w) = \delta_0 + \delta_1 n_{jt} + (1/2)\delta_2(n_{jt})^2 + \sum_k \delta_k w_k,$$

where $\delta_0 > 0$, $\delta_1 > 0$, and $\delta_2 < 0$ or $\delta_2 > 0$ according to the assumptions above and w_k is a vector of prices for inputs to the product-development process.

Roberts and Samuelson describe a firm that does not anticipate the reactions of its rivals as "naive" and one that does as "sophisticated." We extend this concept to differentiate between *ex ante* expectations of current-period reactions and *ex post* responses by rivals. In this way, we are able to test for which, or both, represents an appropriate description of the game played by rival cereal manufacturers. Assuming a general Nash equilibrium, the first order conditions to the problem defined in Equation (5) provide optimal response equations in both price and product line length. First with respect to price, the necessary condition becomes:

$$(8)\quad \frac{\partial V_{j0}}{\partial p_{jt}} = S_{jt}M + (p_{jt} - c_{jt})M\left(\frac{\partial S_{jt}}{\partial p_{jt}} + \sum_i \frac{\partial S_{jt}}{\partial p_{it}}\frac{\partial p_{it}}{\partial p_{jt}}\right) + \rho(p_{j,t+1} - c_{j,t+1}) \times M\left(\frac{\partial S_{j,t+1}}{\partial p_{jt}} + \sum_i \frac{\partial S_{j,t+1}}{\partial p_{i,t+1}}\frac{\partial p_{i,t+1}}{\partial p_{jt}}\right) = 0,$$

where i indexes rival firms, and we define $\varphi_{ij} = \partial p_{it}/\partial p_{jt}$ as the expected current-period response of firm i to a change in the price of firm j, and $\omega_{ij} = \partial p_{i,t+1}/\partial p_{jt}$ as the expected *intertemporal* response.[7] Substituting the expressions $\partial S_j/\partial p_j = -\alpha S_j(1 - S_j)$ and $\partial S_j/\partial p_i = -\alpha S_i S_j$ into Equation (8) and then solving for the retail margin in period t gives an estimable equation for the price-response of firm i in terms of the utility function parameters, the expected margin, and expected competitor reactions:

$$(9)\quad (p_{jt} - c_{jt}) = \left[\frac{-1}{\alpha(1 - S_j) + \sum_i \alpha S_i \varphi_{ij}}\right] - \rho\left[\frac{(p_{j,t+1} - c_{j,t+1})\left(\sum_i S_{i,t+1}S_{j,t+1}\omega_{ij}\right)}{S_{jt}(1 - S_{jt}) - \sum_i S_{it}S_{jt}\varphi_{ij}}\right] \quad \forall j,$$

where $\varphi_{ij} \neq 0$ and $\omega_{ij} \neq 0$ indicate a departure from the Bertrand-Nash pricing rule that is typically assumed in existing price and product line decision models. Although product line decisions produce integer outcomes for the number of brands sold by each retailer, here we assume product line length is continuous in order to make the analysis somewhat tractable. Therefore, the first order conditions with respect to line length are

$$(10)\quad \frac{\partial V_{j0}}{\partial n_{jt}} = (p_{jt} - c_{jt})M\left(\frac{\partial S_{jt}}{\partial n_{jt}} - \sum_i \frac{\partial S_{jt}}{\partial n_{it}}\frac{\partial n_{it}}{\partial n_{jt}}\right) - \rho(p_{j,t+1} - c_{j,t+1}) \times M\left(\frac{\partial S_{j,t+1}}{\partial n_{jt}} - \sum_i \frac{\partial S_{j,t+1}}{\partial n_{i,t+1}}\frac{\partial n_{i,t+1}}{\partial n_{jt}}\right) - \delta_1 - \delta_2 n_{jt} = 0,$$

which we then solve for the optimal line length using the share equations in (4) to yield:

$$(11)\quad \delta_1 + \delta_2 n_{jt} = (p_{jt} - c_{jt})M(\gamma_1 + \gamma_2 n_{jt}) \times \left[S_{jt}(1 - S_{jt}) - \sum_i (\gamma_1 + \gamma_2 n_{it})S_{jt}S_{it}\theta_{ij}\right] - \rho M(p_{j,t+1} - c_{j,t+1}) \sum_i \psi_{ij}S_{i,t+1}S_{j,t+1},$$

where $\theta_{ij} = \partial n_{it}/\partial n_{jt}$ is the expected single-pe-

[7] The parameter φ_{ij} is also known as the conjectural variation (Bresnahan), while ω_{ij} is the dynamic conjectural variation in the sense of Riordan, Dockner, or Roberts and Samuelson. Because both attempt to describe expected responses on the part of rivals, many argue that only the dynamic parameter can truly represent the concept of a conjectural variation.

riod response of firm i to a change in the product line length of firm j and $\psi_{ij} = \partial n_{i,t+1}/\partial n_{jt}$. To arrive at an estimable form of Equation (11), we then substitute the optimal margin from Equation (9) and solve for line length as a function of the share parameters and market shares of each firm.[8] The full model, therefore, consists of Equations (4), (9), and (11) for each firm and is estimated in one simultaneous equations procedure using the data that is described next.[9]

Data and Estimation Methods

To provide a comparison to existing differentiated-products research, we apply our model of market share rivalry to sales and product line data from the RTE cereal industry. Specifically, we focus on the period following the industry-wide price cuts of early 1996 so that our model captures a single competitive regime rather than one in which firms switch from price to nonprice forms of competitive rivalry (Cotterill). The RTE cereal industry is an ideal subject for an analysis of price and product line rivalry because it is one of the most concentrated oligopolies in the packaged product industry and it is widely accepted that new product introductions do indeed form an important method of competitive foreclosure (Scherer; Hausman; Cotterill; Nevo).

