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Abstract

Price conjectural variations are estimated to measure the degree of price competition in a product differentiated oligopoly. The empirical model is a simultaneous equation system of product demand and price reaction functions in which own and cross price elasticities of demand are estimated in conjunction with price conjectural variations. Specifically, the price conjectural variations are estimated directly in the reaction functions, rather than deduced indirectly from profit data. The empirical model is applied to pairs of ready-to-eat breakfast cereal products, using brand data collected during the course of the antitrust case brought by the Federal Trade Commission in the 1970s against Kellogg, General Mills, and General Foods. The empirical results reject competitive brand pricing behavior in favor of independent or interdependent pricing. Further, the hypothesis of a unique consistent conjecture is rejected.

I. INTRODUCTION

Conjectural variation estimates have been used in recent studies to measure the market power of firms in oligopolistic markets. The studies thus far have been limited to homogeneous product industries with a uniform industry price.[1] In this paper, the conjectural variation model is extended in two ways. First, the model is expanded to take into account differentiated products and individual firm prices. Second, firm price conjectural variations are estimated in a price reaction function that defines the firm's price as a function of the price of a substitute product.

The empirical model is a simultaneous equation system of product demand and price reaction functions in which own and cross price elasticities of demand are estimated in conjunction with price conjectural variations. The advantage of this approach is apparent in the context of a differentiated product market. When products are not homogeneous, profits may be a poor indicator of the degree of price competition. Moreover, the slopes of the reaction functions which measure the actual price responses of the firms to one another, provide additional information about competitive firm behavior. This framework allows for statistical tests of various types of oligopolistic behavior to be performed. Specifically, the estimated price conjectural variations can be tested against the conjectural variations derived under alternative hypotheses of competitive and collusive behavior. In addition, the consistent conjectures hypothesis can be tested.

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[1] See Iwata (1974); Gollop and Roberts (1979); Roberts (1983); Geroski (1982); Rogers (1983); and Slade (1984).

The empirical model is tested by examining price competition between pairs of ready-to-eat breakfast cereal products. Individual brand data were collected during the course of the antitrust case brought by the Federal Trade Commission in the 1970s against Kellogg, General Mills, and General Foods.[2] Because the firms produce a large number of differentiated breakfast cereal products, price competition is estimated for competing brand pairs rather than for the competing firms. Given this limitation, the estimated conjectural variations are used to describe the degree of price competition between similar competing cereal products, and generalizations to firm competition have to be qualified.

Overall, the empirical results reject the hypothesis of rivalrous brand pricing in favor of independent or interdependent pricing, and the pricing pattern appears to depend on brand characteristics rather than firm characteristics. Specifically, the degree of price competition between brands depends primarily on how differentiated the products are, and not on the firms that produce the products. In addition, the hypothesis of a unique consistent conjectures equilibrium is rejected although the price conjectural variations are consistent with the actual price responses. The absence of competitive brand pricing may allow the firms to compete in nonprice dimensions, such as in new product introductions.

The price reaction function model is presented in Section II, and the data and estimation procedure are discussed in Section III. The

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[2] Federal Trade Commission antitrust proceeding In the Matter of Kellogg Company, General Mills, Inc., General Foods Corporation, and The Quaker Oats Company, Docket No. 8883.

empirical results are presented in Sections IV and V. Analysis of the empirical results and conclusions follow in Sections VI and VII.

II. A PRICE REACTION FUNCTION MODEL OF OLIGOPOLY

The basic theoretical model employed is standard in the expanding literature on the conjectural variation approach to modeling oligopoly behavior. The price conjectural variation is a firm's anticipated response from a rival firm if the firm changes its price. Depending upon the anticipated response, the resulting equilibrium price and output configuration can range from the competitive to monopolistic outcome. Thus, a firm's price conjectural variation can be used to characterize the degree of competitiveness in a market. Extending this conjectural variation model to a differentiated product market requires that firm specific demand conditions be taken into account when measuring competitive price behavior.

Given firm demand elasticities, the price conjectural variations of each firm are estimated directly in the firm's price reaction function. Price reaction functions arise in oligopolistic markets as a firm realizes over time that changes in its prices may invoke subsequent changes in prices by its rival. The reaction functions define the price the firm charges, based on the rival's price and how the firm expects the rival to respond to its own price changes.

A. Firm Demand Curves

In a differentiated product duopoly setting, the demand function for firm i can be specified as a simple linear relationship:

$$Q_i = a_i - b_i P_i + c_i P_j$$

where $a_i = a_{0i} + h_i GA_i + d_i Y_i$ for $i=1,2, \quad j \neq i$

Q_i is output for firm i, P_i and P_j are the prices for firms i and j, GA_i is a measure of advertising for firm i, and Y_i represents other determinants of demand, such as income and population. Demand is decreasing in own price, increasing in substitute price, and assumed to be more responsive to own price than to the substitute price, so $b_i > c_i > 0$.[3] The demand elasticity that firm i faces is then:

$$e_i = (-b_i + c_i cv_i)\ (P_i/Q_i) < 0.$$

As shown, the demand elasticity for oligopolistic interdependent firms is characterized by three parts: (1) the firm's own partial elasticity of demand $-b_i(P_i/Q_i)$; (2) the cross elasticity of demand between the substitute products, $c_i(P_j/Q_i)$ and (3) the conjectured response elasticity, $cv_i(P_i/P_j)$, where $cv_i = \partial P_j/\partial P_i$ is firm i's price conjectural variation with respect to firm j. The elasticity of demand facing the firm is often interpreted as a measure of market power that the firm can exercise.

From the above formulation of the demand elasticity, the effect of the conjectural variation on the firm's perceived market power can be shown. Simply, $\partial e_i / \partial cv_i > 0$, so demand becomes more inelastic as anticipated price behavior approaches cooperation. Further,

$$\frac{\partial e_i}{\partial c_i} = cv_i \frac{P_i}{Q_i} \gtrless 0 \qquad \text{for } cv_i \gtrless 0.$$

The effect of an increase in the cross price elasticity on the firm's market power depends on the anticipated price behavior. Most simply, if anticipated pricing is independent, the cross elasticity has no

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[3] The assumption of differentiated products allows one to derive a continuous demand curve distinct from the discontinuity of the Bertrand price model (Hotelling, 1929).

effect on perceived market power. If anticipated pricing is cooperative, an increase in the cross elasticity will cause the elasticity of demand to decline and market power is raised; for anticipated rivalrous pricing, the firm's demand elasticity increases.

In a differentiated product setting, the firm demand function may also depend on advertising. The effects of advertising messages on consumer purchases are likely to extend beyond one period, so the stock of advertising goodwill is the advertising variable often used in demand functions.[4] Assuming a linear demand curve, with advertising as a shift variable, advertising will decrease the elasticity of demand that the firm faces.[5]

B. Price Reaction Function Model

Firm i maximizes profits $\mathbf{W}_i$ by choosing price, assuming advertising goodwill is given. The objective function is:

$$\max_{P_i} \mathbf{W}_i = P_i Q_i - C_i(Q_i) - A_i$$

subject to

$$Q_i = a_i - b_i P_i + c_i P_j ,$$

$$\mathbf{W}_i \geq 0,$$

and $$a_i = a_{0i} + h_i GA_i + d_i Y_i .$$

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[4] See Nerlove and Arrow, 1962. Generally, assuming a geometric lag for the effects of advertising, the stock of goodwill is defined as the sum of current advertising expenditures plus the depreciated stock of advertising goodwill (Cable, 1972; Schmalensee, 1972; Cowling, 1976; Lambin, 1976; Grabowski and Mueller, 1978).

[5] An increase in brand advertising will decrease the elasticity of demand that the firm faces. In particular,

$$\frac{\partial e_i}{\partial GA_i} = -\frac{P_i h_i(-b_i + c_i cv_i)}{Q^2} > 0.$$

A_i are current advertising expenditures and are treated as a fixed cost, and C_i are production costs. The first order profit maximization conditions are:

$$Q_i + P_i(\partial Q_i/\partial P_i) - MC_i(\partial Q_i/\partial P_i) = 0$$

where $\partial Q_i/\partial P_i = -b_i + c_i cv_i$,

and MC_i are marginal costs for firm i, assumed to be constant.

The firm's first order profit maximization conditions can be expressed as price reaction functions. Continuous price reaction functions $R_i(P_j)$ define the firm's price as a function of the rival's price and its own marginal costs. Specifically,

$$R_i(P_j):\ \ P_i = f_{0i} + f_{1i}P_j + f_{2i}MC_i + f_{3i}GA_i + f_{4i}Y_i,$$

for i=1,2, $i \neq j$, where the reaction function parameters $[f_{0i} .. f_{4i}]$ are functions of the demand coefficients and the conjectural variation. Of special interest are the coefficients on rival price, f_{1i}, which are direct measures of price interdependence. The rival price reaction function coefficients are identically:

$$f_{1i} = \frac{-c_i}{-2b_i + c_i cv_i} \qquad \text{for } i = 1,2.$$

These coefficients exhibit the same properties as the Lerner measure of profits.[6] In particular, both measures are positive for conjectural variation values between -1 and 1, and both are increasing in the price

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[6] The firm's first order profit maximization conditions can be written in the familiar Lerner index form:

$$L_i = \frac{(P_i - MC_i)}{P_i} = \frac{-1}{(-b_i + c_i cv_i)(P_i/Q_i)}$$

where $\partial L_i/\partial cv_i > 0$, $\partial L_i/\partial b_i < 0$, and $\partial L_i/\partial c_i \gtrless 0$ for $cv_i \gtrless 0$.

conjectures.[7] Even under the competitive scenario, the slopes of the reaction functions are upward sloping, just as profits are greater than zero.[8]

To illustrate the "dynamics" of this duopoly model, consider the simple Bertrand case where each firm assumes independent behavior on the part of the rival firm, $cv_i = 0$. The slopes of the reaction functions reduce simply to $2b_1/c_1$ for $R_1(P_2)$ and $c_2/2b_2$ for $R_2(P_1)$. Under reasonable assumption, $2b_1/c_1 > c_2/2b_2$, and the reaction functions intersect defining unique Bertrand prices, P_i^B, where

$$P_i^B = \frac{2b_j(a_i + d_iY_i + b_iMC_i) + c_i(a_j + d_jY_j + b_jMC_j)}{4b_ib_j - c_ic_j}$$

Instead, the two firms might price interdependently, $cv_i = 1$. (It will be shown in the next section that $cv_i = 1$ represents perfect collusion only under symmetry conditions). The slope of $R_2(P_1)$ becomes steeper and the slope of $R_1^{-1}(P_2)$ becomes flatter. If the intercepts remain constant or increase, the equilibrium shows P_1 and P_2 higher than under the Bertrand assumption. If the intercepts were to decrease, however,

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[7] $$\frac{\partial f_{1i}}{\partial cv_i} = \frac{c_i^2}{(-2b_i + c_icv_i)^2} > 0$$

Further, $\partial f_{1i}/\partial b_i < 0$, and $\partial f_{1i}/\partial c_i > 0$. The coefficients f_{0i}, f_{3i}, and f_{4i} are also increasing in the conjectural variation.

