Food Marketing Policy Center

**Strategic Pricing in a Differentiated Product
Oligopoly Model: Fluid Milk in Boston**

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Research Report Series

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University of Connecticut
Department of Agricultural and Resource Economics

STRATEGIC PRICING IN A DIFFERENTIATED PRODUCT

OLIGOPOLY MODEL: FLUID MILK IN BOSTON

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Abstract

In an imperfectly competitive industry, differentiated products compete with each other with price rather than quantity as the strategic variable. Several previous studies have employed a generalized Nash Bertrand model: Liang (1989), Cotterill (1994), Cotterill, Putsis and Dhar (2000), and Kinoshita, Suzuki, Kawamura, Watanabe and Kaiser (2001); however, only Liang has explored the theoretical foundations of that model. This paper generalizes the Liang two good model to three goods. A surprising and important result follows. Price conjectural variations do not exist in models with 3 or more goods. Price reaction functions, however, exist in multiple good models. We estimate them jointly with a brand level demand system to evaluate the total impact of a brand manager's price change on own quantity. In a differentiated product market this is a useful addition to a partial demand elasticity approach because a change in one brand's price typically engenders a price reaction by other brands which affects own quantity via substantial cross price elasticities among substitutes. Strategic pricing in the Boston fluid milk market was also influenced by the existence of a raw milk price support program, the Northeast Dairy Compact. We find that the advent of the Compact was a focal point event that crystallized a shift away from Nash Bertrand to more cooperative pricing. If the downstream market is not competitive one needs to consider strategic price reactions when designing and evaluating agricultural price programs.

Introduction

Several studies have investigated the nature of competition in differentiated product markets where price is the strategic choice variable. Most have assumed Nash Bertrand competition, i.e. zero valued price conjectures.[1] Residual demand analysis (Baker and Breshnahan, 1985) implicitly relaxes the Nash Bertrand assumption, and the total elasticity approach of Liang (1989), Cotterill (1994) and others explicitly relaxes it. Moreover for the Boston fluid milk market the Northeast Dairy Compact program, a raw milk policy that established a price floor to enhance dairy farm income, serves as an external stimulus that allows one to evaluate shifts in strategic conduct. Cotterill and Franklin (2001), for example, use IRI scanner data in combination with raw fluid milk price data to describe the Northeast Dairy Compact's impact on market pricing strategies. They identify price leaders, and estimate crude brand level demand curves for Garelick, Hood and private label milk in Boston IRI market area.[2] They report that processor-retailer margins increased when farm level fluid milk prices were elevated slightly and stabilized by the Compact. Their estimated market and brand level elasticities suggest that the exercise of market power is a source of wider margins and higher retail prices during the Compact period. Finally, their review of the historical events in the New England milk industry support a focal point collusion strategy at Compact implementation.

Dhar (2001) examines pricing in the Boston fluid milk market in a much more rigorous fashion using structural econometric models. His work is also at the brand level and disaggregated from the market to the supermarket chain level. He concludes that competitive behavior of retailers in Boston during the Compact period changed with oligopolistic retail

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[1] In antitrust analysis this is the well known unilateral effects model (Ivaldi et al., 2003; Hausman et al., 1994).

[2] They fit a regression line through the price quantity scatter plot for each brand.

pricing becoming soft as major retailers responded positively to each other's price changes. The estimated profit margins and the estimated profit per period were higher after the implementation of the Northeast Dairy Compact. Dhar also finds that estimated profit margins across brands are higher for private labels.

Chidmi et al. (2005) ignore product differentiation and aggregate all milk purchases to the market level by assuming milk is a homogeneous good. Then they use Appelbaum's (1982) quantity-setting conjectural variation approach to evaluate the degree of collusion and market power in the Boston fluid milk market. `Their aggregate market level conjectural variation elasticity estimate is .1229 and is significantly different than zero at the 1 % level, which indicates that there is some collusion in Boston fluid milk market. They also examined how the conjectural variation elasticity varied over time to assess the impact of the North East Dairy Compact. They report that the conjectural variation elasticity is higher during the Compact era and the difference is statistically significant.

This paper rigorously extends the Liang (1989) two-brand differentiated product oligopoly model to three brands in the Boston fluid milk market. In Liang's two good model price conjectural variations for each firm can then be estimated directly. The advantage of this approach is apparent in the context of a differentiated product market. When products are not homogeneous, market conduct is brand specific, and strategic. Profits may be a poor indicator of the degree of price competition (Liang, 1989).