Our data are from the Information Resources, Inc. (IRI) InfoScan database for the Baltimore/Washington market covering 65 four-week periods from the third quarter of 1995 to the fourth quarter of 1999.[10] Because our intent is to test the market-level impact of alternative firm-level marketing strategies, it is necessary to use scanner data from a particular sample market rather than an aggregate, national-level data set. Many other studies use a similar market-level approach, both because of the relevance of describing the impact of marketing strategies that are typically targeted to specific geographic markets and the fact that data-gathering firms often make only data from certain markets available for academic research (Slade; Kadiyali, Vilcassim, and Chintagunta 1996). Over the sample period, the top five cereal companies (Kellogg, Post, General Mills, Quaker Oats, and Ralston) sold a total of 224 different cereal brands; some 84 of these were introduced during the sample period. The data include brand-level measures of average price, total unit movements, and the percentage of each brand sold on any sort of merchandising program. This particular IRI data set does not provide any further details on the specific merchandising techniques used, other than to assure users that it includes a wide range of programs supported by the manufacturer intended to provide a temporary increase in sales. The total quantity of cereal sold by each firm is defined as the total number of pounds sold through all retail outlets. Brands sold in different-sized packages are combined by converting all sales into pound-equivalents and aggregating over all brands. Table 1 provides a summary of each firm's average price, unit sales, and market share over the sample period.

Product line length is a simple count of the number of brands each week with nonzero sales for each manufacturer. Because there are several periods during which Ralston had a zero market share, we exclude these cereals from all estimates and subsequent model selection tests. With the relatively short time period covered by these data and the low rate of

[8] Although Vilcassim, Kadiyali, and Chintagunta specify dynamic, cross-tool response parameters, the simplifications necessary to identify all the implied parameters (36 in our case) are unacceptable. Moreover, the effect of product line decisions on pricing, and vice versa, are implicitly estimated in our model through the demand function. For example, if General Mills was to increase its product line by one brand, a positive product line response parameter means that we expect Kellogg to increase its product line in response. This is expected to cause the demand for Kellogg cereals to rise and, therefore, cause Kellogg to raise its prices. In response, General Mills will raise its prices if prices are strategic complements.

[9] Note that we are able to construct weekly brand counts for all firms except for the private label manufacturers. Therefore, the final model consists of five demand and price equations, but only four brand equations.

[10] IRI combines Baltimore and Washington to form a single market for their data gathering activities.

Table 1. Summary Statistics for Top Four Cereal Companies

Variable[a]	Units	n	Mean	SD	Minimum	Maximum
S_1		65	0.229	0.031	0.167	0.323
S_2		65	0.268	0.048	0.159	0.389
S_3		65	0.124	0.028	0.081	0.205
S_4		65	0.065	0.022	0.032	0.126
p_1	$/lb	65	3.603	0.226	2.999	4.033
p_2	$/lb	65	3.099	0.246	2.517	3.725
p_3	$/lb	65	3.054	0.285	2.584	3.744
p_4	$/lb	65	3.013	0.340	2.339	3.760
q_1	m lbs./period	65	1.462	0.192	1.116	1.995
q_2	m lbs./period	65	1.715	0.309	1.087	2.591
q_3	m lbs./period	65	0.788	0.167	0.502	1.250
q_4	m lbs./period	65	0.411	0.141	0.218	0.792
n_1	Count	65	36.123	2.503	32.000	41.000
n_2	Count	65	40.738	2.857	35.000	46.000
n_3	Count	65	26.077	1.915	23.000	31.000
n_4	Count	65	18.354	0.975	16.000	20.000

[a] In this table, the firm indices are defined as follows: General Mills = 1, Kellogg = 2, Post = 3, Quaker Oats = 4. The total share does not sum to 1.0 because firm 5, private label, and the share of the outside option are excluded from this table. Prices are expressed as dollars per pound, quantities as millions of pounds per 4-week period, and product line length is a simple count of brands per company.

prevailing inflation, all dollar values are in nominal rather than real terms.

Input prices for both the cereal production and line cost functions are from the Bureau of Labor Statistics (USDL 2004a,b). Cereal production cost is a function of manufacturing wages in the food products industry and price indexes for two key raw materials: wheat and sugar. Product line length, on the other hand, should reflect a larger proportion of marketing costs relative to production costs. For this reason, we use price indexes for cardboard and for workers in the marketing services industry.[11] All input prices are not seasonally adjusted and reflect national average values because cereal manufacturers tend not to locate near their destination markets.

Given that the demand, price response, and product line response sub-blocks each contain explanatory variables that are likely to be endogenous, the entire system is estimated using nonlinear three-stage least-squares (NL3SLS) where the instruments include all exogenous and predetermined variables, including input prices, promotional decisions, seasonal factors, and binary brand indicators.[12] Given the large number of parameters in the most general form of the model, we require a correspondingly large number of instruments.[13] To this end, we follow Villas-Boas (2003) and interact each of the exogenous and predeter-

[11] Although cardboard prices are also a significant cost in the production of cereals, in preliminary regressions designed to test the quality of the instruments, cardboard prices were found to be negatively related to the number of brands sold each period (statistically significant at a 5% level). Clearly, packaging costs are an important consideration in the decision to introduce a new brand. These preliminary regression results are available from the authors upon request.

[12] A reviewer notes that non-linear pricing arrangements (slotting fees) between manufacturers and retailers may mean that input prices are poor instruments for retail prices. However, slotting fees are a one-time payment from a manufacturer to a retailer in order to ensure that a new product is stocked. There is, however, no guarantee that future wholesale prices will not rise with production costs. Moreover, data on the magnitude of slotting fees is not available on an accurate, systematic basis and so could not be incorporated into the empirical analysis.