[8] Notice that the coefficients f_{1i} measure the slopes of the price reaction functions which need not be consistent with the underlying conjectural variations. Only under the requirements of consistency will the slopes measure the conjectural variations, and it will be the conjectural variation of the rival firm. How firm i anticipates firm j will respond to a price change should correspond to how firm j actually responds to a price change as shown in $R_j(P_i)$.

as anticipated price behavior became more coordinated, the effect on the new equilibrium prices is ambiguous.[9]

C. Price and Quantity Conjectural Variations

Under symmetry, the price conjectural variation estimates would be bounded by negative one and positive one. Where the demand and cost elasticities are allowed to differ by firm, however, the price conjectures are no longer bounded and thus may be difficult to interpret. To define competitive, collusive, and consistent conjectures within this framework, a relationship between price and quantity conjectures is derived from profit maximization conditions. Consider the demand function as defined above, with the corresponding inverse demand function:[10]

$$P_i = \frac{(a_i b_j - a_j c_i) - b_j Q_i - c_i Q_j + b_j d_i Y_i + c_i d_j Y_j}{b_i b_j - c_i c_j}$$

If the firm's decision variable is price, then the first order conditions are:

$$Q_i + (P_i - MC_i)(-b_i + c_i cv_i(p)) = 0.$$

If the decision variable is quantity, the first order conditions are:

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[9] $$\frac{\partial P_i}{\partial cv_i} = \frac{c_i(a_i + d_i Y_i + c_i P_j - b_i MC_i)}{(-2b_i + c_i cv_i)^2} \gtrless 0$$

The effect $\partial P_i/\partial cv_i$ is positive if $MC_i < (a_i+d_iY_i+c_iP_j)/b_i$. As anticipated cooperative behavior increases, the components of the intercept term in the price reaction function all increase except for the marginal cost term which will decrease. Thus, if marginal costs are small relative to the other price determinants, then the net effect will be an increase in the intercept.

[10] This methodology is borrowed from Kamien and Schwartz (1983).

$$(P_i - MC_i) + Q_i\left(\frac{-b_j - c_i cv_i(q)}{b_i b_j - c_i c_j} \right) = 0,$$

where $cv_i(q)$ is the quantity conjectural variation. Equating $-(P_i - MC_i)/Q_i$ defines a relationship between cv(p) and cv(q). Specifically,

$$\frac{1}{-b_i + c_i cv_i(p)} = \frac{-b_j - c_i cv_i(q)}{b_i b_j - c_i c_j}$$

where $\partial cv(q)/\partial cv(p) > 0$, and $\partial^2 cv(q)/\partial cv(p)^2 > 0$, for $-1 \leq cv(p) \leq 1$ and $-1 \leq cv(q) \leq 1$. The function is positive and increasing for values of cv(p) and cv(q) between -1 and 1.

To illustrate the relationship between cv(p) and cv(q), several special cases are considered under general assumptions and under the special case of symmetry. The Cournot quantity model assumes cv(q)=0, with the corresponding price conjecture:

$$cv_i(p)_{CN} = c_j / b_j$$

where $0 < cv_i(p)_{CN} < 1$. A Cournot quantity conjecture corresponds to a positive price conjecture. If firm 1 were to increase Q_1 (and by definition lower P_1), firm 2 would lower P_2 to maintain sales in light of the decrease in P_1.

If cv(q) = 1, then

$$cv_i(p)_{CL} = (b_i + c_j) / (b_j + c_i)$$

where $cv_i(p)_{CL} > cv_i(p)_{CN} > 0$. If quantity changes are perfectly matched, the corresponding price conjectural variation shows that price changes will be matched as well. Note that $cv_i(p)_{CL}$ is not constrained to be less than or equal to one, but may be greater than one, depending on the demand elasticities. For the special case of symmetry, $b_i=b_j$,

$c_i = c_j$, and firms have identical costs, then $cv_i(p)_{CL}$ is identically equal to one.

If $cv(q) = -1$, then

$$cv_i(p)_{CM} = (-b_i + c_j) \;/\; (-b_j + c_i)$$

which cannot be signed unambiguously. In the case of symmetry, $cv_i(p)_{CM} = -1$.

The consistent conjectural variations in price and quantity are a final case of interest. As above, let cv_1 and cv_2 represent the price conjectural variations, and f_{12} and f_{11} represent the corresponding price reaction function slopes. Consistency requires that

$$cv_i = \partial R_j / \partial P_i \qquad \text{for } i = 1,2.$$

Solving for the consistent conjectures leaves quadratics in cv_i. The possible solutions are:

$$ccv_i = \frac{-b_i b_j \pm [(b_i b_j)(b_i b_j - c_i c_j)]^{1/2}}{-b_j c_i} \qquad i = 1,2,\ i \neq j$$

and the restriction that price is positive rules out one of the solutions to the quadratic. Under the assumptions of linear demands and symmetry, the consistent conjectural variations in price and quantity define the same unique equilibrium. The resulting price cost margin is larger than under Bertrand pricing, but smaller than under perfectly interdependent pricing.

The above price reaction function model differs from the standard estimation procedures in two related aspects. First, price reaction functions are estimated so that the direct price response of a firm to the rival's price is estimated along with the anticipated price response. Second, the conjectural variations are not deduced from the residual profits left unexplained by the demand elasticity. Thus, precise profit or cost data are not required for the analysis. The data required are exogenous firm specific cost data that will shift a firm's reaction function independently of the rival firm's function.

III. EMPIRICAL APPLICATION OF THE PRICE REACTION FUNCTION MODEL

A. Ready-to-Eat Breakfast Cereal Industry

The price reaction function model is applied to pairs of breakfast cereal products from the U.S. ready-to-eat breakfast cereal industry. The breakfast cereal industry can be characterized as a product differentiated oligopoly.[11] Since the initial shakeout of beginning firms in the early 1900s, the market has been dominated by Kellogg, General Mills, and General Foods Post, whose aggregate share of the market was 71% in 1954, and 83% in 1970. Kellogg has consistently been the market leader in terms of volume, with market shares of 35% in 1954, and 47% in 1970. General Mills and Post have vied for second place, with respective market shares of 16% and 20% in 1954, and 21% and 15% in 1970. In conjunction with the high concentration, the accounting profit rates are high. Over the period 1966-1970, the average profit rate for Kellogg was 10.4%, for General Mills 12.8%, but only 5.3% for Post.

The high concentration level in this industry cannot be entirely explained by production economies of scale. Several studies suggest

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[11] See Scherer (1985) for a more detailed description of the ready-to-eat breakfast cereal industry.

that plant economies are attained at 4-6% of industry output.[12] A partial answer might be found in multi-plant or firm economies. In particular, marketing economies are important as the industry is one of the most advertising intensive industries in the U.S., and television is the primary marketing medium. The advertising-sales ratio for the breakfast cereal industry is 15-17%, compared to 3.8% for consumer goods.

Another key characteristic of interest in the breakfast cereal industry is the high degree of product differentiation. In 1950, 26 brands were offered by six firms. The number of brands steadily increased, with 28 new brand introductions between 1965 and 1970, and 22 brands between 1970 and 1973. By 1973, there were 80 different brands offered by the leading six cereal firms.

B. Cereal Submarkets

The high degree of product differentiation makes it difficult to assess overall firm price competition. Thus, it may be more appropriate to examine price competition between competing brands produced by the firms rather than price competition between the firms in the aggregate. Accordingly, twelve individual submarkets with two cereal brands each are identified and the price reaction function model is applied separately to each submarket[13] (See Table 1). The

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[12] See Headen and McKie, 1966, and Glassman (Docket No. 8333). The results of these studies are supported by the facts that Kellogg and General Mills operate multiple plants, and that new plants have been built to operate in this capacity range (Scherer, 1985).

[13] The degree of product differentiation makes the segmentation of products into duopolies difficult and somewhat subjective. As an objective starting point, the companies' marketing plans were used. Submarkets of "closely related" brands are analyzed in these plans in

submarkets are restricted to two brands each so that the empirical application is kept relatively simple and the problem of defining the appropriate substitute price is avoided. In light of the possibility that particular cereal brands may have more than one direct competitor, submarkets were selected primarily on the basis of whether a single, significant (in terms of volume sales) direct or close competitor could be identified.[14]

The twelve submarkets represent on average 52% of total volume in the breakfast cereal industry. Five submarkets characterize competition between Kellogg and Post, accounting for 38.6% of Kellogg volume and 57.6% of Post. Additionally, six submarkets characterize competition between Kellogg and General Mills, with 53.8% of Kellogg volume, and 78.1% of General Mills. Only one pair of Post and General Mills brands could be identified as direct competitors.[15]

C. Data

The primary source of data is that collected during the antitrust case brought by the Federal Trade Commission in the 1970s.

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terms of sales and advertising. For example, in Kellogg's marketing plans, a Corn Flakes market, a Raisin/Prune market, a Bran/Prune Flakes market, among others are identified.

[14] This selection procedure should help to minimize any specification bias in the demand equations. However, if more than one direct competitor might exist for a particular brand, then the brand was included in two separate submarkets. For example, Kellogg considered Post Toasties to be the most direct competitor of Corn Flakes, and vice versa; however, General Mills considered Kellogg Corn Flakes to be most directly competitive with Wheaties. Consequently, Kellogg Corn Flakes is included in both the CF and AF2 markets.

[15] The other three firms, Nabisco, Quaker, and Ralston were excluded from the analysis primarily due to lack of firm cost data and difficulty in identifying direct competitors.

