# STRATEGIC EFFECT OF PRIVATE LABEL IN A VERTICAL BARGAINING MODEL

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Abstract

Private label products have been studied extensively and theoretical frameworks were developed to show private label products lend their retailers bargaining power over factory brands. Because of unobservable factory or wholesale prices empirical evidence has been lacking. This paper, using an efficient bargaining model in a multilateral bargaining setup and IRI brand level data, provides for the first time empirical evidence supporting the existence of such bargaining power by retailers with strong private labels. Estimation results show that the retailers in the Boston fluid milk market are able to leverage their private label products to gain concessions when negotiating wholesale prices with two major factory brands. This suggests that the relationship between retailers and milk processors is competitive even though the retailers enjoy channel power.

Key words: private label, efficient bargaining, market channel, fluid milk

I am grateful to Ronald Cotterill for providing many insights into vertical channel modeling and analysis and issues related to industrial organization.

## 1. Introduction

Private label has been the subject of much research for decades. Private label attracts broad research interest mainly because it is marketed by retailers. Such private label products often create marketing impact on manufacturer or factory brands in the same distribution channel. This impact primarily stems from a retailer's capability to integrate production and marketing processes of private label while still carrying branded products in the same distribution channel.

The seminal work of Myers (1967) hypothesizes the existence of a different consumer valuation of private label and tests the determinants of this valuation. Recent research has focused on why a retailer introduces a private label and what strategic impact a private label has. Mills (1995) develops a hierarchical model that allows consumers to rank brands and private label. The analytical results predict, among others, that private label's market share is negatively related to the difference between national brand's and private label's retail prices. Raju, Sethuraman and Dhar (1995) develop the conditions for private label to increase a retailer's category profits. Narasimhan and Wilcox (1998) show analytically that private label is used as a strategic weapon to gain concessions from the national brands. Bontems, Montier-Dilhan and Requillart (1999) find that there is a negative relation between private label quality and the wholesale price of a national brand if quality is cost independent. This model implies a negative relation between private label's market share and a national brand's wholesale price. Cotterill, Putsis and Dhar (2000) empirically analyze the interaction between private label and national brands in six categories and find that private label distribution significantly reduces national brands' market shares and price competition may not be an effective tool for private label to steal market share from national brands. Steiner (2002) makes an intuitive elaboration of different scenarios of competition between private label and leading national brands and how intra-brands and inter-brands elasticity drives this competition. He concludes that vigorous competition between private label and leading national brands is socially optimal. With direct observation of wholesale prices and margins through surveys, Ailawadi and Harlam (2004) find that retailers earns higher profit margin on national brands where store brands' market shares are high. Recently Bonano and Lopez (2005) conduct an empirical analysis of the competition between national brands and private label in 10 large US markets using IRI data and their results suggest that private label expansion increases the gap between private label price and manufacturer brands' prices.

Bargaining models have been studied analytically and empirically in modeling vertical interactions between a downstream and an upstream firm. Nash (1950) lays the foundation of a bilateral bargaining theory. Blair, Kaserman and Romano (1989) in a static analysis show that prices in a bilateral bargaining situation are indeterminate. Devadoss (2000) presents a dynamic bilateral bargaining framework that resolves price indeterminacy. Gervais and Devadoss (2006) use a bargaining model with dynamic adjustment of prices to estimate the bargaining power of processors and producers in the Canadian chicken market. Oczkowski (2004) analyzes bargaining cooperatives with two Nash bargaining models and concludes that maximizing members' price may be irrelevant when trading with a single processor.

This is the first empirical study to analyze in a bargaining context and without observing wholesale prices or margins, find supporting evidence of the strategic advantage and bargaining power a retailer acquires by marketing private label products. Specifically this analysis studies the Boston fluid milk market where three major brands dominate the market: Hood, Garelick, and private label. Private label products have the highest market share (58%). This market structure is the result of profit maximization by retailers and manufacturers given consumer demand schedules. Besides, the retailers' and manufacturers' marketing strategies also have significant impact on this structure. In this study a retailer's use of its private label is analyzed to show that private label gives the retailer sizable bargaining power over factory brands.