As analyzed in Canan (2002) and the next section conjectural variation parameters cannot be identified in Bertrand differentiated product oligopoly that has more than two brands. Fortunately the slopes of the reaction functions also provide useful information about strategic firm behavior. In models with 3 or more goods one must use price reaction elasticities, not conjectural variations to measure market power at the brand level. Reaction

elasticities capture actual price behavior rather than conjectured behavior, and can be estimated for any oligopoly model.

Theoretical Models

Liang's structural econometric model has 2 demand equations and 2 price reaction equations. More succinctly, the market has 2 brands that are owned by separate firms. Cross equation restrictions link the estimated price reaction function coefficients to estimated demand coefficients. This aids in estimating the model and allows one to identify the two brand managers' price conjectures. Liang assumes that the differentiated product demand function for firm 1 is a simple linear relationship and is a function of the two prices and income:

$$Q_1 = a_1 - b_1 P_1 + c_1 P_2 + d_1 Income \qquad\qquad \text{Equation (2.1)}$$

where: Q_1 is the output of firm 1, P_1 is the price for firm 1 and P_2 is the price for firm 2.

Differentiating this demand equation with respect to own price, one obtains:

$$\frac{\partial Q_1}{\partial P_1} = -b_1 + c_1 \frac{\partial P_2}{\partial P_1} = -b_1 + c_1 cv_1 \qquad\qquad \text{Equation (2.2)}$$

where: $cv_1 = \dfrac{\partial P_2}{\partial P_1}$ is the firm i's price conjectural variation with respect to firm j. The total own price demand elasticity that firm 1 faces is;

$$\eta_1 = (-b_1 + c_1 cv_1)(\frac{P_1}{Q_1}) \qquad\qquad \text{Equation (2.3)}$$

This total own price demand elasticity has 3 parts; (a) the firm's partial own-price elasticity

$(-b_1 \frac{P_1}{Q_1}) = \eta_{11}$, (b) the cross price elasticity of demand $(c_1 \frac{P_2}{Q_1}) = \eta_{12}$, and (c) the conjectural

response elasticity $(cv_1 \frac{P_1}{P_2}) = \varepsilon_{21}$. One can restate Equation (2.3) as:

$$\eta_1 = \eta_{11} + \eta_{12}\varepsilon_{21} \qquad\qquad \text{Equation (2.4)}$$

The elasticity of this firm level demand curve provides a measure of the market power that the

firm can exercise. If $\frac{\partial \eta_1}{\partial cv_1} > 0$, then demand becomes more inelastic as anticipated price

behaviour approaches cooperation. Since $\frac{\partial \eta_1}{\partial c_1} = cv_1 \frac{P_i}{Q_i} \geq 0$ for $cv_1 \geq 0$, an increase in the

cross elasticity will cause the elasticity of demand to decline and market power is raised.

When one has rivalrous pricing one has $cv, > 0$ and $\frac{\partial \eta_1}{\partial c_1} = cv_1 \frac{P_i}{Q_i} < 0$. Rivalry makes a firm's

demand more elastic. If the conjectural variation, cv_1 and the corresponding conjectural

elasticity, ε_{21} equals 0, i.e. one has Bertrand competition, then the total own price demand

elasticity, η_1 is equal to the partial own price elasticity, η_{11}. The partial own price elasticity is

called the unilateral demand elasticity in antitrust analysis (Ivaldi et al., 2003).

One completes the Liang model by analyzing each firm's profit maximization problem

when price is the strategic choice variable. Firm 1's profit maximization problem is:

$$\underset{P_1}{Max\Pi_1} = P_1Q_1 - C_1(Q_1) \qquad\qquad \text{Equation (2.5)}$$

subject to $Q_1 = a_1 - b_1P_1 + c_1P_2 + d_1 Income$

where C_1 is the production cost of firm 1. Firm 1 maximizes profits, Π_1, by choosing price, P_1. The firm's first order condition for profit maximization is;

$$\frac{\partial \Pi_1}{\partial P_1} = Q_1 + P_1 (\frac{\partial Q_1}{\partial P_1}) - MC_1 (\frac{\partial Q_1}{\partial P_1}) = 0 \qquad \text{Equation (2.6)}$$

where $\frac{\partial Q_1}{\partial P_1} = -b_1 + c_1 cv_1$ and MC_1 is the marginal cost of firm 1. This first order condition can

be expressed as a price reaction function. The continuous price reaction function $R_1(P_2)$ define

the firm's price as a function of its rival's price and its own marginal cost.