Monthly sales, quantity, advertising expenditures, and wholesale list prices are available by brand. Data for Kellogg and Post were available for the entire estimation period, 1962-1972. General Mills' data were generally available for only 1967-1972.

Wholesale list price data were used as an estimate of retail prices, as trade deals were seldom used. Price per pound were adjusted for coupon redemptions where data were available. Brand advertising goodwill stocks were based on a Koyck lag, assuming a constant 60% decay rate.[16] Firm cost data were used instead of brand cost data because cost data is not available at the brand level, and marketing strategies of the firms suggest that using a firm-wide cost measure is preferred to brand costs. Generally, prices were raised to generate additional revenues on those brands that had the most inelastic demand, and not necessarily on those whose particular costs had increased (See Appendix A).

D. Econometric Model

The equations to be estimated for each of the twelve submarkets are the two brand demand functions and the two price reaction functions:

(1) $Q_1 = b_{11}P_1 + b_{12}P_2 + c_{11}GA_1 + c_{12}Y_1 + c_{10} + u_1$

(2) $P_1 = f_{11}P_2^* + f_{12}MC_1 + f_{13}GA_1 + f_{14}Y_1 + f_{10} + w_1$

(3) $Q_2 = b_{21}P_1 + b_{22}P_2 + c_{21}GA_2 + c_{22}Y_2 + c_{20} + u_2$

(4) $P_2 = f_{22}P_1^* + f_{21}MC_2 + f_{23}GA_2 + f_{24}Y_2 + f_{20} + w_2$

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[16] Alternative decay rates, ranging from 10% to 90% were also specified, but as the monthly advertising measures were not significant in the demand equations, only the advertising coefficients based on a 60% decay rate are reported.

and the following cross equation parameter restrictions are imposed by substitution for i=1,2:

(5) $f_{i0} = -c_{i0}/(2b_{i1} + b_{i2}cv_i)$

(6) $f_{i1} = -b_{i2}/(2b_{i1} + b_{i2}cv_i)$

(7) $f_{i2} = (b_{i1} + b_{i2}cv_i)/(2b_{i1} + b_{i2}cv_i)$

(8) $f_{i3} = -c_{i1}/(2b_{i1} + b_{12}cv_i)$

(9) $f_{i4} = -c_{i2}/(2b_{i1} + b_{12}cv_i)$

Let Q_i, i=1,2 be quantity sales of brand i, P_i the prices of the brands, MC_i the constructed marginal costs of the firm producing brand i, GA_i the constructed stocks of advertising goodwill for brand i, and Y_i the other demand determinants such as income and population, and may include lagged quantity. Prices, costs, advertising, and income are represented in constant dollars, and quantity and advertising are divided by population.

In the reaction functions (2) and (4), P_1^* and P_2^* represent the expected values of P_1 and P_2. Expected prices will be measured by the actual price since the companies monitor price changes by rivals at the retail level almost daily, and the average lag between a decision to change a price and its implementation averages 27 days. The disturbance terms in (1) - (4) may be autocorrelated. Finally, cereal sales volume is seasonal, so monthly dummy variables are included in the demand equations.

The four equations are estimated using a nonlinear three stage least squares (NL3SLS) procedure, accounting for autocorrelated errors.[17] The restrictions on the price reaction function coefficients are imposed on the estimation procedure by substitution to get a unique estimate of the price conjectures. The NL3SLS estimators obtained are consistent and asymptotically normally distributed when lagged dependent variables are not used as predetermined variables (Amemiya, 1983). Gallant (1977) has argued that it may be reasonable to include lagged dependent variables as predetermined and still retain the result that the estimators are consistent.

IV. PRICE REACTION FUNCTION AND DEMAND FUNCTION ESTIMATES

The four equations, two demand functions and two price reaction functions, are estimated for each market. Cross equation parameter restrictions are imposed across the equations for each firm, yielding unique estimates of the price conjectural variations.

A. Price Reaction Function Estimates

The empirical results show that the price reactions functions fit the data well. In twenty two of twenty four equations, the rival price and cost coefficients fall in the expected range between zero and one.

Kellogg and Post. In the Kellogg-Post markets, the rival brand's price appears to be the most important determinant of price (See Table 2). In nine of the ten equations, the price reaction function

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[17] An alternative procedure is to use a full information maximum likelihood (FIML) estimation procedure. Unlike the linear case, however, the nonlinear full information maximum likelihood estimator may be inconsistent if the error terms are not normally distributed (Amemiya, 1977). The NL3SLS estimates are consistent even if the error terms are not distributed normally, but the estimation procedure may be less efficient than the FIML procedure. Amemiya (1983) has shown that for NL2SLS, when the model is nonlinear only in parameters, the NL2SLS estimator is as efficient as the limited information maximum likelihood estimator.

elasticities are positive and significant, and relatively high in value. That is, in these particular submarkets, as Kellogg increases the price of its product, Post does so as well, and vice versa. Moreover, the slopes of the reaction functions are quite steep for seven brands, ranging from 0.56 to 0.95. For example, in the CF market, the rival price elasticities are 0.69 and 0.72 for Kellogg and Post respectively. In the two presweet markets SS and FF1, the rival prices in the Kellogg price equations are not quite as important as in the other equations, with coefficients of only 0.27 and 0.28. The Post FF1 rival price elasticity of -0.00 shows that the Post price does not depend on the Kellogg price.

Where the rival price is an important determinant in the Kellogg-Post price equations, the cost elasticities are relatively low. Costs are significant in six of the ten equations and overall explain only a small part of brand price. The largest cost elasticities for both Kellogg and Post are found in the FF1 market which show cost coefficients of 0.38 for Kellogg and 0.28 for Post. The cost elasticity for Kellogg SS is 0.19 and significant.

Kellogg and General Mills. The reaction function elasticities and the cost elasticities in the Kellogg-General Mills markets are quite different from those in the Kellogg-Post markets. Rival price no longer appears to be the primary determinant of price. Firm costs, on the other hand, are significant in thirteen of the equations, with considerably larger elasticities.

A comparison between Tables 2 and 3 shows the differences in the price reaction functions between the markets. In the Kellogg-Post markets, all but one of the price reaction function elasticities are positive, and most are relatively large in value and significant. In contrast, in the Kellogg-General Mills markets, only five of twelve elasticities are significant (one of these is negative)[18], and two are marginally significant. The insignificance of seven out of fourteen rival price coefficients suggests independent pricing behavior for these brands.

Consistent with the hypothesis of independent pricing behavior, the cost coefficients in the Kellogg-General Mills' price equations are large. Under independent pricing, a firm responds more to costs than under interdependent pricing. Most of the cost coefficients fall in the range between 0.16 and 0.50.

The NT1 and AF1 price reaction functions resemble closely the Kellogg-Post CF, RB, BF, and SS submarkets. In particular, the reaction function elasticities for Kellogg and General Mills NT1 and AF1 are high, and the cost coefficients are low.

B. Demand Function Estimates

The demand function estimates that underly the price reaction function estimates fit the data less well than the price reaction functions, but are fairly reasonable. Twenty of the twenty four demand curves have negative demand elasticities, but four equations show the own price elasticity as positive or insignificant. Many of the demand curves, however, do not show strong cross price elasticities.

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[18] The negative elasticity should not arise, however, if demand is negatively related to own price and positively related to substitute price. The negative reaction function elasticity arises for this brand because the cross elasticity in the General Mills FF2 demand equation is negative.

1. Own and Cross Price Elasticities

Kellogg and Post. In the ten estimated demand equations, eight of the own price elasticities are negative and significant, and seven of the cross price elasticities are positive and significant (See Table 4). For example, in the CF market, the own price elasticities are -1.53 and -3.24 for Kellogg and Post respectively, and just slightly larger than the cross price elasticities, suggesting that the competing products are close substitutes. The results in the BF market are similar, with own price elasticities of -1.32 and -2.02 for Kellogg and Post, which are just larger than the cross price elasticities of 0.89 and 1.39.

The demand elasticities for the RB market are not as reasonable. The price elasticities in the Kellogg RB equation has a price elasticity of -5.43, but the cross price elasticity of 5.57 is slightly larger. The Post RB equation shows quantity as being positively related to own price, and negatively related to the substitute price.[19]

In the SS market, the demand elasticities have the expected signs. The cross price coefficient in the Kellogg SS equation of 2.24 is small relative to the own price elasticity of -5.83. These estimates imply that demand for Kellogg SS is not very responsive to the price of the Post SS substitute product. In the FF1 market, the demand elasticities

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[19] When the Post RB equations are run on a quarterly basis, the Post RB demand equation has the expected signs. The own and cross price elasticities are -1.27 and 1.02, but are not significant. It is not clear why the Post RB demand equation is sensitive to the choice of the time period, monthly or quarterly, when none of the other Post demand equations yield such unreasonable estimates.

in the Post equation are both insignificant, although the demand elasticity of -1.28 has the expected sign.

Kellogg and General Mills. In the fourteen estimated demand equations, twelve of the own price elasticities are negative, with nine significant at the 5% level (See Table 5). For example, Total shows an estimated elasticity of -5.95 (-2.64 in NT2)[20], and Wheaties has an elasticity of -3.45. Two of Kellogg's presweet brands, CH and FF2, appear to be responsive to price with elasticities of -2.95 and -2.44. Kellogg AF1 has a negative demand elasticity of -1.70. The remaining two of the fourteen demand elasticities are positive, but only one is significant.[21]

For the FF3 market, the demand elasticities for both General Mills and Post are negative and consistent with the demand estimates in the FF1 and FF2 markets. General Mills Trix has estimated elasticities of

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[20] The difference in the price elasticities for General Mills Total in NT1 and NT2 may be due to omitted variable bias. If the true demand equation for General Mills Total is a function of the substitute prices for both Kellogg Product 19 and Special K, then estimating the demand equation with only one substitute price will cause the own price coefficient to be biased towards zero. From the empirical results, it appears that Total is a closer substitute to Product 19 than to Special K. Thus, leaving the Product 19 price out of the Total demand equation in the NT2 market biases the price elasticity towards zero.

[21] The significant positive demand elasticities for Kellogg NT1 and AF2 can be explained by the sample period. Kellogg Product 19 in NT1 was introduced into the market in 1967 at a slightly lower price than General Mills Total. Demand for the product continued to grow over the period 1969-1972 as more consumers became aware of the product, even as Kellogg raised its price. Kellogg's Corn Flakes, in AF2, is estimated over the period 1967-1972, just when private label cereals began to be introduced. Although price was lowered in response, demand continued to decline. The estimated demand elasticity for Kellogg CF over the longer period 1962-1972 is negative and significant.