This paper is organized as follows. Section 1 is introduction. Section 2 presents a framework for modeling bargaining between retailers and manufacturers. Section 3 specifies the marginal cost functions used in the econometric models. Section 4 establishes the demand specifications and supply side equations for estimation. Section 5 introduces two alternative models to a bargaining model. Section 6 briefly discusses the data used in the estimation of the bargaining model and the two alternative models. Section 7 presents estimation results. Section 8 concludes the paper.

## 2. An Efficient Bargaining Framework

The reason this paper chooses to specify an efficient bargaining model is that it gives an analytic and feasible econometric framework to analyze a bargaining process. In the marketing field bargaining is usually modeled as a fully integrated process, and the division of retail revenue between the manufacturers and retailers is impossible to determine due to unobservable wholesale prices. The full integration approach is analytically insufficient to study marketing strategies such as selling private label products.

In an efficient bargaining situation, a retailer and a manufacturer bargain over both retail and wholesale prices and obtain a contract curve that maximizes each party's profit for a series of combinations of retail and wholesale prices. A typical retailer behaves as a category manager, i.e., maximizing the joint profit of n brands and private label products it sells. The retailer's profit maximization problem is stated as follows:

$$\max_{p_i} \pi^R = \sum_{i}^{n} (p_i - w_i - c_i)s_i M + (p_L - c_L - mc_L)s_L M; \qquad i \neq L$$

where $p_i$ is the retail price, $w_i$ is the wholesale price, $s_i$ is the market share of brand i, $c_i$ is the retailer's marginal cost for brand i, and M is the market size (total expenditure) of fluid milk sold in supermarkets. L stands for private label brands and $mc_L$ is the processing marginal cost of the private label. Note that wholesale price for prate label is not present because it is fully integrated.

A typical manufacturer is assumed to maximize its profit by setting its wholesale price:

$$\max_{w_i} \pi^W = (w_i - mc_i(\omega_i, z))s_i M\,; \qquad i \neq L$$ [1]

where $mc_i$ is marginal cost as a function of $\omega_i$, which is brand i's cost of raw milk, and $z_i$ costs of other input factors.

The corresponding contract curve for brand i is obtained by equating the retailer's and manufacturer's isoprofit functions:

$$\frac{\partial \pi_i^R / \partial p_i}{\partial \pi_i^R / \partial w_i} = \frac{\partial \pi_i^W / \partial p_i}{\partial \pi_i^W / \partial w_i}\,; \qquad i \neq L \qquad (1)$$

After differentiating the retailer's and the manufacturer's profit maximization problems, equation (1) becomes:

$$\frac{s_i + \sum_{j=1}^{n}(p_j - w_j - c_j)\frac{\partial s_j}{\partial p_i} + (p_L - c_L - mc_L)\frac{\partial s_L}{\partial p_i}}{s_i} = -\frac{(w_i - mc_i(\omega_i))\frac{\partial s_i}{\partial p_i}}{s_i}\,;\quad i, j \neq L \quad (2)$$ [2]

Equation (2) states the situation in which manufacturers and retailers set wholesale prices as well as retail prices jointly. Simplifying equation (2) gives:

$$s_i + \sum_{j=1}^{n}(p_j - w_j - c_j)\frac{\partial s_j}{\partial p_i} + (p_L - c_L - mc_L)\frac{\partial s_L}{\partial p_i} = -(w_i - mc_i(\omega_i))\frac{\partial s_i}{\partial p_i}\,;\; i, j \neq L \qquad (3)$$

Note that when the right-hand side of equation (3) is moved to the left-hand side, one obtains the first order condition that cancels out the wholesale prices for brand i on both sides of the equation. This means that in this bargaining model a retailer and the

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[1] Private label does not have profit maximization problem in the processing stage because it is fully integrated.