[13] Because the model is estimated in panel data and contains a lagged endogenous variable, least squares estimates will also be biased and inconsistent due to the "incidental parameters problem" (Hsiao) However, by using an instrumental variables estimator our NL3SLS estimates address this problem as well as the endogeneity of prices and product-line lengths.

mined variables with firm-specific binary variables. Consequently, the number of available instruments is 105, while there are 100 estimated parameters so the model is slightly overidentified. Further, we define the size of the outside option in a manner similar to Nevo and Berry, Levinsohn, and Pakes. Specifically, we assume consumers in the Baltimore/Washington market purchase RTE cereal at the same per capita rate as in the rest of the United States (approximately 10.1 lbs. per capita per year, or 0.625 servings per capita based on a typical 20 oz. serving size) and then calculate the implied market size as if the entire Baltimore/Washington population purchased cereal at this rate within the four-week period. The difference between this implied "saturation rate" and observed sales is the size of the outside option, or the implicit number of consumers who choose the no-purchase option during each four-week period. Because population estimates are available only on a quarterly basis, we smooth the data series using a quadratic regression filter where the implied total market consumption rate is a function of a quadratic four-week time trend:

$$M_t = \beta_0 + \beta_1 t + \beta_2 t^2 + \mu_t, \tag{12}$$

where μ is an iid normal error term.[14] This regression provided an excellent fit to the aggregate consumption data, so fitted values from the regression in Equation (12) were used to estimate the entire model.[15] Finally, because the general form of the game described contains many potential competitive structures as plausible alternatives, we select from among candidate models using a quasi-likelihood ratio testing procedure.

[14] Besanko, Gupta, and Jain encounter a similar problem in their data, but use the linear filter proposed by Slade instead. In the four-week data series used here, however, the data smoothed in this way provided a much poorer fit than with the quadratic filter and, moreover, the linear filter is imposed on the data in an *ad hoc* way rather than allowing the data to determine its own optimal interpolation scheme as in Equation (12).

[15] The coefficient of determination from this regression is 77.8% and all coefficients are more than 10 times their standard errors.

Results and Discussion

Much has been written regarding the marketing strategies of the largest cereal manufacturers prior to and following the industry-wide price reductions of early 1996 (Cotterill, for example). Consequently, it is important to put the data describing these firm's strategies in context before analyzing the results of estimating the dynamic behavioral models described earlier. First, note from Table 1 that General Mills has a leadership role in the Baltimore/Washington market. However, over the sample period used for this study, their local market share was considerably less than their share of the national market. Therefore, as is the case with all other studies that use brand-level data in a single sample market (for example, Slade, or Besanko, Gupta, and Jain), all of the results presented here should be interpreted as the realization of larger corporate strategies in a local market rather than an indication of the overall performance. Second, note that the number of brands (product line length) for Kellogg is significantly greater and its average price significantly lower than that of General Mills, despite Kellogg's slightly lower market share. However, the simple snapshot provided by these summary statistics does not reveal the evolution of each firm's strategic choices over time. In fact, over this period Kellogg had been spending less in all areas of marketing in order to lower costs—a strategy that resulted in sharply declining market share and the loss of their once-dominant market position to General Mills. This table also does not show the general trend toward lower aggregate cereal sales across the entire sample data period. As U.S. consumers move more toward convenient meal solutions targeted to specific tastes and perceived nutritional requirements, mass-market ready-to-eat cereals are becoming less popular among working-age market segments. New brands are, in fact, making inroads into niche markets, such as cereals targeted specifically to women, healthy snack-food alternatives, or as functional foods. Further, generic and private label cereals, generally produced by Quaker Oats and Ralston, are making gains at the value-end of the market at the expense of the leading firms. In summary, the data in Table 1 are significant in three ways. First, they highlight the importance of controlling for aggregate trends in demand when investigating firm-level changes in marketing strategy. Second, it is clearly necessary to include a measure of the outside option, or likely cereal purchases that do not involve any of the firms included in the sample. Third, the fact that General Mills has a higher market share despite charging higher prices and offering less variety suggests that the nature of strategic interaction among these firms is highly complex and does not yield to simple explanations.[16]

Prior to presenting the results obtained by testing among alternative forms of the game played by cereal manufacturers, estimates of the demand system are presented. While it is not the primary focus of this study, the structure of demand is always of considerable interest. Table 2 provides estimates of the structural utility model as well as estimates of the marginal production cost and product line expansion cost functions. In terms of brand preference, these estimates show that consumers tend to have a slight preference for General Mills cereals over Kellogg, while both leading firms hold a rather larger advantage over Post and Quaker. With respect to the marginal utility parameter estimates, each of the promotion, line length, lagged share, and price have the expected sign and are significantly different from zero. As is generally the case in dynamic models of consumer demand, the lagged share parameter estimate suggests that factors such as habit formation, learning, or brand loyalty are important determinants of consumer utility. Specifically, the estimate of 0.119 indicates that current-period utility is only relatively weakly related to utility in the previous period. This is perhaps not surprising given that the data are in four-week time periods and the consumption cycle for RTE cereals is likely to be somewhat shorter than this.[17] Further, the fact that both price and line length are highly significant suggests that each are likely to be regarded as important marketing variables by managers of all firms, but the managerial significance of each is better conveyed by the elasticities of demand with respect to price and line length.