$$R_1(P_2): \quad P_1 = f_{01} + f_{11}P_2 + f_{21}MC_1 \qquad \text{Equation (2.7)}$$

The coefficient on rival price (f_{11}) is a direct measure of price interdependence.

$$f_{11} = \frac{-c_1}{-2b_1 + c_1 cv_1} \qquad \text{Equation (2.8)}$$

Liang demonstrates that these coefficients in the 2 good case exhibit the same properties as the

Lerner Index (Liang, 1989). Price cost margin (PCM), which is the difference between price

(P) and marginal cost (MC) as a fraction of price ([P-MC]/P) and is also called the Lerner

Index, can be calculated by using the following form:

$$PCM_1 = \frac{-1}{(-b_1 + c_1 cv_1)(P_1 / Q_1)} \qquad \text{Equation (2.9)}$$

In this 2 good model, conjectural variations (cv_1, cv_2) can be identified and actually estimated

by using the first order profit maximization conditions because the price reaction function

coefficients depend upon the demand coefficients and the conjectural variations. If one has an

estimate of f_{11}, and the demand function coefficients b_1, c_1, one can solve Equation (2.8) for an

estimate of cv_1. The formula is:

$$cv_1 = \frac{-1}{f_{11}} + \frac{2b_1}{c_1}$$

Equation (2.10)

Expanding Liang's model to 3 goods is not a trivial exercise. The corresponding demand and price reaction equations for brand 1 in the 3 brand case are:

$$Q_1 = \beta_{10} + \beta_{11}P_1 + \beta_{12}P_2 + \beta_{13}P_3$$

Equation (2.11)

$$P_1 = \alpha_{10} + \alpha_{11}P_2 + \alpha_{12}P_3$$

Equation (2.12)

Demand for brand 1 is a function of the prices of the three brands and the price reaction function for brand 1 is a function of the rival brands' prices. The price reaction coefficients for brand 1 derived from the first order profit maximization conditions are;

$$\alpha_{11} = \frac{-\beta_{12}}{2\beta_{11} + \beta_{12}cv_{21} + \beta_{13}cv_{31}}$$

Equation (2.13)

$$\alpha_{12} = \frac{-\beta_{13}}{2\beta_{11} + \beta_{12}cv_{21} + \beta_{13}cv_{31}}$$

Equation (2.14)

One can not explicitly solve for individual brand level conjectural variations when one has 3 or more brands in the model because of a singular matrix in the solution (Canan, 2002). Note that one has two equations and two unknowns; however, one has the same estimated parameters on cv_{21} and cv_{31} in the two equations. This redundancy generates the singularity. Moreover assuming equal conjectural variations across firms does not solve the singularity problem.

This result presents a critical question. How can one determine the degree of competition in a market or the degree of market power that is being exercised by brand managers if one can not identify and measure conjectural variations? In this study, we will use price reaction elasticities, not conjectural variations to measure market power at the brand level and test for conduct that is not Bertrand. To illustrate our approach let us examine the

focal point collusion hypothesis that others have suggested that explains the observed price conduct in the Boston fluid milk market.

In the 3 good model we assume that competition is Bertrand before the Compact. Each brand's pre-Compact PCM is an inverse function of its unilateral own price elasticity, η_{ii}. One can calculate a brand's PCM before the Compact as follows:

$$PCM_i = \frac{P_i - MC_i}{P_i} = \frac{-1}{\eta_{ii}} = \frac{-1}{\beta_{i1}(\frac{P_i}{Q_i})} \qquad i=1,2,3 \qquad \text{Equation (2.15)}$$