[2] Equation (2) can also be derived from $\left.\frac{dp_i}{dw_i}\right|_{d\pi^R=0} = \left.\frac{dp_i}{dw_i}\right|_{d\pi^W=0,\ \frac{d\pi^W}{dp_\omega}=0,\ \frac{d\pi^W}{dp_z}=0}\,; \quad i \neq L$ by total differentiating a retailer's and a processor's profit maximization problem.

manufacturer of brand i do not directly take into account how the retail price is split between them. The wholesale prices of other brands, however, do remain in the equation. This means how the retailer bargains with other manufacturers does affect how the retail price is set. As the retailer acquires more shares of other brands' retail prices (through lower wholesale prices), the retail price of brand i becomes higher, and vice versa. This result should be anticipated because a retailer would want to sell the brands that have a higher profit margin via a lower wholesale price. This result also points out the difference between the interpretations of a vertical bargaining model and a full integration model in which retailers and manufacturers are assumed to be fully integrated. However, in the vertical bargaining model the estimated marginal costs include wholesale price although one cannot recover estimates of the wholesale price. Empirically there is no difference between a full integration model and a vertical bargaining model since wholesale prices are not measurable in either. The empirical gain lies in the fact that private label strategies can be modeled in a vertical bargaining model, but not in a full integration model. This empirical difference between the two models makes a big difference because it allows us to measure a retailer's bargaining power from private label.

For private label the contract curve becomes the standard first order condition given that private label is vertically integrated:

$$s_L + (p_L - c_L - mc_L)\frac{\partial s_L}{\partial p_L} + \sum_i^n (p_i - w_i - mc_i)\frac{\partial s_i}{\partial p_L} = 0; \qquad i \neq L \tag{4}$$

The introduction of a private label is considered a strategic move by a retailer to counter the power of factory brands rather than merely add a profit center. What is usually overlooked is this strategic move may not be effective once the private label is in the market. For a private label that has negligible market share its strategic effect is minimal or even non-existent as if it had never been introduced into the market, that is, zero market share. If there exists a threshold market share for private label to be strategically effective, its effect can be assumed to be a function of the degree of its presence, that is, its market share after such a threshold market share is reached. Such a function should predict that an increase in a private label's presence, i.e. market share, increases its strategic effect. The driving forces for private label's strategic effect are consumers' willingness to switch between brands and retailers' ability to set the prices of private label and factory brands.

Since a retailer is a price-setting oligopoly, a private label's presence is managed by the retailer to a very large extent, if not completely, through its retail price. By setting private label's retail price and thus its presence a retailer is able to exert influence on factory brands. Knowing that its decision to set the price and presence of private label reduces the power of factory brands to bargain over their wholesale prices, a retailer has an incentive to take advantage of its category manager status by incorporating this knowledge into its first order condition for private label:

$$s_L + (p_L - c_L - mc_L)\frac{\partial s_L}{\partial p_L} + \sum_i^n (p_i - w_i - mc_i)\frac{\partial s_i}{\partial p_L} + \sum_i^n s_i \frac{\partial (p_i - w_i)}{\partial p_L} = 0 ; \quad i \neq L \quad (5)$$

where $\frac{\partial (p_i - w_i)}{\partial p_L}$ captures such effect on factory brands when the retailer actually uses or threaten to use private label when negotiating with manufacturers over retail and wholesale prices of factory brands.

A negative $\frac{\partial (p_i - w_i)}{\partial p_L}$ indicates a competitive relationship between a retailer and a brand manufacturer. This predicts that a lower private label price gives the retailer higher profit margin, $(p_i - w_i)$, at equilibrium as a result of lower wholesale price for brand i. If the retail price of the branded product also goes lower then one should expect that the decrease in the wholesale price, $w_i$, is greater than that in the retail price, $p_i$, of the branded product. A positive $\frac{\partial(p_i - w_i)}{\partial p_L}$, on the contrary, indicates a cooperative relationship between the retailer and manufacturer. The cooperative relation is anti-competitive because it increases both private label and brand products' prices.

Figure a and b compare a double marginalization model such as vertical Nash and a bargaining model. As illustrated in Figure a, double marginalization is not Pareto efficient since both the retailer and manufacturer can do better in area A (enclosed by the two isoprofit curves[3]) by negotiating with each other both the retail and wholesale prices. The optimal point in the double marginalization model is where w* and p* are located. This bargaining process will result in, as shown in Figure b, lower retail and wholesale prices but higher overall channel profit, that is, the sum of the retailer's and manufacturer's profits. Efficient bargaining is characterized by the contract curve along which the isoprofit curves of the retailer and manufacturer are tangent to each other. A tangent point, also a Pareto optimal point for profit maximization problems of the retailer and manufacturer, is where $w^{**}$ and $p^{**}$ are located. Contract curve I is obtained when other wholesale prices are held constant while contract curve II is obtained by holding own wholesale price constant. Contract curve III, located between I and II, is the locus of Pareto optimal points at equilibrium that rotates from contract curve I.