To this end, Table 3 presents the partial elasticity estimates with respect to price and line length for each firm. These elasticities are partial in the sense that they reflect the marginal impact of a particular firm's price or line change on its own sales, and do not net out the effect of all competitor interactions—either strategic or structural. The IIA attribute of logit models is apparent from these results. Namely, that the cross-price and cross-line elasticities of demand are equal for each firm relative to all others. While IIA can be alleviated by using either a mixed logit or nested logit approach, the complexities involved in estimating the first-order conditions with respect to either of these other specifications make them unsuited to the general Nash solution concept used here. Given this caveat, however, the elasticity estimates do appear to be plausible and, most importantly, do not suffer from some of the anomalies (such as complementarity of products that are obvious substitutes in use or positive own-price elasticities) that can arise when using other flexible demand systems or simple linear models (Gasmi, Laffont, and Vuong; Dhar et al.). In particular, all own price elasticities are less than -1.0, which is consistent with firm-level profit maximization, and all cross-price elasticities are greater than zero. Notice that private label cereals have the least-elastic demand among all brands included in the sample. While one would expect the firm with the most market power, or the dominant firm—General Mills—to have the lowest elas-

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[16] Although some studies of cereal demand consider the substitutability among specific brands within certain subcategories such as "children's cereals," "adult cereals," or "family cereals," the objective of this study is to better understand firm-level market share strategies (Hausman). Consequently, the number of brands a firm sells is a strategic variable of considerable interest, the impact of which is lost by invoking assumptions of separability among cereal categories.

[17] In fact, based on 2002 AC Nielsen Homescan data, the purchase cycle for RTE cereal is 20 days (Progressive Grocer).

Table 2. Structural Model Parameter Estimates: Logit Demand, Marginal Cost, Line Cost

Utility Function			Marginal Cost			Product Line Cost		
Variable[a]	Estimate	t-ratio	Variable	Estimate	t-ratio	Variable	Estimate	t-ratio
General Mills	3.024*	25.232	General Mills	−0.830	−0.591	General Mills	−19.745*	−6.552
Kellogg	2.695*	24.528	v_{11}	0.212*	4.882	w_{11}	2.333*	3.409
Post	1.933*	18.803	v_{21}	0.002	0.100	w_{21}	0.206*	2.078
Quaker	1.191*	11.558	v_{31}	0.011*	4.048	w_{31}	0.267*	2.381
Promotion	0.004*	7.604	Kellogg	−2.029	−1.936	w_{41}	3.488*	4.496
Lagged share	0.119*	2.852	v_{12}	0.162*	4.074	Kellogg	−3.813*	−3.347
Line-length	31.052*	12.062	v_{22}	0.023	1.153	w_{12}	13.878*	14.402
Price	−0.894*	−31.022	v_{32}	0.016*	2.039	w_{22}	0.456	1.567
			Post	−1.838	−1.543	w_{32}	1.456*	2.567
			v_{13}	0.224*	5.651	w_{42}	17.014*	18.192
			v_{23}	0.027	1.328	Post	0.068	0.068
			v_{33}	0.010*	3.124	w_{13}	24.781*	16.111
			Quaker	−1.744	−1.271	w_{23}	1.919*	5.383
			v_{14}	0.175*	4.011	w_{33}	1.725*	4.097
			v_{24}	0.020*	6.033	w_{43}	43.506*	27.888
			v_{34}	0.016	1.465	Quaker	−3.250*	−2.923
						w_{14}	15.121*	10.218
						w_{24}	0.126	0.468
						w_{34}	3.065*	6.896
						w_{44}	31.192*	17.732
Q	387.322							
χ^2	194.451							

[a] In this table, a single asterisk indicates significance at a 5% level. The marginal production-cost function includes a firm-specific constant in addition to firm-specific responses to input price indices for v_{1j} = manufacturing wages for food industry workers, v_{2j} = price of wheat, v_{3j} = price of sugar (domestic), while the marginal cost of introducing new products is a function of firm-specific constants and other variables including: w_{1j} = linear line-length, w_{2j} = quadratic line-length, w_{3j} = price of cardboard, and w_{4j} = marketing services wage index. Q is the minimized NL3SLS objective function value. The chi-square goodness-of-fit statistic compares the minimized NL3SLS objective function value under the estimated model to the value of Q from a null model consisting only of firm-specific constants. Under the null hypothesis, the test statistic is chi-square distributed with 88 degrees of freedom, so the critical chi-square value at a 5% level of significance is 110.897.

Table 3. Demand Elasticities With Respect to Price and Brand

Marketing Tool:[a]	Demand Response of each Firm:				
	General Mills	Kellogg	Post	Quaker	Private Label
p_{GM}	−2.484	0.737	0.737	0.737	0.737
p_K	0.744	−2.026	0.744	0.744	0.744
p_P	0.338	0.338	−2.392	0.338	0.338
p_Q	0.174	0.174	0.174	−2.519	0.174
p_{PL}	0.136	0.136	0.136	0.136	−1.923
n_{GM}	0.043	−0.013	−0.013	−0.013	−0.013
n_K	−0.017	0.046	−0.017	−0.017	−0.017
n_P	−0.005	−0.005	0.036	−0.005	−0.005
n_Q	−0.002	−0.002	−0.002	0.026	−0.002

[a] In this table, all elasticities are significantly different from zero at a 5% level. The variable subscripts refer to General Mills (GM), Kellogg (K), Post (P), Quaker (Q), and private label (PL). The t-ratio for all price elasticities is 31.0219 (in absolute value), while for the product line elasticities the t-ratio is 12.0623 in absolute value.

ticity, IRI does not report individual private label brands, so the elasticity of private-label demand estimated here is actually a category-level elasticity. At this higher level of aggregation, we would expect to observe a lower elasticity of demand. With respect to RTE cereal prices, General Mills and Kellogg appear to be the most vulnerable to substitution from other firms' products. This result is also intuitively plausible given the leadership role played by these two firms.

With respect to product line length, all of the estimated elasticities are again of the correct sign and are of plausible magnitude. Individually, Kellogg derives the greatest benefit from introducing new brands, followed closely by General Mills, Post and Quaker, in that order. It is also apparent that the magnitude of these elasticities is relatively small. Using a product line analog of the Dorfman-Steiner rule (that the optimal ratio of product development expenditures to sales is equal to the ratio of the product line length elasticity to the price elasticity of demand), the optimal budget allocation for product line extension is approximately 1.7% of sales for General Mills and 2.3% for Kellogg—figures that are considerably higher than estimates of each company's actual spending on product development as a share of sales. In 1999, the actual ratios were approximately 1.1% for General Mills and 1.8% for Kellogg. Similar to the price-elasticity case, the cross-line length elasticities for General Mills and Kellogg are considerably higher than for the other companies, suggesting that Quaker and Post are relatively more vulnerable to product line competition from the leading firms than vice versa. In fact, this result helps explain the profusion of brand-extensions in the cereal industry by the leading firms.