-1.13 and -0.70; Post Alpha-Bits demand estimates are -1.46 and -1.28. Unlike the General Mills and Post brand counterparts, Kellogg Froot Loops price coefficients of -3.59 and -2.44 show that demand is relatively more responsive to price.

Finally, the cross price elasticities in the Kellogg - General Mills markets are mostly insignificant, and are not consistently positive in the fourteen equations. Of seven significant cross elasticities, only three are positive. The cross elasticity for General Mills NT1 is significant, showing that Product 19 is a close demand substitute. This result can be contrasted to the cross price coefficient in the NT2 market, which shows that Special K is not as close a demand substitute. The Kellogg AF1 demand equation also has a positive cross elasticity of 0.71, but only marginally significant.

2. Other Effects

The other variables in the demand and price reaction function equations include brand advertising goodwill stock per pound, disposable income per capita, and lagged quantity where significant.[22] These variables were treated exogenously. Unfortunately, none of the advertising stock coefficients are positive and significant. Advertising coefficients are reported for the Kellogg - Post CF, RB, BF, and SS markets, and for the Kellogg - General Mills NT1 and NT2 markets. The advertising variables for the remaining variables were excluded because they were insignificant, and so that the equations

[22] Advertising stock per capita and advertising stock levels were also tried in the demand equations, but the variables were still insignificant in the equations. In addition, the rival brand's advertising goodwill stocks were included in the equations but were dropped because they were insignificant in all cases.

could be extended to the 1967 to 1972 period to gain degrees of freedom.[23]

The insignificance of the vast majority of the advertising stock coefficients is disturbing in an industry which is as advertising intensive as the breakfast cereal industry. The principle explanation for these estimates rests with the advertising data. The advertising data used in this study are monthly advertising expenditure data from accounting reports. The monthly advertising expenditures are not necessarily correlated with monthly advertising messages, although quarterly advertising expenditures were found to be correlated with messages. Some preliminary work with brand demand functions in the quarterly framework show that advertising does increase sales.

Personal disposable income is also an explanatory variable in the demand equations and the coefficients vary in sign across the brands. The income coefficients appear to reflect simply a trend in the brand sales, not accounted for by deflating quantity by population.

C. Specification of Demand Functions

In this conjectural variation model, the demand functions have been specified as linear in own price, substitute price, and

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[23] Price and advertising expenditures for a cereal brand may be correlated, and thus not including advertising in the demand functions may bias the price coefficients. In particular, the own price coefficient may be biased towards zero if advertising is positively correlated with price. However, if monthly advertising and price are not positively correlated as the empirical results suggest, then the price coefficient is unbiased.

Further, where advertising is included in the demand equations but is not treated endogenously, the price coefficients may be subject to simultaneous bias. In this case, both the price and advertising coefficients are biased towards zero if they are positively correlated.

advertising goodwill stock. To test whether this linear specification of the brand demand functions is too restrictive, linear quadratic demand functions were estimated for all the brands. The majority of the demand curves show that the specification of demand curves as linear in prices and advertising goodwill does not appear to be too restrictive. Only seven of the estimated demand functions reject the linear hypothesis, with four of these functions showing that brand demand may be nonlinear in advertising goodwill but still linear in prices (See Appendix B).

In addition, because some of the demand function coefficients do not have the expected signs, the monthly data were aggregated to quarterly, and the demand and price reaction functions were estimated again. Most of the demand coefficients do not vary between the monthly and quarterly estimations, although several of the equations appear more reasonable using quarterly data (See Appendix C). Thus, the statistical tests for competitive, collusive, and consistent behavior are conducted using monthly estimates. However, the empirical results suggest that if enough quantity data were available to provide sufficient degrees of freedom, the equations might be better estimated with quarterly data.

V. PRICE CONJECTURAL VARIATION ESTIMATES AND HYPOTHESIS TESTING

A. Price Conjectural Variation Estimates

Kellogg and Post. The conjectural variation values presented in Table 6 suggest that pricing behavior is interdependent within four of the five Kellogg-Post submarkets. Of the ten price conjectural variations, eight are positive and significantly greater than zero. For these pairs of brands, CF, RB, BF, and SS, each firm anticipates cooperative price changes by the rival firms. For example, the estimated price conjectures for the CF market are 0.63 and 0.94 for Kellogg and Post respectively, which correspond to actual price responses by Post of 0.72 and by Kellogg of 0.69. These estimates conform to the positive price reaction function elasticities reported in the previous section.

In the FF1 market, the estimated conjectural variations are not positive and significant. The price conjectural variation for Post FF1 is insignificant and Kellogg has a price conjecture of -1.78 which is marginally significant. These results indicate that the firms do not anticipate interdependent pricing in this submarket.

Kellogg and General Mills. The conjectural variation estimates for these markets are not as uniform as they are in the Kellogg - Post markets (See Table 7). The NT1 submarket results suggest interdependent pricing behavior for General Mills, and the AF1 submarket shows interdependent behavior for Kellogg. The other five sets of estimates show the price conjectural variation terms to be insignificant.

The results in the NT1 submarket suggest interdependent pricing behavior, with an estimated conjecture of 1.24 for General Mills. General Mills anticipates that Kellogg will follow its price changes and Kellogg's reaction function elasticity of 0.80 supports this. These results can be contrasted to the insignificant conjectural variation estimates for the NT2 submarket that show that although

General Mills Total and Kellogg Special K were the leading nutrition brands, neither viewed the other as a direct competitor.[24] The AF1 market results also suggest some interdependent pricing. Kellogg's conjecture of 1.47 shows that Kellogg prices its Rice Krispies brand assuming that General Mills will price Cheerios cooperatively. For General Mills, however, the conjectural variation estimate is insignificant.

B. Hypothesis Testing

1. Competitive and Collusive Conjectures

The estimated conjectural variations are tested to show whether they represent competitive or collusive behavior. The null hypotheses to be tested are that the estimated conjectural variation is equal to either the competitive or collusive conjectures, as derived in Section II C. Specifically, the null hypothesis is specified as H_o: $cv - cv_k = 0$, where k represents competitive or collusive behavior. The limiting distribution of the variable $(cv - cv_k)$ is normal with zero mean and unit variance.[25]

The calculated competitive and collusive price conjectural variations are reported for seven of the twelve submarkets in Table 8. These markets include CF, RB, BF, SS, and NT1, where the price conjectural variations are significant for both of the competing brands

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[24] Total's marketing strategies targeted the nutrition-minded consumer, while Special K's targeted the weight-conscious consumer. Marketing strategy statements shuggest that the two brands are competitive, although they target different audiences.

[25] Alternative tests, such as the likelihood ratio test, would require substituting directly the specific parameter restriction for the conjectural variations in the price reaction functions.

in the market, and the AF1 and FF1 markets, where one of the conjectures is marginally significant. The conjectures in the remaining five markets are not reported as they are not significantly different from zero. Moreover, these estimates cannot reject either the competitive or the collusive hypothesis.

The calculated competitive and collusive conjectures appear to set up reasonable parameter ranges since many of the estimated price conjectures fall within the defined limits. The calculated competitive price conjectures are all negative, and are less than the corresponding collusive conjectures, except for General Mills NT1.[26] These relationships follow the symmetric case where competitive pricing behavior is represented by a conjectural variation of negative one, and interdependent pricing behavior by a conjectural variation of positive one. For example, in the CF market, the calculated competitive conjectures are -1.27 and -0.79 for Kellogg and Post; the collusive conjectures are 0.97 and 1.03. These calculated conjectures define a reasonable range as the CF estimates of 0.63 and 0.94 fall within this range.

Ten conjectural variation estimates - CF, RB, SS, NT1, and Kellogg BF and AF1 - reject the hypothesis of competitive behavior. The rejection of the competitive hypothesis for ten brands shows that the firms do not anticipate rivalrous pricing behavior from their

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[26] When the NT1 market is estimated using lagged advertising goodwill stock in place of current goodwill stock, and parameter restrictions are not imposed on advertising, similar results emerge for General Mills NT1. In particular, the conjectural variation estimate is 0.92, and the competitive and collusive conjectures are calculated to be -0.76 and 2.95, thus setting up a reasonable range. Further, the hypothesis of competitive behavior is rejected.

competitors, and thus prices are higher than competitive prices in these markets. Although the Post BF estimate cannot reject the hypothesis that the price conjecture of 1.34 is significantly different from the competitive conjecture of -3.28 (due to the large standard error for the competitive conjecture), the estimated conjecture of 1.34 is close to the collusive conjecture of 1.13. The hypothesis of independent pricing is also rejected for these ten brands and Post BF because the estimates are positive and significant.

On the other hand, only two of the estimates can reject the hypothesis of interdependent or collusive pricing. In particular, the Kellogg NT1 estimate of 2.29 is significantly different from -0.10. The NT1 estimate, however, also rejects the competitive conjecture of -0.88, so it is difficult to interpret what the NT1 estimate shows. For Kellogg FF1, the hypothesis of collusive behavior is rejected. Pricing by Kellogg in this submarket may be characterized as rivalrous.

The hypothesis of interdependent pricing cannot be rejected for the other eleven estimates. For example, in the SS market, Kellogg anticipates cooperative behavior from Post when choosing its optimal price, and Post anticipates the same from Kellogg. This behavior is shown by price conjecture estimates of 1.54 and 0.97, which are not statistically different from the collusive conjectures of 1.11 and 0.90. Firms anticipate interdependent pricing from the competing firm, and thus prices may be noncompetitively high.

2. Consistent Conjectures

The conjectural variation model estimated also allows for a simple test of consistency. The duopoly models for the cereal submarkets have been estimated under the assumption of a constant conjectural variation. The consistent conjectural variation for each firm was derived as a function of the demand elasticities by equating the firm's constant conjecture to the slope of the rival's price reaction function. Under the conditions of symmetry, the consistent conjecture leads to higher prices than a Bertrand conjecture, but lower prices than a collusive conjecture.

The simplest method of testing for consistency is to compare the estimated conjectural variations from the structural model to the calculated consistent conjectural variations as defined by the demand elasticities. This test was performed only for the conjectural variation estimates that are significantly different from zero and that were able to reject competitive or collusive behavior.