[3] In oligopoly theory isoprofit curves do not exist because price is set in the profit maximization problem and thus is a function of constants that specify demand curves and firm behaviors. However, in a vertical situation retail prices cannot be determined until wholesale prices are determined, that is, wholesale prices are given parameters (not constants). Therefore, for a retailer there exits an isoprofit curve that is a function of w, p(w). For the processor there exits an isoprofit curve that is a function of p, w(p).

Figure a: Double Marginalization Model

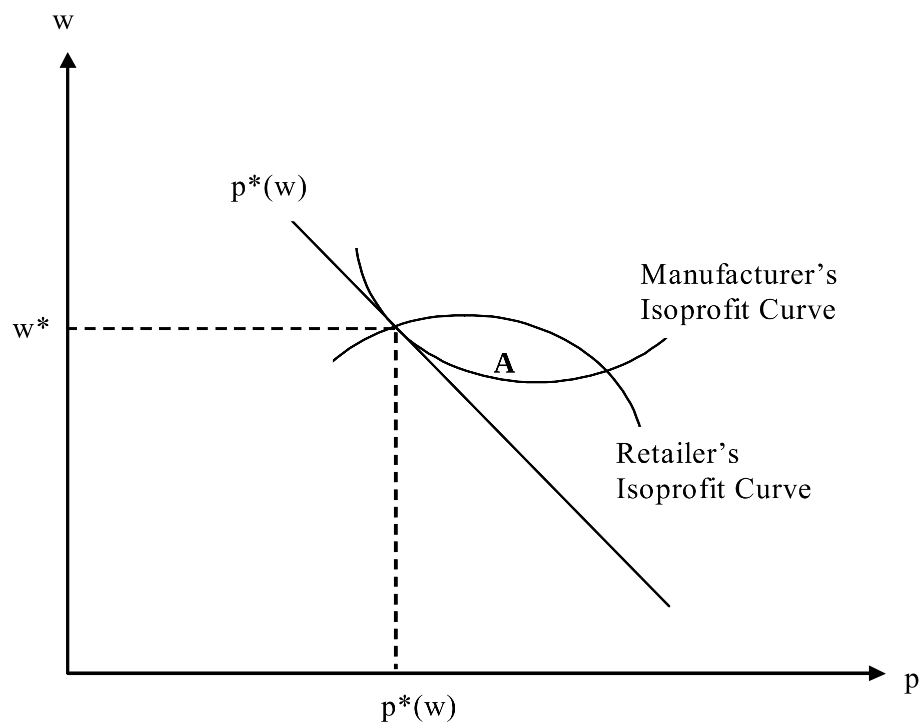
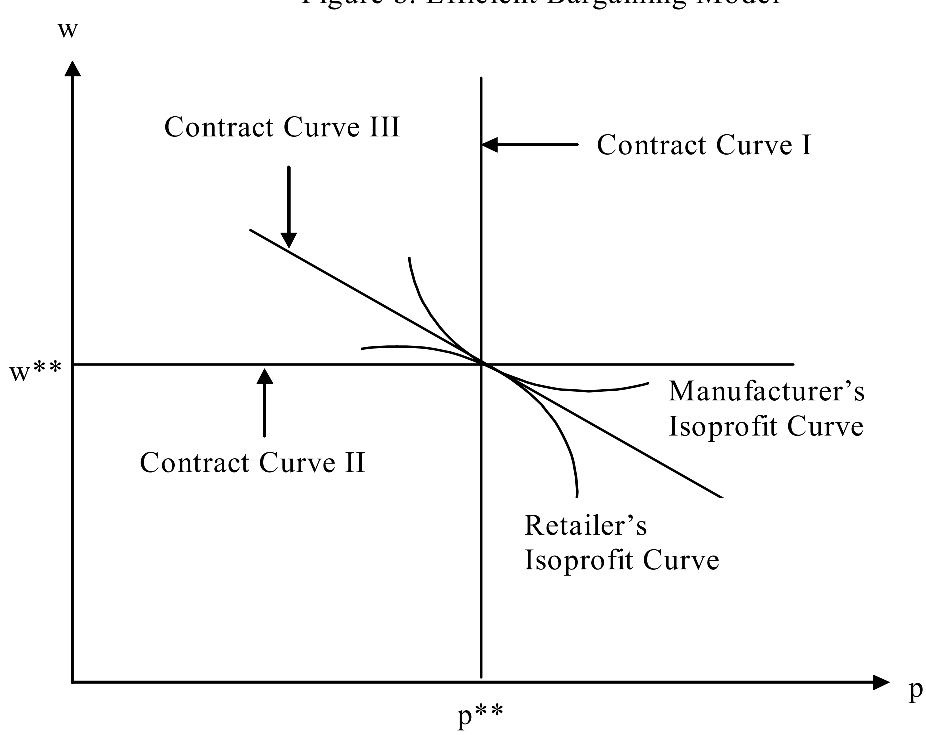