Table 2 also includes estimates of the marginal cost of cereal production and of introducing new brands, or increasing line length. Although the theoretical model presented above maintains a Generalized Leontief production-cost structure, the interaction terms were all found to be statistically insignificant, so only the linear terms were included in the final model estimates. With this more parsimonious model, all input prices have the expected sign and the majority are significantly different from zero. At the sample mean of each input price, these estimates indicate that Post has a significant cost advantage ($0.437/lb) relative to the market leaders, Kellogg ($0.722/lb) and General Mills ($1.303/lb), and the other minor competitor, Quaker ($1.028/lb). Comparing marginal cost estimates between General Mills and Kellogg may explain some of the price differential shown in Table 1 and the intrinsic brand preference parameters in the demand model—by producing higher cost cereals, General Mills appears to be engaging in vertical, as well as horizontal, differentiation from Kellogg and the other indus-

Table 4. Model Selection Tests

Model[a]	Restriction	QLR	R	χ^2_q
1. General Model	None	NA	NA	NA
2. Static Only	$\omega_{ij} = \psi_{ij} = 0$	251.452*	28	41.337
3. Dynamic Only	$\phi_{ij} = \theta_{ij} = 0$	184.388*	28	41.337
4. Bertrand-Nash	$\omega_{ij} = \psi_{ij} = \phi_{ij} = \theta_{ij} = 0$	395.698*	56	74.451
5. Bertrand in Prices	$\phi_{ij} = \omega_{ij} = 0$	347.668*	40	55.759
6. Bertrand in Product Line	$\theta_{ij} = \psi_{ij} = 0$	72.022*	32	46.170

[a] The column QLR refers to the value of the quasi-likelihood ratio test statistic calculating using Equation (13) in the text. The column R refers to the number of restrictions implied by the restriction described in the second column. The fifth column is the critical chi-square value using a 5% level of significance and R degrees of freedom. A single asterisk indicates rejection of the restriction at a 5% level.

try members. These results also show reasonably strong support for the quadratic product line cost hypothesis, with the cost of introducing a new brand an increasing, convex function of the number of brands in the lineup. Clearly, introducing a new brand must bring either direct or strategic economic benefits to warrant the incremental cost of research, development, marketing, and, ultimately, cannibalization of existing products—net of the portfolio effects discussed by Nevo.

Any strategic benefits will be apparent from the CV parameter estimates. As suggested above, the most general form of the structural model described in Equations (5), (9), and (11) encompasses many possible forms of strategic interaction as special cases. These include: (1) a static CV model ($\omega_{ij} = \psi_{ij} = 0$); (2) a dynamic CV model ($\varphi_{ij} = \theta_{ij} = 0$); (3) Bertrand-Nash in prices and product line length ($\omega_{ij} = \psi_{ij} = \varphi_{ij} = \theta_{ij} = 0$); (4) Bertrand-Nash in prices and Nash in product line length ($\varphi_{ij} = \omega_{ij} = 0$); (5) Bertrand-Nash in product line length and Nash in prices ($\psi_{ij} = \theta_{ij} = 0$), or, of course; and (6) one that includes both static and dynamic reactions in both price and product line length. Because each of the first five models is nested in the six, we select the best from among them using quasi-likelihood ratio (QLR) tests (Gallant and Jorgenson). In each case, the QLR test compares a restricted version to the most general, unrestricted model (6). As is well known, the test statistic used to compare the restricted and unrestricted versions is calculated by finding the difference between the minimized NL3SLS objective function values:

$$(13) \quad QLR = [Q_i(\Theta_i) - Q_j(\Theta_j)] \sim \chi^2_q,$$

where Q_i is the objective function value of the unrestricted model and Q_j is the objective function value of the restricted version for parameter vectors Θ_k. The resulting statistic is chi-square distributed with q degrees of freedom, where q is the number of restrictions. Table 4 shows the results of applying this test to each of the five restricted models. Clearly, each of the five sub-models are rejected in favor of the most general, dynamic Nash version, so the remainder of this section concerns only the parameters from the unrestricted model.

While other models of Bertrand-Nash rivalry in differentiated products are able to estimate the degree of differentiation using an endogenous price- and product line-response framework, they do not account for the likelihood that rivals in concentrated industries anticipate each others' reactions when making marketing decisions. Although subject to many criticisms (Genesove and Mullin), an approach that allows for nonzero conjectures at least cannot be accused of this oversimplification. Moreover, allowing for both static and dynamic conjectures addresses one of the primary criticisms of the CV approach, namely that it attempts to capture an inherently dynamic phenomenon in a static measure of behavior. Estimates of the single and multi-period CV parameters for both price and