For the reduced sample of twelve estimates in the CF, RB, BF, SS, and NT1 markets, and General Mills AF1 and Kellogg FF1, eight reject the consistency hypothesis H_0: $cv - ccv = 0$ at the 5% significance level, and two reject consistency at the 10% significance level (See Table 9).[27] The two estimates in the CF market cannot reject consistency: the estimated conjectures of 0.63 and 0.94 for Kellogg and Post are not significantly different from the consistent conjectures of 0.61 and 0.69. With the exception of the CF market, the overall results indicate that the consistency requirement may not be a good predictor of behavior for these cereal submarkets. The rejection

[27] In Table 9, t statistics for the calculated consistent conjectural variations are reported in parenthesis. The test statistic (not reported) used to test the null hypothesis is the t statistic for (cv-ccv).

of consistency implies that a unique equilibrium may not exist in these markets.

The question arises whether the conjectural variation estimates appear plausible, despite their failing a strict definition of consistency. If so, "rational" behavior suggests that a broader generalized conjectural variation function might be more appropriate for an empirical analysis than a constant conjectural variation. A second test, comparing the price conjectures to the rival firms' price reaction function elasticities, can show whether firms are behaving "rationally." This test is not as strong as the consistency test because it does not impose the additional condition that the behavior will define a unique equilibrium.

The test is performed for twenty four estimates. Twenty estimates cannot reject the hypothesis of rational behavior; four estimates can reject the hypothesis. It appears that firms do behave in a rational manner, although the uniqueness property of consistency is rejected.

The overall results suggest that the reaction functions and the price conjectural variations reveal the same behavior in most cases, although the hypothesis of a unique consistent conjectural variation is rejected. Support for a more generalized conjectural variation function is found in these results. More precisely, since the results do not appear to contradict rational behavior, yet a strict definition of consistency can be rejected, a plausible explanation for the results might be found in the specified functional form of the conjectural variation.

VI. ANALYSIS OF EMPIRICAL RESULTS

The majority of the estimated conjectural variations show that independent pricing behavior prevails in the defined cereal submarkets. Fourteen of the twenty four price conjectural variation estimates are insignificant, suggesting that pricing behavior between the two paired products in the submarkets is independent. These include all the presweet brands included in the analysis, except for the economical SS brands, and the all family brands without direct competitors. Kellogg FF1 may show rivalrous pricing behavior. Only in the well defined "homogeneous" product markets do the price conjectural variations suggest interdependent pricing behavior. In the CF, RB, BF, and SS markets, and to a lesser extent the NT1 and AF1 markets, the hypothesis of competitive pricing is rejected. The Kellogg NT1 conjecture has rejected both the hypotheses of competitive and collusive behavior, raising interpretation problems.

At the outset, it was pointed out that the choice of brand pairs to estimate as a cereal submarket is somewhat subjective. From the empirical estimates, it is clear that some of the brand pairs define better submarkets than others. Where the cross price elasticities are strong, the products are closer substitutes, and the price conjectural variations are easily interpreted. High cross price elasticities are shown in the Kellogg-Post CF, RB, BF, and SS markets, and the Kellogg-General Mills NT1 market. Price conjectural variations reflecting interdependent behavior are found in these markets. In the remaining submarkets, the cross price elasticities are weak or the wrong sign.

Correspondingly, the conjectural variations are insignificant and reflect independent pricing.

In addition, the result emerges that those brands with low or insignificant price conjectural variations have relatively high cost coefficients in their price reaction functions. These cost estimates are consistent with the basic intuition that where competing products are more independent, so that the products are less than perfect substitutes, the ability to pass along cost increases is greater.

The estimated price conjectural variations divide the submarkets into two major groups on the basis of whether the price conjectures show interdependent pricing behavior, or whether the conjectures are insignificant. Except for the NT1 and FF1 markets, the split is between the Kellogg-Post markets and the Kellogg-General Mills markets. Part of the difference could lie in the shorter time period over which the Kellogg-General Mills equations were estimated. Some degree of price interdependence emerges in the NT1 and AF1 markets, however, which were estimated over a shorter period. Further, the NT2 equations were estimated over a ten year period, as were the Kellogg-Post FF1 equations, and did not show price interdependence.

If the differences cannot be attributed to the shorter time period, then the explanation for the division into two groups must lie in the nature of the products themselves or behavior between the firms. The evidence suggests that the differences in results arise from the differences in the products, and not overall firm behavior. The differences in the products produced by these firms also help to explain differences in firm market share and profits. Where the products appeared to be slightly differentiated, independent pricing was the result, regardless of whether the defined market consisted of Kellogg-Post brands, or Kellogg-General Mills brands.

On an overall firm level, Post and General Mills differ significantly in market share, prices, and profits (See Table 10). For the period 1966-1969, General Mills' average market share was 21.9%, while Post followed with a 17.5% market share. General Mills maintained a larger market share despite the higher prices charged for its brands. General Mills' average list price was $0.49, higher than Kellogg's price of $0.48, and significantly higher than Post's price of $0.41. Accordingly, General Mills' profit rate is 12.8%, and Post's is 5.3%.

These differences in market share and profits can be explained by the differences in the products produced by the firms. On an overall firm level, Post does not appear to be as successful as General Mills at introducing new and distinct cereal products. From 1960-1972, Post introduced only fifteen new brands, of which six remained on the market past 1972.[28] In addition, the Post brands that do not have direct competitors are few, such as Honeycomb and Grape Nuts. The brands that do face direct competition, such as Post Raisin Bran, Post Toasties, Bran Flakes, and even Sugar Crisp account for roughly half of Post's volume. On the other hand, General Mills introduced twenty eight new products, of which twelve were successful.[29] Moreover, the largest General Mills brands are premium priced with respect to their closest

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[28] Source: CX-GF-556, and B Tables, Docket No. 8333.

[29] Source: CX-GM-2111, and B Tables, Docket No. 8333.

competitors. For example, Wheaties is priced above Kellogg Corn Flakes, and Cheerios is priced similarly to Rice Krispies.

Thus, although many of the empirical results could be considered firm specific, it is only because of the differences in the products that are produced and marketed by these firms. Should General Mills market products more substitutable with Kellogg, then it might also adopt a more cooperative pricing strategy. These results suggest that nonprice competition may dominate price competition in the breakfast cereal industry, particularly in the form of new brand introductions (Schmalensee, 1978). Firm maximize profits by creating independent product niches, and price according to demand. Close competitive brands prevent the firm from charging monopoly prices.

To make the argument stronger that firms do not compete with price, an analysis of profit margins on the competing brands is required. If the objective of the firms is to introduce new products, and not to collude explicitly on price, then one would expect higher profit margins on the brands in the markets characterized by price independence. Brand profits, however, are not available so brand prices and a proxy for profits are examined instead.

A brand price index and constructed "profit margin" index, along with the price conjectural variation estimates are shown and reported in Table 11. The weighted average three firm cereal price of $0.48 for 1967-1972 is used to construct the price index. The mean price for each of the brands for the period 1967-1972 is divided by the average three firm price, and then converted to an index with 100 representing the average price of all the brands. The price index ranges from 66.1 for Post Toasties to 131.7 for Kellogg Special K.

According to the price index, the lowest priced brands are the Kellogg and Post CF, RB, and BF brands, with price indices below 100. The highest priced brands are the Kellogg and General Mills NT1 and NT2 brands. Except for the NT1 market, the prices of the brands for which interdependent pricing behavior are found are concentrated at the low end of the price spectrum. Thus, although price interdependence is apparent, the prices of these brands are lower than the brands that are more independently priced. The prices support the argument that pricing behavior depends upon brand rather than firm characteristics.

High brand prices do not translate necessarily into high profits, once brand advertising expenditures are taken into account. To proxy brand profits, firm costs plus brand advertising expenditures are subtracted from brand price, and then divided by brand price to get a profit margin for each brand. An average profit margin for all brands in the sample is calculated in this manner, and used to convert the profit margins into a profit index. Again, the brands with average profit margins are those brands with an index of 100.[30] Notice that

[30] The constructed profit margin index may reflect accurately relative profit margins although the constructed profit margins do not represent the true level of brand profits. The constructed index orders relative profit levels correctly if the assumption holds that the ratio of brand price to average price is an increasing function of the ratio of brand cost to average cost. The price-cost margins for the CF, RB, and BF brands, which are relatively low price cereal products, will be understated if the brand costs do not reflect the same relative relationship to average firm cost as brand price to average firm price. For the NT1, NT2, and FF products, which are relatively high priced, the price-cost margin indices will be overstated if brand costs are not proportionately higher than average costs.

the variance of the profit margin index is much greater than the variance of the price index because of the large differences in brand advertising expenditures across the brands.

According to the constructed profit margins, the CF, RB, and BF brands are the lowest profit brands, and the FF1, FF2, FF3 and CH brands are the highest profit brands. Interdependent pricing behavior is associated with the brands with the lowest profits.

The price and constructed profit margin indices show that interdependent pricing behavior is found on those brands that have the lowest prices and the lowest profit margins. Thus, the appearance of interdependent pricing behavior does not imply necessarily that there is explicit collusive price behavior, but that prices are higher than if pricing were rivalrous. Rather, pricing behavior may be simply interdependent, particularly when one observes the high cross demand elasticities and low cost elasticities. The high cross demand elasticities prevent any one firm from unilaterally raising price because of potential large market share loss; the low cost elasticities show the firm's reluctance to raise price unilaterally to cover rising costs unless the rival firm raises price as well.

VII. SUMMARY AND CONCLUSION

The price conjectural variation model estimated proposes that pricing behavior in the cereal brand submarkets can be characterized with linear demand and price reaction functions, utilizing the result from brand profit maximization conditions that the functions share the same coefficients. Estimating the equations and imposing the restrictions on the coefficients yielded demand elasticities, and two measures of price interdependence - the rival price reaction function elasticities and the price conjectural variations.

The hypotheses that pricing behavior in the highly concentrated breakfast cereal industry is either collusive or competitive were tested empirically within this conjectural variation framework. Because breakfast cereals are so highly differentiated, the empirical tests were conducted at a disaggregated brand level rather than an aggregate firm level. Twelve brand submarkets were chosen with the highest probability of exhibiting price interdependence.