For the Compact period, we relax the Bertrand competition assumption and test for more collusive conduct among brands. If the test rejects Bertrand competition then each brand's PCM is an inverse function of its total own price elasticity. Here we use the actual price reaction elasticities instead of the conjectural elasticities to estimate the total elasticities. For brand 1,

$$\eta_1 = \eta_{11} + \eta_{12}R_{21} + \eta_{13}R_{31} \qquad \text{Equation (2.16)}$$

where R_{21} (% change in P_2 for a % change in P_1) and R_{31} (% change in P_3 for a % change in P_1) are the price reaction elasticities, η_{12} and η_{13} are cross-price elasticities. Therefore brand 1's post-Compact PCM takes the form;

$$PCM_1 = \frac{-1}{\eta_{total}^1} = \frac{-1}{\eta_{11} + \eta_{12}R_{21} + \eta_{13}R_{31}} \qquad \text{Equation (2.17)}$$

Empirical Model Specification

In Boston there are 3 major brands of fluid milk: Hood, Garelick and private label. We aggregate to the brand level by taking a market share weighted average of different types of milk, including skim and whole milk, to obtain brand prices for gallons of milk. Based upon the 3 good model developed above we specify a simultaneous system of 6 equations. There are 3 demand equations, one for each brand of milk. The 3 corresponding price reaction equations complete the model. Table 1 defines the variables used in the 3 good empirical model for branded milk in Boston. In addition to the endogenous brand price and per capita quantity variables we specify the following exogenous variables: per capita income in the demand equations: and for each brand two cost proxies, unit sales per volume, and the share of skim milk in a brand's sales. The first cost variable measures the higher cost of packaging when milk is sold in less than gallon sizes; and the second measures the lower raw product cost when milk has less butterfat. Finally, we specify a binary variable, D, to identify the Compact era and test for different price conduct in it as opposed to during the pre-Compact era.

Our initial work revealed that there is an extremely high level of multicollinearity between the price of Garelick and private label milk.[3] Table 2 reports the regression results of the relationship between Garelick and PL retail prices ($P_G = \delta_0 + \delta_1 P_{PL}$). The coefficient on PL retail price is significantly different than zero at the 1 % level and the adjusted R^2 is 0.95. We have also tested whether the estimated coefficient for private label price in Table 2 is different from one and the hypothesis is rejected with the t-ratio of 6.88.

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[3] This is more than a sample problem. A Garelick regional manager explained to the second author that Garelick actively requests that retailers price their milk at a fixed premium to private label milk.

The high multicollinearity between Garelick and PL affected our initial estimation results causing a bizarre complementarity between Garelick and PL, which is not the case. Garelick and private label milk are substitutes. Because of the high multicollinearity between Garelick and PL, we have dropped Garelick price from the model which is presented in Table 3. The model now has three demand equations but only two prices, Hood and private label prices. Also there are only two reaction functions since the Garelick price is effectively linked to private label price. If we want to analyze Garelick pricing we use the regression equation in Table 2 to recover the Garelick price given the model's predicted private label price.

We impose Bertrand competition in the pre-Compact period, i.e. the conjectural variations (cv) in Equations (2.12) and (2.13) are zero, by imposing cross equation restrictions in Table 3. The cross equation restrictions of Bertrand conduct require that price reaction coefficient be exact functions of the demand equation coefficients as given in Table 3. We can test for different conduct during the Compact by relaxing the Bertrand restrictions in the Compact period. In effect we do this by interacting each price in a price reaction equation with a binary variable, D. The binary has value 0 before the Compact and 1 after. If strategic conduct is Nash Bertrand through the entire sample period, the coefficients on these binary interaction terms will be 0. If the coefficients λ_{H4} and λ_{PL4} on the interaction terms in Table 3 are positive, the reaction functions are steeper and indicate more collusive pricing during the Compact era. We hypothesize that λ_{H4} and λ_{PL4} are positive. In other words, we expect that the price reaction slopes are steeper than Bertrand competition due to enhanced tacit collusion via a focal point pricing move at Compact implementation. Cotterill and Franklin (2001) explain how retailers opposed the Compact. They implemented larger than normal price increases when the Compact began operation in July 1997 attributed all of the

retail price increase to the higher raw milk price regime of the Compact era. As Schelling (1960) first explained, an event such as the advent of the Compact can serve as a focal point for a shift in pricing strategy to a different regime.