Table 5. NL3SLS Logit Response Parameter Estimates

	General Mills[a]		Kellogg		Post		Quaker	
	Estimate	*t*-ratio	Estimate	*t*-ratio	Estimate	*t*-ratio	Estimate	*t*-ratio
Static price response								
ϕ_{1j}	1.000	NA	1.232*	6.629	1.333*	10.018	1.500*	10.078
ϕ_{2j}	1.171*	11.984	1.000	NA	1.113*	17.714	1.317*	11.416
ϕ_{3j}	1.366*	6.050	1.477*	7.090	1.000	NA	1.567*	6.704
ϕ_{4j}	2.108*	4.542	1.766*	3.839	2.074*	6.002	1.000	NA
ϕ_{5j}	−8.682*	−4.086	−7.611*	−3.593	−6.818*	−4.998	−8.290*	−4.939
Dynamic price response								
ω_{1j}	1.000	NA	−0.343*	−2.483	−0.456*	−4.798	−0.304*	−2.397
ω_{2j}	−0.233	−1.831	1.000	NA	−0.131	−1.750	0.069	0.815
ω_{3j}	−0.719*	−2.993	−0.741*	−3.559	1.000	NA	−0.488*	−2.528
ω_{4j}	−0.697	−1.849	−0.370	−1.502	−0.468*	−2.431	1.000	NA
ω_{5j}	−0.385	−0.692	0.218	0.416	0.433	1.371	0.173	0.360
Static line-length response								
θ_{1j}	1.000	NA	4.419*	7.006	6.825*	3.284	5.299*	3.247
θ_{21j}	2.251*	8.386	1.000	NA	6.178*	3.992	−4.464*	−4.483
θ_{31j}	3.007*	5.152	5.174*	5.033	1.000	NA	7.982*	3.305
θ_{41j}	5.029*	4.966	8.529*	8.547	−9.616*	−5.989	1.000	NA
Dynamic line-length response								
ψ_{1j}	1.000	NA	−1.258*	−3.865	−1.220*	−3.141	−10.071*	−4.997
ψ_{2j}	−0.718*	−4.537	1.000	NA	6.164*	10.591	6.248*	5.709
ψ_{3j}	0.880*	2.733	−2.388*	−4.167	1.000	NA	−14.499*	−12.681
ψ_{4j}	1.473*	2.907	2.847*	4.179	−10.381*	−3.736	1.000	NA

[a] In this table, a single asterisk indicates significance at a 5% level. Each parameter represents the expected response by the column firm (j) to each of its rivals' price or product line strategies.

product line responses are shown in Table 5. With respect to both marketing variables, a positive conjecture indicates a form of strategic complementarity—a firm expects its rival to respond to an increase in price or product line length with an increase of its own—while a negative conjecture suggests a form of strategic substitution.[18] Complementarity in this context is analogous to cooperative pricing or product development, while substitutability implies competitive behavior between pairs of firms. Focusing first on the price-response estimates, the results in Table 5 demonstrate the depth of insight provided by estimating both static and dynamic CV parameters. Interestingly, prices are strategic complements in the current period among each of the four major cereal manufacturers, but are very strong strategic substitutes with respect to the private label products. This result suggests that the major manufacturers tend to price cooperatively, albeit in an implicit way, but regard the presence of private label suppliers as somewhat of a moderating influence on prices.

Allowing for dynamic reactions, however, produces an entirely different picture. While the firms appear to expect others to follow their price changes in the current period, all expect opposite reactions in the next. Therefore, what may appear to be implicit collusion breaks down over time, which is somewhat contrary to the generally accepted notion that repeated play facilitates coordinated behavior (Friedman). Vilacassim, Kadiyali, and Chintagunta (1999) report a similar result among

[18] Note that this usage is not the same as the usual sense in which quantities are strategic substitutes in a Cournot game and prices strategic complements in a Bertrand game even with zero conjectures.

personal-care product firms and attribute their findings to differences in fundamental competitiveness factors among manufacturers (i.e., cost or loyalty advantages). The same can be said with respect to the cereal manufacturers represented here as the two strongest firms in terms of brand preference (General Mills and Kellogg) appear to price most competitively in the second period. However, neither Kellogg's cost advantage over General Mills nor Post's cost advantage over all other firms appear to influence their long-run price behavior. For three of the major firms, their conjectures with respect to private label pricing behavior switch from negative to positive, indicating that these firms expect private label suppliers to price cooperatively after an initial period of competitive pricing. Indeed, it seems logical that private label firms price competitively in the current period in order to capture market share when presented with the opportunity following a price increase by the national brands.

With respect to product line length, the current-period CV parameters again suggest that the lengths of rival firms' product lines are strategic complements. Because the data do not include the number of private label brands, implicit cooperation among each of the major firms appears to be nearly homogeneous. Only the cases of Post/Quaker and Quaker/Kellogg show any tendency to compete in product line length in the sense that opposing moves are used to gain strategic advantage over a rival. When dynamic reactions are included, the estimates in the lower panel of Table 5 reveal a pattern of behavior that is not nearly as consistent as in the price-conjecture case. Rather, firms appear to single out specific competitors and react, often in a relatively strong way. For example, General Mills tends to accommodate, or match line changes from Kellogg in the current period but counter them in the longer run. Although the dynamic reaction by General Mills is relatively timid, Quaker tends to respond to expected changes from General Mills and Post in an aggressive way that is directly opposite to their current-period response. This result may reflect Quaker's fundamental competitive weakness relative to the other firms. While Post has a distinct cost advantage, General Mills has strong intrinsic brand preference and Kellogg has a combination of the two, Quaker has no apparent advantage over the other firms. Thus, it is forced to compete aggressively in new product introductions with respect to General Mills and Post. Interestingly, however, Quaker and Post both appear to follow Kellogg in new product introductions. Although it is neither the cost nor preference leader, Kellogg is arguably the most active and innovative in product development, often inspiring "me too" behavior among less competitive firms. Whether Kellogg's net competitive position puts it at an advantage relative to the other firms, however, can be tested using the equilibrium pricing model developed here.