Price reaction function and demand function estimates revealed that some brand pairs are better described by this price reaction function model than others. Overall, the price reaction functions were found to fit the data quite well, as substitute prices and firm costs were able to explain brand prices. Twenty two of twenty four coefficients yielded reasonable rival price and firm cost coefficients showing a large variation in price interdependence between brands. Where pricing interdependence was high, brands were less responsive to costs.

Demand function estimates were less consistent. Twenty brands showed quantity demanded negatively related to price, and positively related or independent of the substitute price. Demand function estimates for several brands, however, posed interpretation problems because the own demand elasticities were not negative, or the cross price elasticities were negative. Also, brand advertising was not found to have a significant effect on demand although this result is probably due largely to using monthly advertising accounting data.

In spite of the limitations that some of the estimates present, some general results can still be drawn across the twelve submarkets. Primarily, the price conjectural variations show that pricing behavior is not rivalrous, and thus the allegation that prices are noncompetitively high has some empirical support. On the other hand, collusively pricing on brands that are close substitutes does not appear to be an overall firm objective. In particular, the brands with significant, positive price conjectural variations are associated with low prices, low profit margins, and insignificant cost elasticities. For these brands, it appears that pricing is merely interdependent. Moreover, the brands with high prices and high profits are represented by price conjectural variations of zero, reflecting independent behavior. Finally, the estimated conjectural variations suggest that competition occurs at the brand level rather than at the overall firm level. Where brands are sufficiently differentiated from close demand substitutes, regardless of the firm, the brands were priced independently. The absence of rivalrous firm pricing in this market may permit the firms to compete in nonprice dimensions such as through advertising and promotion of existing brands, or new product introduction.

Overall, the empirical results obtained from applying the price reaction function approach to breakfast cereal brand pairs appear reasonable. Thus, the price reaction function approach is a feasible procedure for estimating pricing behavior, particularly when profit data are unavailable. Instead, firm or brand specific cost data are used to estimate pricing behavior, where costs are used as an instrumental variable for identification of the simultaneous equation system.

As seen, however, the price reaction function approach is not the simplest method of testing for price competition and market power in an industry. For a differentiated product industry, the approach requires that own and cross demand elasticities, price reaction function elasticities, and cost elasticities be estimated. Further, the approach is restrictive in that it can only estimate price behavior between two brands or firms and cannot be easily extended to three brands. The benefits of this approach, however, are important. Specifically, this approach distinguishes between market power attributed to interdependent pricing behavior and market power attributed to demand elasticities. In addition, this approach is efficient because it utilizes the information from the first order profit maximization conditions that the price reaction function coefficients depend upon the demand elasticities.

Table 1

RTE CEREAL SUBMARKETS

Submarkets	Sample Period
CF - Kellogg Corn Flakes Post Toasties	1962 - 1972
RB - Kellogg Raisin Bran Post Raisin Bran	1962 - 1972
BF - Kellogg 40% Bran Flakes Post Bran Flakes	1962 - 1972
SS - Kellogg Sugar Smacks Post Sugar Crisp	1962 - 1972
FF1 - Kellogg Froot Loops Post Alpha-Bits	1966 - 1972
NT1 - Kellogg Product 19 General Mills Total	1969 - 1972
NT2 - Kellogg Special K General Mills Total	1962 - 1972
AF1 - Kellogg Rice Krispies General Mills CHeerios	1967 - 1972
AF2 - Kellogg Corn Flakes General Mills Wheaties	1967 - 1972
CH - Kellogg Cocoa Krispies General Mills Cocoa Puffs	1967 - 1972
FF2 - Kellogg Froot Loops General Mills Trix	1967 - 1972
FF3 - General Mills Trix Post Alpha-Bits	1967 - 1972

Table 2

PRICE REACTION FUNCTIONS[1]
KELLOGG - POST MARKETS
(t Statistics reported in parentheses)

	RIVAL PRICE ELAS.	FIRM COST ELAS.	ADVG. STOCK	INCOME	LAGGED QUANT.	CONSTANT	R^2 [2]
CF							
KELLOGG	.69 (5.76)	.26 (3.23)	-.004 (-.92)	-.56 (-2.40)		3171.8 (2.40)	.99
POST	.72 (7.91)	.13 (2.04)	-.004 (-1.22)	-.80 (-4.03)		3403.4 (4.03)	.99
RB							
KELLOGG	.95 (5.06)	.06 (1.11)	-.002 (-.98)	.26 (2.30)		-293.7 (-.42)	.92
POST	.56 (3.72)	.02 (.57)	.003 (1.91)	-.34 (-2.99)		2002.8 (2.30)	.89
BF							
KELLOGG	.61 (4.08)	.08 (1.84)	-.000 (-.24)	-.17 (-2.29)		3624.4 (2.91)	.96
POST	.64 (4.17)	.06 (.87)	.000 (.15)	-.53 (2.45)		4491.6 (3.21)	.93
SS							
KELLOGG	.27 (2.28)	.19 (3.54)	-.010 (-4.04)	-.05 (-2.25)	.02 (2.39)	2745.8 (6.09)	.87
POST	.76 (7.41)	.13 (3.58)	.001 (.43)	.25 (4.69)		1194.6 (.60)	.87
FF1							
KELLOGG	.28 (3.20)	.38 (10.22)			.04 (5.40)	48.6 (.10)	.88
POST	-.00 (-.03)	.28 (3.52)		.17 (1.78)	.03 (3.03)	2941.1 (2.93)	.95

[1] Coefficients are reported as elasticities at the mean.

[2] The R^2 is calculated by formulating the price function with the estimated coefficients, taking into account the autocorrelation coefficient. The correlation between the fitted values and actual values is reported as the R^2 term.

Table 3

PRICE REACTION FUNCTIONS[1]
KELLOGG - GENERAL MILLS MARKETS
(t Statistics reported in parentheses)

	RIVAL PRICE ELAS.	FIRM COST ELAS.	ADVG. STOCK	INCOME	LAGGED QUANT.	CONSTANT	R^2 [2]
NT1							
KELLOGG	.80 (2.48)	-.21 (-2.22)	.018 (1.66)			2189.1 (1.15)	.80
GEN. MILLS	.43 (3.67)	.11 (5.17)	-.012 (-3.16)			2897.5 (4.02)	.83
NT2							
KELLOGG	-.09 (-.81)	.33 (6.35)	.019 (1.71)			4658.7 (6.22)	.81
GEN. MILLS	.03 (.33)	.38 (5.29)	.014 (1.10)			1060.1 (.91)	.96
AF1							
KELLOGG	.30 (3.59)	.16 (2.58)				4519.6 (3.10)	.95
GEN. MILLS	-.00 (-.01)	.30 (1.63)				3871.6 (2.03)	.96
AF2							
KELLOGG	-.23 (-.76)	.26 (1.85)		.36 (.85)		-2105.6 (-.63)	.98
GEN. MILLS	-.07 (-1.32)	.30 (7.92)		-.37 (-2.74)		4648.5 (6.85)	.87
CH							
KELLOGG	.05 (.69)	.26 (7.31)		-.20 (-1.92)	-.49 (-.31)	4495.7 (5.77)	.97
GEN. MILLS	.47 (1.38)	.48 (3.62)		-.62 (-2.13)	-.02 (-1.70)	-2848.5 (-.85)	.94
FF2							
KELLOGG	.07 (1.82)	.46 (15.56)			.03 (2.39)	432.2 (1.54)	.90
GEN. MILLS	-.37 (-2.50)	.31 (8.46)			.16 (2.05)	4345.6 (2.87)	.96
FF3							
GEN. MILLS	.12 (.84)	.26 (4.03)			.01 (.59)	3821.0 (3.54)	.98
POST	-.01 (-.01)	.27 (3.55)		.14 (1.31)	.05 (4.51)	2982.4 (4.21)	.92

[1] Coefficients are reported as elasticities at the mean.

[2] The R^2 is calculated by formulating the price function with the estimated coefficients, taking into account the autocorrelation coeffient. The correlation between the fitted values and actual values is reported as the R^2 term.

Table 4

BRAND DEMAND FUNCTIONS[1]
KELLOGG - POST MARKETS
(t Statistics reported in parentheses)

	OWN PRICE	CROSS PRICE	ADVG. STOCK	INCOME	LAGGED QUANT.	CONSTANT[2]	R^2 [3]
CF							
KELLOGG	-1.53	1.48	-.008	-1.19		118185	.76
	(-2.30)	(2.30)	(.85)	(-6.53)		(6.42)	
POST	-3.24	2.79	-.015	-3.08		61191	.89
	(-4.30)	(3.78)	(-1.22)	(-14.58)		(11.13)	
RB							
KELLOGG	-5.43	5.57	-.014	1.50		-6960.7	.80
	(-3.15)	(2.85)	(-.94)	(6.05)		(-.43)	
POST	5.84	-3.39	-.016	2.07		-40781.9	.87
	(3.19)	(-2.30)	(-1.77)	(8.37)		(-2.71)	
BF							
KELLOGG	-1.32	.89	-.000	.25		10555.2	.87
	(-2.66)	(1.88)	(-.24)	(-2.98)		(8.38)	
POST	-2.02	1.39	.001	-1.15		25619.0	.86
	(-3.09)	(2.19)	(.15)	(-6.28)		(11.32)	
SS							
KELLOGG	-5.83	2.24	-.084	-.41	.13	43484.7	.78
	(-5.65)	(2.06)	(-3.57)	(-2.21)	(2.36)	(5.92)	
POST	-6.44	5.63	.009	1.91		8862.5	.88
	(-6.87)	(4.94)	(.43)	(5.41)		(.60)	
FF1							
KELLOGG	-3.59	3.88			.61	1092.4	.91
	(-4.88)	(3.45)			(8.64)	(.10)	
POST	-1.28	-.01		.52	.09	10828.0	.62
	(-1.45)	(-.03)		(1.72)	(2.22)	(2.05)	

[1] Coefficients are reported as elasticities at the mean.

[2] The constant term measures the intercept relative to December of each year, the monthly dummy variable excluded from the equation.

[3] The R^2 is calculated by formulating the demand equation with the estimated coefficients, then correlating the predicted values with the actual values.