Estimation and Interpretation of Results

Data from the Information Resources Incorporated (IRI) Infoscan database available at the University of Connecticut Food Marketing Policy Center is used for this study. The IRI database provides four-week period data on volume, unit and dollar sales for Boston for 58 periods from March 1996 to July 2000[4]. Generalized Method of Moments (GMM) is used to estimate the simultaneous system of equation with SHAZAM. Nonlinear estimation is necessary because of the cross-equation restrictions in our model. GMM estimation increases efficiency if heteroscedasticity exists. If the disturbances are homoscedastic, then it is asymptotically the same as nonlinear three-stage least square estimation (Green, 2000). Table 4 reports the estimation results. In the Hood demand equation, the own price coefficient for Hood is -1.458 and significant at 1% level. As hypothesized the demand curve has negative slope. The Cross-price coefficient for the private label in the Hood demand equation is 1.22 and significant at the 1% level. PL and Hood are substitutes in the Hood demand equation. When price of PL increases, Hood quantity demanded increases, because consumers switch to from PL to Hood.

When we look at the Garelick demand equation, we see that the coefficients for Hood and PL prices are 0.362 and –2.68 respectively. They are both significant at 1% level. When price of Hood increases $1, Garelick quantity demanded increases 0.362 which tells us that

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[4] The series have been tested for the existence of unit root by using the augmented Dickey-Fuller unit root test. The hypothesis of the existence of unit root has been rejected for the series.

consumers switch to Garelick from Hood. When price of PL goes up $1, the price regression on Table 2 predicts Garelick price goes up $1.25. Garelick quantity demanded decreases 2.68 gallons.

In the PL demand equation, the own-price coefficient for PL is –2.60 and significant at 1% level. The cross-price coefficient for Hood is positive and significant at 1% level. Hood and PL are substitutes as in the Hood demand equation.

The coefficient for income is expected to be positive assuming that milk is a normal good, i.e. as income of a household increases the milk consumption of that household is going to increase. In fact it is positive and significant at 1% level in the Hood and Garelick demand equations, but in the PL demand equation it is negative and significant at 1% level. The negative sign in the PL demand equation suggests that as income increases consumers switch to the more expensive brands from the store brand. As reported in Figure 1 PL has a lower retail price than Hood and Garelick throughout the sample period. At low income levels households consume mostly PL, and as their income increases they switch to higher priced brands, Hood and Garelick.

To determine whether competition in the Compact era deviates from Nash-Bertrand conduct, we examine the Compact binary and price interaction variable coefficients. Both are positive significantly different from zero at 1% level in the price reaction equations. Therefore, competition during the Compact period is not Bertrand. Conduct before and after Compact implementation is different. The slope of Hood price reaction function increases from .4183 in the pre-Compact period to .4526 during the Compact era. The slope of the PL price reaction function increases from .4767, pre-Compact, to .5618 during the Compact. These results suggest that pricing conduct became more collusive during the Compact period.

When strategic pricing becomes more collusive as documented in this market, one

would expect to see brand level demand curves become more inelastic, price cost margins become higher, and prices increase. Table 5 reports brand level own price demand elasticities before and during the Compact. Elasticities before the Compact are unilateral demand elasticities, i.e. they are based on Nash-Bertrand pricing. Note that Hood, the highest priced brand, has the most elastic demand at -5.1639; and, private label is least elastic at -1.533. Consumers are much less sensitive to price changes for the low price brand than to changes for the high price brand. After the shift to more collusive price conduct during the Compact period Hood's price elasticity becomes much less elastic, Garelick's becomes somewhat less elastic and at -.8661 private label's becomes inelastic. Consumers have less opportunity to switch between brands due to the addition in divergent price offers among the brands.

Table 6 reports estimated price cost margins for each brand during the two periods. The price cost margins shift dramatically for Hood, increasing from 19.37% pre-Compact to 36.53% during the Compact. Hood clearly benefited from the shift towards cooperative pricing. The Garelick brand's margins increase is much more modest, from 30 to 32 percent. The private label price cost margin shift is literally off the chart. During the Compact it increases to 115 percent, which is impossible since it implies negative marginal cost.