Application: Estimating Value-Added and Profit-Added

A number of authors estimate the competitive effects, and welfare effects, of introducing new products. For example, Hausman and Leonard and Hausman use a traditional demand systems approach to estimate the value of a new product introduction. Essentially, their insight is that consumers gain in two ways when a firm extends its product line: (1) they have a greater variety of products to choose from, and (2) if the new product is close to another, the price of the incumbent product is likely to be lower due to heightened competition. By calculating the compensating variation (i.e., the utility-constant change in consumer surplus), they are able to estimate the value of a new brand of bathroom tissue. Alternatively, Kadiyali, Vilcassim, and Chintagunta (1999) use a simple linear model to estimate the effect of introducing a new type of yogurt on the structure of competitive prices. Besanko, Gupta, and Jain provide yet another insight by using a random utility model of demand to estimate the value created for an average consumer of an individual brand and then using this information to determine the competitive position of a number of yogurt brands. Following their logic, we calculate the value-added across each cereal manufacturer's product line as the difference between the average willingness to pay and the

Table 6. Value-Added, Consumer Surplus, and Operating Profit: Top Four Cereal Companies: 1995–1999

		Competitive Regime			
		Nash C.V.		Nash-Bertrand	
Firm	Value Added[a]	Consumer Surplus	Profit	Consumer Surplus	Profit
General Mills	7.400 (0.569)	5.825 (0.700)	1.575 (0.247)	5.946 (0.581)	1.454 (0.061)
Kellogg	8.469 (0.549)	6.730 (0.684)	1.739 (0.258)	6.928 (0.570)	1.541 (0.099)
Post	5.720 (0.433)	3.770 (0.652)	1.950 (0.336)	4.442 (0.438)	1.279 (0.042)
Quaker	3.480 (0.232)	1.528 (0.473)	1.952 (0.369)	2.284 (0.229)	1.196 (0.029)

[a] Values in parentheses are standard errors. Profit is operating earnings as it excludes fixed costs such as advertising, overhead, and depreciation. Value-added, consumer surplus, and operating profit are measured in dollars per pound. Under either competitive regime, value added is the sum of consumer surplus and unit profit. Line length is held constant to show effect of different competitive regimes in prices only.

cost of production using the expression for value-added given by[19]

$$(14)\quad va_t^j = mv_t^j - c_t^j = \left[\frac{\beta_0^j + \lambda S_{t-1}^j + \sum_k \beta_{1k} x_k^j + b(n_t^j)}{\alpha}\right] - c_t^j(v),$$

where va^j is the amount of value added by firm j, and mv^j is the average willingness to pay for the cereals produced by firm j, for all $j = 1, 2, \ldots, N$. Notice from Equation (14) that value added can also be expressed as the sum of consumer surplus and producer surplus, or operating profit, by subtracting the market price from the first term on the right-hand side and adding it to the second. However, while the amount of value added from a given level of production and product line length is independent of the type of price competition, the allocation of total value between consumers and producers is not.

Table 6 shows the value added by each firm, as well as its decomposition into consumer surplus and operating profit components under Bertrand-Nash competition and the conjectural variations equilibrium maintained in this study. Despite consumers' preference for General Mills cereals, Kellogg generates the most value added due to its combination of relatively high valuation and low-cost of production. This result may reflect the growth of brand equity over time through aggressive marketing and branding efforts directed at cereals such as Corn Flakes, Frosted Flakes, or Rice Krispies—Kellogg is able to maintain relatively high brand preference without incurring the cost of producing truly better cereals. Such branding effects are only possible if cereal manufacturers are able to vertically differentiate their products to a certain extent. Clearly, this is indeed the case. Second, the results in Table 6 also show that "value added" is not necessarily the same as profitability. While Kellogg is the value-added leader, Post generates the most profit per box of cereal, followed by Quaker, Kellogg, and General Mills in that order. Although consumers may perceive cereals to be vertically differentiated and pay for the apparent difference in quality, the premium that they are willing to pay does not justify the added input costs. Moreover, profit leadership on the part of the "second tier" firms is enhanced by the nature of strategic interaction among these firms. While all firms' profits are higher under the conjectural variations equilibrium than the Bertrand-Nash benchmark, due to the cooperative pricing outcome reported above, it is

[19] Besanko, Gupta, and Jain point out that firm-level value creation can only be estimated by calculating the inclusive value across all of a firm's brands. However, in this paper we do not estimate a brand-level model of demand, so we rely on the average valuation for a firm's brands to calculate the amount of value created.

Table 7. Line Length and Value Added, Net of Line Costs: Top Four Cereal Companies: 1995–1995

	Competitive Regime				
	Nash C.V.		Nash-Bertrand		Change in
Firm	Line Length	Value Added[a]	Line Length	Value Added	Value Added
General Mills	36.003 (2.473)	7.400 (0.569)	23.301 (2.251)	5.496 (0.989)	−1.904
Kellogg	42.335 (2.649)	8.469 (0.549)	36.469 (2.403)	6.626 (0.835)	−1.843
Post	26.362 (1.083)	5.720 (0.433)	25.102 (1.118)	3.278 (0.557)	−2.442
Quaker	19.187 (0.526)	3.480 (0.232)	18.957 (0.551)	2.412 (0.247)	−1.068

[a] Values in parentheses are standard errors. Change in value added is net of product line cost.

the lesser firms that experience the greatest profit differential. Indeed, this is understandable given the apparent market power exercised by the dominant firms. While the estimated CV parameters in Table 5 do not suggest that Post or Quaker are Stackelberg followers, the relatively low cross-price elasticities both exhibit with respect to General Mills and Kellogg prices indicate that the lesser firms benefit by matching price increases by the dominant firms.[20] Logically, if minor competitors are able to participate in the industry-wide monopoly without losing sales to other firms, it is in their interest to do so.