Table 5

BRAND DEMAND FUNCTIONS[1]
KELLOGG - GENERAL MILLS MARKETS
(t Statistics reported in parentheses)

	OWN PRICE	CROSS PRICE	ADVG. STOCK	INCOME	LAGGED QUANT.	CONSTANT[2]	R^2 [3]
NT1							
KELLOGG	6.01 (5.09)	-3.37 (-2.17)	-.077 (-1.89)			-10450.0 (-1.12)	.82
GEN. MILLS	-5.95 (-4.11)	3.34 (3.08)	-.097 (-2.96)			40517.1 (2.95)	.90
NT2							
KELLOGG	-.80 (-1.86)	-.26 (-.82)	.052 (1.68)			-10931.9 (3.95)	.86
GEN. MILLS	-2.64 (-2.14)	.44 (.35)	.23 (2.91)			90025.6 (1.71)	.89
AF1							
KELLOGG	-1.70 (-2.43)	.71 (1.75)				64296.9 (5.09)	.86
GEN. MILLS	-1.33 (-2.72)	-.00 (-.01)				82249.9 (5.66)	.87
AF2							
KELLOGG	.56 (1.83)	.18 (.66)		-.27 (-.94)		25402.4 (.88)	.64
GEN. MILLS	-3.45 (-4.38)	-.46 (-1.32)		-2.35 (-3.18)		14416.2 (6.01)	.82
CH							
KELLOGG	-2.95 (-4.95)	.26 (.69)		-1.10 (-1.68)	.15 (2.42)	27221.4 (3.94)	.84
GEN. MILLS	-.04 (-.09)	-.75 (-1.85)		1.00 (2.08)	.03 (1.37)	3589.0 (.99)	.82
FF2							
KELLOGG	-2.44 (-2.87)	1.23 (2.94)			.57 (6.48)	14842.3 (1.90)	.90
GEN. MILLS	-.70 (-2.42)	-1.48 (-2.36)			.62 (5.65)	17253.0 (2.89)	.89
FF3							
GEN. MILLS	-1.13 (-1.95)	.35 (.80)			.02 (.58)	12461.8 (3.17)	.89
POST	-1.46 (-1.54)	-.02 (-.07)		.48 (1.37)	.17 (2.84)	11607.8 (2.04)	.72

[1] Coefficients are reported as elasticities at the mean.

[2] The constant term measures the intercept relative to December of each year, the monthly dummy variable excluded from the equation.

[3] The R^2 is calculated by formulating the demand equation with the estimated coefficients, then correlating the predicted values with the actual values.

Table 6

PRICE CONJECTURAL VARIATIONS[1]
KELLOGG - POST MARKETS
(t Statistics reported in parentheses)

	PRICE CONJECTURAL VARIATION	REACTION FUNCTION ELASTICITY
CF		
KELLOGG	.63 (3.08)	.69 (5.76)
POST	.94 (6.31)	.72 (7.92)
RB		
KELLOGG	.90 (5.58)	.95 (5.06)
POST	1.67 (3.82)	.56 (3.72)
BF		
KELLOGG	1.34 (4.22)	.61 (4.08)
POST	1.34 (4.72)	.64 (4.17)
SS		
KELLOGG	1.54 (2.87)	.27 (2.28)
POST	.97 (7.44)	.76 (7.41)
FF1		
KELLOGG	-1.78 (-1.89)	.28 (3.20)
POST	42.91 (.03)	-.00 (-.03)

[1] Coefficients are reported as elasticities at the mean.

Table 7

PRICE CONJECTURAL VARIATIONS[1/]
KELLOGG - GENERAL MILLS MARKETS
(t Statistics reported in parentheses)

	PRICE CONJECTURAL VARIATION	REACTION FUNCTION ELASTICITY
NT1		
KELLOGG	2.29	.80
	(2.47)	(2.48)
GENERAL MILLS	1.24	.43
	(3.12)	(3.67)
NT2		
KELLOGG	4.35	-.09
	(.80)	(-.81)
GENERAL MILLS	-25.86	.03
	(-.32)	(.33)
AF1		
KELLOGG	1.47	.30
	(1.95)	(3.59)
GENERAL MILLS	7.71	(-.00)
	(.01)	(-.01)
AF2		
KELLOGG	-2.05	-.23
	(-.73)	(-.76)
GENERAL MILLS	-1.33	-.07
	(-.68)	(-1.32)
CH		
KELLOGG	1.61	.05
	(.40)	(.69)
GENERAL MILLS	-2.01	.47
	(-1.10)	(1.38)
FF2		
KELLOGG	-11.70	.07
	(-1.52)	(1.82)
GENERAL MILLS	1.52	-.37
	(1.61)	(-2.50)
FF3		
GENERAL MILLS	-1.17	.12
	(-.40)	(.84)
POST	26.23	-.01
	(.07)	(-.01)

[1/] Coefficients are reported as elasticities at the mean.

Table 8

COMPETITIVE AND COLLUSIVE CONJECTURES[1/]
(t Statistics reported in parentheses)

	PRICE CONJECTURAL VARIATION	COMPETITIVE CONJECTURE	COLLUSIVE CONJECTURE
CF			
KELLOGG	.63	-1.27*	.97
	(3.08)	(-2.68)	(10.90)
POST	.94	-.79*	1.03
	(6.31)	(-2.68)	(10.90)
RB			
KELLOGG	.90	-.79*	3.84
	(5.58)	(-6.66)	(.38)
POST	1.67	-1.26*	.26
	(3.82)	(-6.66)	(.38)
BF			
KELLOGG	1.34	-.30*	.89
	(4.22)	(-.80)	(7.77)
POST	1.34	-3.28	1.13
	(4.72)	(-.80)	(7.77)
SS			
KELLOGG	1.54	-.55*	1.11
	(2.87)	(-3.58)	(9.71)
POST	.97	-1.82*	.90
	(7.44)	(-3.58)	(9.71)
NT1			
KELLOGG	2.29	-.88*	-.10*
	(2.47)	(-4.36)	(-.38)
GEN. MILLS	1.24	-1.14*	-9.65
	(3.12)	(4.36)	(-.38)
AF1			
KELLOGG	1.47	-2.24*	2.08
	(1.95)	(-3.53)	(1.75)
FP1			
KELLOGG	-1.78	-1.20	.76*
	(-1.89)	(-2.43)	(3.52)
POST	42.91	-1.02	1.32
	(.03)	(-2.43)	(3.52)

[1/] Coefficients reported as elasticities at the mean.

*Hypothesis rejected at the 5% significance level. Test statistic is the t statistic for ($CV - CV_k$), not just for CV_k, and is asymptotically normally distributed (test statistic not reported).

Table 9

CONSISTENT CONJECTURAL VARIATIONS
(t Statistics reported in parentheses)

	ESTIMATED CONJECTURAL VARIATIONS	CONSISTENT CONJECTURAL VARIATIONS	RIVALS REACTION FN. ELAS.
CF			
KELLOGG	.63 (3.08)	.61 (5.56)	.72 (7.92)
POST	.94 (6.31)	.69 (4.01)	.69 (5.76)
RB			
KELLOGG	.90 (5.58)	1.59* (4.49)	.56 (3.72)
POST	1.67 (3.82)	2.82* (3.04)	.95 (5.06)
BF			
KELLOGG	1.34 (4.22)	.40* (4.01)	.64 (4.17)
POST	1.34 (4.72)	.39* (3.57)	.61* (4.08)
SS			
KELLOGG	1.54 (2.87)	.48* (2.01)	.76 (7.41)
POST	.97 (7.44)	.21* (2.41)	.27* (2.28)
NT1			
KELLOGG	2.29 (2.47)	3.24** (2.35)	.43 (3.67)
GEN. MILLS	1.24 (3.12)	3.26* (3.34)	.80 (2.48)
AF1			
KELLOGG	1.47 (1.95)	-.00** (-.00)	.00* (-.01)
FF1			
KELLOGG	-1.78 (-1.89)	-.00** (-.04)	-.00** (-.03)

*Hypothesis rejected at 5% significance level;
**Hypothesis rejected at 10% significance level. Test statistics are the t statistics for the variables (CV - CVV) and (CV - F_1), which are asymptotically normally distributed. (Test statistics not reported here.)

Table 10

FIRM CHARACTERISTICS
(1966-1970 Averages)

	Market[1] Share	Profits[2]	Price[3] per lb.	Costs[4] per lb.	Costs/ Sales	Adv./[5] Sales
Kellogg	42.5%	10.4%	$0.48	$0.296	63.2%	13.2%
General Mills	21.9%	12.8%	0.49	0.254	53.7%	17.4%
Post	17.5%	5.3%	0.41	0.248	62.0%	18.7%

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1 Based on 1966-1969 market share data.

2 Return on Capital/Sales (KX-97A).

3 GMX-560A.

4 Kellogg's costs adjusted for promotional expenditures.

5 GMX-555A and CX-430C.

Table 11

COMPARISON OF PRICE CONJECTURES TO PRICE AND PROFIT MARGINS
(t Statistics reported in parentheses)

	PRICE CONJECTURAL VARIATIONS	PRICE INDEX	PROFIT INDEX
KELLOGG			
BF	1.34 (4.22)	66.2	24.5
CF	.63 (3.08)	66.4	0
RB	.90 (5.58)	77.1	11.2
SS	1.54 (2.87)	95.6	85.4
CH	1.61 (.40)	110.0	143.4
AF1	1.47 (1.95)	112.7	133.5
FF1	-1.78 (-1.89)	123.0	167.4
FF2	-11.70 (-1.52)	123.0	167.4
NT1	2.29 (2.47)	126.2	116.2
NT2	4.35 (.80)	131.7	149.6
POST			
CF	.94 (6.31)	66.1	40.8
BF	1.34 (4.72)	68.4	88.4
RB	1.67 (3.82)	77.4	63.2
SS	.97 (7.44)	94.9	104.5
FF1	42.91 (.03)	113.0	139.9
GENERAL MILLS			
AF2	-1.33 (-.68)	85.6	80.3
AF1	7.71 (.01)	105.9	139.6
FF2	1.52 (1.61)	119.0	167.1
CH	-2.01 (-1.10)	123.0	172.6
NT2	-25.86 (-.32)	123.0	116.3
NT1	1.24 (3.12)	127.0	149.6

APPENDIX A - Firm Costs

To specify firm costs, a departure from specific brand data is necessary to complete the model. All price, quantity, and advertising data are brand specific. For costs, however, firm cost data are used instead of brand data. First, cost data are not available at the brand level. Second, pricing strategies of the firms suggest that using a firm wide cost measure is preferred to brand costs.