Perhaps a chart of the data will aid in understanding brand price strategies and our estimation results. Figure 1 shows the brand retail prices and farm level price of milk for the pre-Compact and the Compact period. The Compact began on July 1, 1997. As one can see, there is no relationship between the brand level and the farm level prices for the pre-Compact period. Retail brand prices trend up in a fairly steady fashion while raw milk prices move cyclically. At Compact implementation retail price strategy changes abruptly. Retail prices closely match the raw milk price move. This is the focal point move to a new strategic pricing game that we capture in our model. Note that the spread between retail and raw milk prices

for all brands are visibly higher during the Compact period. Our model confirms that an increase in price cost margins is a significant source of this increase in the marketing spread between raw and retail milk prices.[5]

Note also in Figure 1 that private label and the "tethered" Garelick price move up much more than Hood price. In a more collusive pricing strategy it makes sense for the most price elevation to occur on the least elastic brands. Hood milk becomes less elastic because the prices of its rivals move up towards its premium price. Consumers in fact did switch to Hood during this period, shifting the Hood demand curve out (Cotterill and Franklin, 2001). Although private label prices are the lowest in Figure 1, private label price cost margins are the highest because marginal costs for private label are much lower. Others have documented theoretically and empirically that private label have lower prices and higher margins than branded products (Cotterill, Putsis, and Dhar 2000; Mills 1995).

Conclusions

This study generalizes the Liang two good strategic pricing model to three goods. With more than two goods one can not estimate price conjectures to measure pricing conduct in a differentiated product market. We propose and use price reaction functions and related price reaction elasticities to assess the degree of competition. Using data from the Boston fluid milk market for three brands we specify and estimate a three good model. Estimated brand level demand elasticities are extremely useful for strategic pricing. Events in the industry, most notably the advent of the Northeast Dairy Compact, allow us to identify and test for different strategic pricing games during the pre-Compact and Compact periods. The

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[5] Note that price cost margins are not identical to the marketing spreads in Figure 1. PCMs are based on marginal cost when included other costs as well as raw milk costs.

results suggest that retail pricing strategy shifted at that focal point event from Nash-Bertrand pricing to a more collusive pricing game. Recognizing rivals' price reaction responses reduces own price elasticities and elevates price cost margins. Models of this type for differentiated products are useful for mangers who seek to maximize profits as well as for policy analysis. On the latter, the Northeast Dairy Compact generated an unintended strategic price response that exacerbated its impact on consumers. Retail milk prices went up by more than one would have expected given prior retailer price conduct. Therein lies an important insight for agricultural policy. If the downstream market is not competitive one needs to consider strategic price reactions when designing and evaluating agricultural price programs.

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Table 1: Description of the Variables Used in the Empirical Model

P_H	Retail price of Hood fluid milk (Dollars/Gallon)
P_G	Retail price of Garelick fluid milk (Dollars/Gallon)
P_{PL}	Retail price of Private Label milk (Dollars/Gallon)
P_{raw}	Price of raw milk (Dollars/Gallon)
Q_H	Volume sales of Hood per capita (Gallons)
Q_G	Volume sales of Garelick per capita (Gallons)
Q_{PL}	Volume sales of Private Label per capita (Gallons)
I	Per Capita Income in Boston ($1000)
U/V_H	Unit sales/Volume sales of Hood
U/V_G	Unit sales/Volume sales of Garelick
U/V_{PL}	Unit sales/Volume sales of Private Label
SS_H	Market Share of Hood Skim Milk (%)
SS_G	Market share of Garelick Skim Milk (%)
SS_{PL}	Market share of Private Label Skim Milk (%)
D	Binary variable to capture the effect of Northeast Dairy Compact on prices

Table 2: The Relationship between Garelick and Private Label Retail Prices

Variable	Estimated Coefficient	Standard Error	t-ratio[a]	t-ratio[b]
Constant	-0.35708*	0.09312	-3.835	-
P_{PL}	1.25620*	0.03722	33.75	6.88
R^2	0.9531			
R^2 Adjusted	0.9523			

[a] Hypothesis test for the coefficient being different than 0
[b] Hypothesis test for the coefficient being different than 1
*Significant at 1% level

Table 3: A Strategic Pricing Model without Garelick Retail Price

$$Q_H = \beta_{H0} + \beta_{H1}P_H + \beta_{H3}P_{PL} + \beta_{H4}I$$

$$Q_G = \beta_{G0} + \beta_{G1}P_H + \beta_{G3}P_{PL} + \beta_{G4}I$$

$$Q_{PL} = \beta_{PL0} + \beta_{PL1}P_H + \beta_{PL3}P_{PL} + \beta_{PL4}I$$

$$P_H = (\frac{-\beta_{H0}}{2\beta_{H1}}) + (\frac{-\beta_{H3}}{2\beta_{H1}})P_{PL} + (\frac{-\beta_{H4}}{2\beta_{H1}})I + \lambda_{H1}U/V_H + \lambda_{H2}P_{raw} + \lambda_{H3}ss_H + \lambda_{H4}DP_{PL}$$