In order to conduct a similar analysis for product line strategy, it is necessary to first calculate the value added for line lengths consistent with a general CV equilibrium in product lines and then compare this result to the value added consistent with Bertrand-Nash competition. The difference in line length and value added under each competitive regime is shown in Table 7. Note that just as the results in Table 6 were generated holding the form of product competition constant, price competition is maintained to be general Nash in order to show the independent effect of different product strategies. Again, the cooperative nature of line strategies is evident in these results as a reversion to Bertrand-Nash behavior results in shorter product lines for each firm. Unlike the pricing-strategy results, however, the difference between Bertrand and general Nash behavior for the dominant firms is far greater than for the lesser firms. In fact, the equilibrium line lengths for Post and Quaker change very little under Bertrand rivalry while Kellogg would shed 16% of its brands, and General Mills fully 55% of its brands. This reduction in variety under competition is in contrast to the theoretical models of equilibrium variety developed by Dixit and Stiglitz in the context of continuous, CES preferences and with Anderson and de Palma, who model the demand for differentiated products from a discrete choice perspective. Both of these papers demonstrate that equilibrium variety rises the more competitive an industry becomes, not less.

Because line length is an argument of consumer utility, we use the implied differences in line lengths to calculate the effect of product strategy on value added, net of product line cost. Using Equation (14) to find the change in value added from a discrete change in product line length, the incremental value added from moving from one competitive regime to another is

$$(15) \quad va_t^i = (\Delta n_t^i, p_t^i)$$
$$= b(\Delta n_t^i)/\alpha - g_t^i(\Delta n_t^i, w),$$

where Δ indicates the difference in line length titive regimes. Although it is not clear from the results in Table 7 whether dominant firms or lesser firms benefit the most from non-Ber-

[20] If Post and Quaker were Stackelberg followers, then their CV parameters with respect to General Mills and Kellogg would not be significantly different from zero, while the CV parameters for leaders with respect to the followers would be non-zero. In other words, if they were indeed followers, then neither Post nor Quaker would expect the leaders to react to a change in their own prices.

trand competition in product lines, they nevertheless illustrate the fundamental tradeoff between generating value and incurring additional cost. For example, in moving from Bertrand to a CV equilibrium in product line length, General Mills adds the greatest number of additional brands. While they benefit from a significant increase in consumers' willingness to pay, they also incur a high cost to generate this added value. However, notice that General Mills has the lowest cost of product line expansion next to Quaker, so if it can gain market advantage by adding brands, it is likely to do so. On the other hand, neither Post nor Quaker, despite its line-expansion cost advantage, appear to change line strategies significantly between a hypothetical Bertrand equilibrium and the observed CV outcome. This is a reflection of the realization that they rely on cooperation with the dominant firms for their pricing power and not on unilateral nonprice strategies like General Mills and Kellogg appear to do.

Conclusions, Limitations, and Implications

This study investigates the roles played by price and product line length decisions in a model of dynamic strategic interaction in the U.S. ready-to-eat cereal industry. Empirical research questioning the price-competitiveness of firms in this industry has proliferated in the last three decades, but relatively little attention has been given to cereal manufacturer's nonprice marketing strategies. Given the number of new cereal brands introduced annually by all firms, however, the role of product line length as a strategic factor is a natural topic of interest. By allowing for general Nash equilibrium behavior, we are able characterize firm-level conduct as either more cooperative or competitive than a Bertrand-Nash standard in both price and product line length. The empirical application of this model uses a structural equilibrium approach in which the demand side consists of a dynamic logit share system with an outside option, as well as first order conditions that describe optimal price and product line responses. Estimates of the entire system are obtained using a NL3SLS instrumental-variables procedure.

Following other recent studies in the empirical industrial organization and marketing literatures, we use scanner data from a sample market to study firm-level strategic interactions. Specifically, the data consist of 65 four-week periods of price (1995 through 1999), quantity, and merchandising activity data for all brands of RTE cereal sold in the Baltimore/Washington market. With these data, we find a general Nash, conjectural variations equilibrium to be the best characterization of RTE cereal competition in this market. In the preferred equilibrium, all firms appear to price cooperatively in the current period, but price more competitively once multi-period reactions are allowed. Similarly, static product line strategies tend to be cooperative among all firms, while dynamic interactions are more heterogeneous, with some firms cooperating in the long run and others using line length as a competitive tool.

We then use these structural parameter estimates to derive simulated value-added estimates for each firm in the industry. Perhaps not surprisingly, we find that the dominant firms (General Mills and Kellogg) generate significantly more value added compared to the lesser firms (Post and Quaker) under both the observed CV equilibrium and a hypothetical Bertrand outcome. However, the lesser firms tend to generate less consumer surplus and more profit by cooperating with the dominant firms in both price and product line. While this is not a formal "followship" outcome, these firms clearly benefit by cooperating with the dominant firms, thus supporting the virtual duopolistic structure. Comparing equilibrium product lines between the CV and Bertrand solutions shows a marked difference between the two dominant firms. Although General Mills would significantly reduce its brand offerings if it were to ignore possible product line responses from the other firms, its reduction in total value added, net of product line costs, would be similar to the change experienced by both Kellogg and Post simply because it has the lowest product development costs. This insight points to the value of conducting competitive analyses that include both price and nonprice marketing tools—and allowing for both static and dynamic responses—because it is driven largely by the uniform negative dynamic conjectural variations by General Mills relative to the product lines of all other firms.

Despite our belief that this research provides powerful insights into firm-level competition in a closely contested industry, there are a number of other questions future research may investigate, or methods that others may wish to employ. First, allowing for Markov-perfect dynamic equilibria in a model as equally as rich as the current one would represent a key methodological advance. Although we are uncertain as to how the results would change, the approach used here, and in much of the dynamic marketing literature, is only an approximation to a true dynamic equilibrium. Second, our data set encompasses a critical time period in the RTE cereal industry, but a longer data set would allow other researchers to target specific eras in competitive strategies followed by each firm. Similarly, if our data had included national-level sales, then we would have been able to make more general statements regarding the role of price and variety in this industry. Finally, the modeling insights presented in this research can serve as a useful basis for similar research into industries that possess similar characteristics to RTE cereal. For example, although the carbonated soft drink industry has been the subject of much research in recent years (see Dhar et al.), the key question of product line length has not been adequately addressed, although casual observation suggests that it is likely of critical importance to beverage manufacturers.

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