The variable used to measure monthly firm costs is a weighted average of monthly wholesale list prices of cereals, multiplied by the ratio of annual costs to price per pound sold. Specifically, for brand i produced by firm j, the cost variable for firm j is:

$$MC_j = \sum_i MS_{ij}P_{ij} * (C_j/P_j) \qquad 1,\ldots \text{ n brands}$$

where MS_{ij} is the monthly market share of brand i in firm j's quantity sales, P_{ij} is the monthly price of brand i, and (C_j/P_j) is the ratio of annual firm costs to annual price. The monthly weighted average wholesale list price reflects general cost and price movements, so multiplying by the ratio of cost to price should remove the price component of this variable. In this way, annual firm cost data are distributed monthly.

The weighted average wholesale list price variable is constructed by weighting the cereal prices by its market shares, and then summing across the brands within the company. The price for Kellogg averages fourteen cereal brands accounting for over 90 percent of cereal sales. For Post, eleven brands account for 89 percent of sales, and for General Mills, seven brands account for 87 percent of total sales.

The percentage of cost to price per pound (C_j/P_j) was calculated for each firm based on company submitted annual cost and profit data. Operating costs per pound (C_j) are defined as dollar sales, less profits, interest, taxes, research and development expenditures, advertising expenditures, and other promotional expenditures, divided by the pound volume sold. Kellogg had the highest operating cost per pound, which is due in part to its higher capital employed and lower advertising expenditures per pound.

Operating costs per pound C_j are then divided by price P_j to get a ratio of cost to price. The average price per pound was highest for General Mills, followed closely by Kellogg. These cost and price data conform to the company profit data. General Mills continuously has been the most profitable with an average 13% profit rate over the 1966-1970 period. Kellogg follows with a 10% profit rate. Post's profits are only 5%.

Other data necessary for estimating the model are collected from the <u>Survey of Current Business</u>. These include total civilian population, real personal disposable income per capita, consumer price index for food, and consumer price index for services.

APPENDIX B - Linear Quadratic Demand Functions

To test whether the linear specification of the brand demand functions is too restrictive, linear quadratic demand functions were estimated for all the brands. In particular, the demand functions were estimated as:

$$Q_i = a_{0i} + b_i P_i + c_i P_j + h_i GA_i + t_{i1} P_i^2 + t_{i2} P_j^2 + t_{i3} P_i P_j + t_{i4} P_i GA_i + t_{i5} P_j GA_i + t_{i6} GA_i^2 + u_i$$

A likelihood ratio test is then used to test the hypothesis H_o: $t_{i1} = t_{i2} = t_{i3} = t_{i4} = t_{i5} = t_{i6} = 0$. The test statistic -2 log R, where R is the ratio of the value of the likelihood functions for the restricted and unrestricted models, is distributed chi-square with r = 6 degrees of freedom.

Seven of the twenty four estimated demand functions appear to reject the linear hypothesis. The NT1 equations (Kellogg Product 19 and General Mill Total) reject the linear specification hypothesis for both price and advertising, but only over shorter sample period 1969-1972.[31] In particular, when the General Mills Total demand equation is estimated over the longer 1963-1972 period, the linear hypothesis cannot be rejected. The Kellogg CH equation also shows that a polynomial of the second degree in prices may be a better specification of the demand function, although the own price elasticity of demand of -2.95 is similar to the elasticities for the other presweet cereals.[32]

For four of the seven equations that reject the linear specification, the results suggest that brand demand may be linear in prices, but nonlinear in advertising goodwill.

In sum, the specification of the demand curves as linear in prices does not appear to be too restrictive for the majority of brands. The likelihood ratio tests, however, show that advertising goodwill stock may have a nonlinear effect on demand.

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[31] The NT1 equations, for the sample period 1969-1972, were tested with six parameter restrictions and the test statistics are 13.50 and 17.14 for Kellogg and General Mills respectively. In addition, Box-Cox estimates for the Kellogg NT1 equation were estimated. The price elasticity of demand remains positive, 2.26 (t=1.62), though less significant. The positive price coefficient may be due to the sample period that overlaps its introductory period.

[32] For Kellogg CH, only three parameter restrictions were tested as advertising goodwill is not included in the demand equation. The test statistic is 12.96.

Table C-1

PRICE ELASTICITIES OF DEMAND - MONTHLY VERSUS QUARTERLY

	Monthly		Quarterly	
	Own Price	Cross Price	Own Price	Cross Price
CF				
KELLOGG	-1.53 (-2.30)	1.48 (2.30)	-1.66 (-2.45)	.74 (2.47)
POST	-3.24 (-4.30)	2.79 (3.78)	-5.12 (-3.65)	4.62 (3.20)
RB				
KELLOGG	-5.43 (-3.15)	5.57 (2.85)	-3.91 (-1.60)	4.97 (1.66)
POST	5.84 (3.19)	-3.39 (-2.30)	-1.27 (-.93)	1.02 (.93)
BF				
KELLOGG	-1.32 (-2.66)	.89 (1.88)	-2.29 (-2.42)	1.60 (2.12)
POST	-2.02 (-3.09)	1.39 (2.19)	-.97 (-1.61)	.62 (1.36)
SS				
KELLOGG	-5.83 (-5.65)	2.24 (2.06)	-5.58 (-3.03)	2.95 (1.98)
POST	-6.44 (-6.87)	5.63 (4.94)	-5.52 (-4.20)	4.26 (2.96)
AF1				
KELLOGG	-1.70 (-2.43)	.71 (1.75)	-.73 (-1.99)	.51 (.99)
GEN. MILLS	-1.33 (-2.72)	-.01 (-.01)	-1.19 (-2.55)	-.38 (.85)
AF2				
KELLOGG	.56 (1.83)	.18 (.66)	1.30 (1.02)	.18 (2.04)
GEN. MILLS	-3.45 (-4.38)	-.46 (-1.32)	-2.11 (-3.56)	-.36 (-2.21)
CH				
KELLOGG	-2.95 (-4.95)	.26 (.69)	-2.37 (-4.66)	.47 (1.12)
GEN. MILLS	-.04 (-.09)	-.75 (-1.85)	.28 (.93)	-1.59 (-1.28)
FF1				
KELLOGG	-3.59 (-4.88)	3.88 (3.45)	-3.17 (-2.07)	.72 (.27)
POST	-1.28 (-1.45)	-.01 (-.03)	-3.39 (-2.43)	-.07 (-.10)
FF2				
KELLOGG	-2.44 (-2.87)	1.23 (2.94)	-2.78 (-2.21)	-.00 (-.00)
GEN. MILLS	-.70 (-2.42)	-1.48 (-2.36)	-.69 (-2.93)	-.61 (-1.50)

APPENDIX C - Quarterly versus Monthly Data

The demand functions have been estimated using monthly data. Because some of the demand coefficients did not have the expected signs, the monthly data were aggregated to quarterly, and the equations were estimated again. There appear to be some gains to aggregating to quarterly observations as some of the demand curves become more reasonable. For the majority of the estimated demand curves, however, the quarterly and monthly data yield similar results. Nevertheless, the empirical results suggest that if enough quantity data were available to provide sufficient degrees of freedom, the equations might be better estimated with quarterly data.

Most of the demand coefficients do not vary between the monthly and quarterly estimations (See Table C-1). However, several of the estimated demand equations appear more reasonable. In particular, the Post RB equation has a negative own price elasticity and a positive cross price elasticity, although both are insignificant. The Post RB rival reaction function elasticity and conjectural variation, however, are invariant across the monthly and quarterly estimations. Specifically, the price conjectural variations are 1.22 using quarterly data, and 1.67 using monthly data (See Table C-2).

Smaller gains are also made by aggregating to quarterly data. For the FF1 market, the Kellogg own price elasticities are similar for monthly and quarterly (-3.59 and -3.15), but the cross price elasticity is more reasonable using the quarterly data because the cross price coefficient is smaller than the own price coefficient. The conjectural variation estimates for both FF1 brands are insignificant in both the monthly and quarterly estimations.

The major drawback to using the quarterly data is that not enough observations are available for many of the brands. For example, for the General Mills brands, only twenty observations are available.

Table C-2

PRICE CONJECTURAL VARIATIONS - MONTHLY VERSUS QUARTERLY

	Monthly		Quarterly	
	Rival Price	Conjectural Variation	Own Price	Conjectural Variation
CF				
KELLOGG	.69 (5.76)	.63 (3.08)	.58 (3.27)	.20 (.37)
POST	.72 (2.91)	.94 (6.31)	.69 (8.77)	.76 (6.12)
RB				
KELLOGG	.95 (5.06)	.90 (5.58)	1.27 (4.66)	.78 (4.31)
POST	.56 (3.72)	1.67 (3.82)	.80 (3.27)	1.22 (5.79)
BF				
KELLOGG	.61 (4.08)	1.34 (4.22)	.65 (6.13)	1.32 (4.60)
POST	.64 (4.17)	1.34 (4.72)	.63 (3.58)	1.53 (3.23)
SS				
KELLOGG	.27 (2.28)	1.54 (2.87)	.35 (2.54)	.88 (1.94)
POST	.76 (7.41)	.97 (7.44)	.55 (3.77)	.78 (3.20)
AF1				
KELLOGG	.30 (3.59)	1.47 (1.95)	.38 (1.87)	.18 (.12)
GEN. MILLS	-.00 (-.01)	7.71 (.01)	-.12 (-.80)	2.38 (.99)
AF2				
KELLOGG	-.23 (-.76)	-2.05 (-.73)	.08 (.86)	-26.94 (-.03)
GEN. MILLS	-.07 (-1.32)	-1.33 (-.68)	-.07 (-2.48)	2.86 (1.14)
CH				
KELLOGG	.05 (.69)	1.61 (.40)	.09 (1.08)	-1.08
GEN. MILLS	.47 (1.38)	-2.01 (-1.10)	.03 (.91)	-31.40 (-.00)
FF1				
KELLOGG	.28 (3.20)	-1.78 (-1.89)	.14 (2.28)	1.51 (.27)
POST	-.00 (-.03)	42.91 (.03)	-.01 (-.10)	-21.40 (-.10)
FF2				
KELLOGG	.07 (1.82)	-11.70 (-1.50)	.01 (.00)	-29.09 (-.02)
GEN. MILLS	-.37 (-2.50)	1.52 (1.61)	-.46 (-1.66)	4.44 (1.40)

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