$$P_{PL} = (\frac{-\beta_{PL0}}{2\beta_{PL3}}) + (\frac{-\beta_{PL1}}{2\beta_{PL3}})P_H + (\frac{-\beta_{PL4}}{2\beta_{PL3}})I + \lambda_{PL1}U/V_{PL} + \lambda_{PL2}P_{raw} + \lambda_{PL3}ss_{PL} + \lambda_{PL4}DP_H$$

Table 4: Empirical Results

	Dependent Variables				
	Q_H	Q_G	Q_{PL}	P_H	P_{PL}
Intercept	0.19998	5.9542	5.1580	0.068568	0.99071
	(2.0834)**	(45.058)*	(16.006)*	(2.3079006)**	(6.0620004)*
P_H	-1.4583	0.36212	2.4819	-	0.47669
	(-12.887)*	(1.4874)	(7.6704)*		(10.029047)*
P_{PL}	1.2200	-2.6828	-2.6032	0.41830	-
	(7.4813)*	(-6.9927)*	(-6.0206)*	(11.943601)*	
I	0.10121E-03	0.7636E-04	-0.9235E-04	0.34703E-04	-0.1773E-04
	(10.169)*	(3.7970)*	(-4.2798)*	(7.0096121)*	(-2.784373)*
U/V_H				0.56954	-
				(18.194)*	
U/V_{PL}				-	-0.02538
					(-0.21582)
P_{raw}				0.020244	0.23945
				(0.41960)	(3.8667)*
SS_H				0.017077	-
				(7.2733)*	
SS_{PL}				-	-0.0018389
					(-0.60194)
$D*P_H$				-	0.085123
					(16.850)*
$D*P_{PL}$				0.034256	-
				(5.5371)*	

*significant at 1% level, **significant at 5% level, ***significant at 10% level

t-ratios are given in parentheses.

Table 5:   Brand Level Own Price Demand Elasticities

Brand	Before the Northeast Dairy Compact	During the Northeast Dairy Compact
Hood	-5.1639	-2.7371
Garelick	-3.3249	-3.1220
Private Label	-1.5233	-0.8661

Table 6:   Estimated Percent Price Cost Margins

Brand	Before the Northeast Dairy Compact	During the Northeast Dairy Compact
Hood	19.37	36.53
Garelick	30.07	32.03
Private Label	65.66	115.46

Figure 1: Brand Retail vs Farm Level Milk Price, Boston
March 1996-July 2000
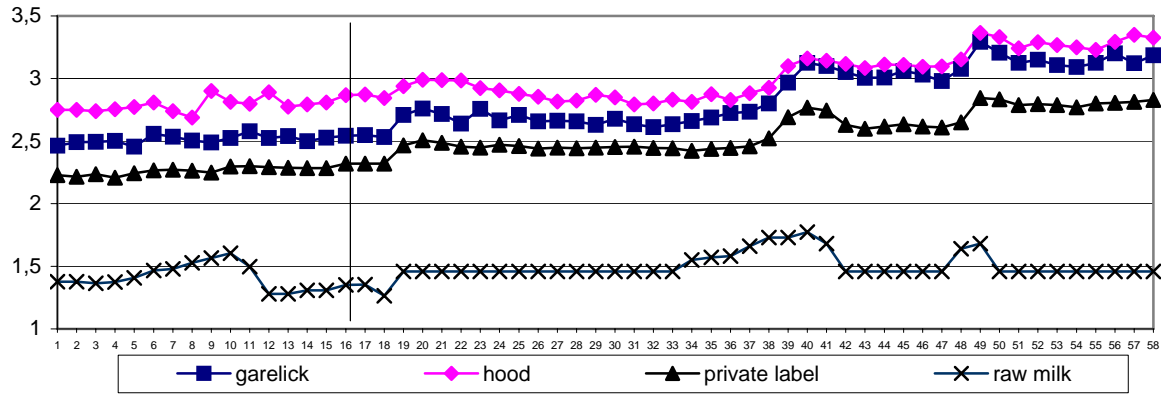
Source: Calculated from Food Marketing Policy Center IRI database

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