Figure b: Efficient Bargaining Model




Note: p** < p* and w** < w*.

3. Marginal Costs

Since the empirical part of this study targets the Boston fluid milk market, the marginal cost functions and demand specifications are presented for the three major brands, Hood, Garelick, and private label. We assume that the processing marginal costs of the three brands are derived from a Leontief production process:

$$mc_H = \lambda_{H0} + \sum_{i}^{k} \lambda_{Hi} w_{Hi} \tag{6}$$

$$mc_G = \lambda_{G0} + \sum_{i}^{k} \lambda_{Gi} w_{Gi} \tag{7}$$

$$mc_L = \lambda_{L0} + \sum_{i}^{k} \lambda_{Li} w_{Li} \tag{8}$$

where w is a vector of input prices and cost shift variables, and $\lambda_{H0}, \lambda_{G0},$ and $\lambda_{L0}$ are the constant terms that help capture the unobserved effects in the marginal cost functions.

Three input factors are included in the processing marginal cost functions: raw milk price, package size and share of skim milk sold. Raw milk is the primary input. We also include the share of a brand's milk that is skim milk to measure the butterfat-adjusted cost of raw milk for each brand[4]. We expect that variation in raw milk price explain variation in marginal cost and brand prices. Also a higher share of skim milk is hypothesized to give lower brand prices because skim milk has lower marginal cost than 1%, 2% and whole milk. The package size variable, units per gallon, is included to

[4] The 3.5 butterfat milk price established by the Federal Milk Market Order and the North East Dairy Compact Commission is the price that processors pay in the Boston market. However the milk that they sell has less butterfat, a valuable commodity that is sold as a byproduct.

measure a brand's packaging costs.  Brands with higher units per gallon are hypothesized to have higher packaging cost per gallon and thus higher wholesale and retail prices.

We have tested two variables that could be included for retailers' marginal cost functions: hourly wage rate and energy rate.  The test shows the two variables significantly worsen the performance of all models, thus suggesting they are not the right variable choices for retailers' marginal cost functions.  In absence of good marginal cost variables for retailers, we choose to use the constant term in each supply-side equation to control for retailers' marginal cost.

## 4. Econometric Specification of Demand and Supply Side Functions

The demand specification will be the Logit. The Logit demand specification is a special case of the nested Logit model or mixed Logit model. This simple Logit model is very restrictive because it assumes additive consumer utilities. The simple Logit model also has been criticized for its restricted proportional substitution pattern. In this paper the simple Logit specification is used because there are only 3 major products in the market and data are available at brand level. Dhar and Cotterill (2002) use data at store level to estimate a nested Logit model that exhibits flexible substitution patterns. Tian and Cotterill (2005) however report that the simple Logit models fit the Boston milk data better than Mills address model or a restricted price model that is based on actual pricing rules for private label and Garelick milk. A simple Logit specification is as follows[5]:

$$\ln s_H - \ln s_O = a_H - \beta p_H + \delta_H \mathrm{Inc} + \xi_H \quad (9)$$

$$\ln s_G - \ln s_O = a_G - \beta p_G + \delta_G \mathrm{Inc} + \xi_G \quad (10)$$

$$\ln s_L - \ln s_O = a_L - \beta p_L + \delta_L \mathrm{Inc} + \xi_L \quad (11)$$

where $\ln s_H$, $\ln s_G$, and $\ln s_L$ are natural log of market shares of Hood, Garelick, and private label, $a_H$, $a_G$, $a_L$ are constant terms, $\beta$ is the common slope coefficient, Inc is the income variable, and $\xi_H$, $\xi_H$, and $\xi_H$ are residual terms.

The contract curves are derived as described in equation (3) from corresponding first order conditions of the retailer's and manufacturer's profit maximization problems:

[5] The demand specifications in (6) – (8) are derived from subtracting the natural log of the outside option's density function from the natural log of a brand's density function. In this study the outside option is the residual brands.

$$p_H = \frac{1}{\beta(1-s_H)} + MC_H - \left(p_G - \frac{s_G(w_G + c_G)}{1-s_H}\right) - \left(p_L - \frac{s_L(MC_L + c_L)}{1-s_H}\right) \quad (12)$$

$$p_G = \frac{1}{\beta(1-s_G)} + MC_G - \left(p_H - \frac{s_H(w_H + c_H)}{1-s_G}\right) - \left(p_L - \frac{s_L(MC_L + c_L)}{1-s_G}\right) \quad (13)$$

$$p_L = \frac{1}{\beta(1-s_L)} + MC_L - \left(p_H - \frac{s_H(w_H + c_H)}{1-s_L}\right) - \left(p_G - \frac{s_G(w_G + c_G)}{1-s_L}\right) + \beta_H s_H + \beta_G s_G \quad (14)$$

The two parameters that measures retailers' bargaining power, $\beta_H$ and $\beta_G$, are defined as $\frac{\partial(p_H - w_H)}{\partial p_L}$ and $\frac{\partial(p_G - w_G)}{\partial p_L}$ respectively. Negative estimates of these two parameters indicate the retailer's use of private label as a source of bargaining power. Since wholesale prices are not observable it is decomposed into the following:

$$w_i = m_i + mc_i \quad (15)$$

where $m_i$ is the unobserved margin the manufacturers realize from bargaining with the retailers over both wholesale and retail prices. A value of zero indicates no bargaining power by the manufacturers and a value of $p_i - c_i - mc_i$ indicates no bargaining power by the retailers. Since $m_i$ depends on the bargaining power and is assumed as a constant[6] that can be considered the average of $m_i$ over time, it can be modeled to be part of the constant term in the marginal cost function. This in fact solves the problem of unobserved brand-level wholesale prices and thus profit margin at wholesale. The unpleasant outcome is that this manufacturer's profit margin, $m_i$, cannot be recovered because the constant term in each supply side equation includes the constant terms in marginal costs of retailers and manufacturers and the wholesale profit margin. However,

[6] Note that in the double marginalization model $m_i$ depends on the price-setting behaviors of a manufacturer and can be solved for its optimal solution.

this approach, even with unobservable wholesale prices and cost data at retail, allows one to analyze changes in wholesale price with respect to that in private label price, which is the purpose of this paper. Moreover, no important information is lost empirically since wholesale prices are not observed and private label's bargaining advantage can be econometrically analyzed. Note that the resulting model is econometrically identical to that for the full vertical integration scenario, which can be considered a special case of efficient bargaining outcomes. In the full vertical integration model the wholesale price is constrained to be zero.

The supply side equations for estimation of the bargaining model are stated as follows:

$$p_H = \frac{1}{\beta(1-s_H)} + h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H - \left( p_G - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_H} \right) - \left( p_L - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_H} \right)$$

$$p_G = \frac{1}{\beta(1-s_G)} + g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G - \left( p_H - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_G} \right) - \left( p_L - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_G} \right)$$

$$p_L = \frac{1}{\beta(1-s_L)} + l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L - \left( p_H - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_L} \right) - \left( p_G - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_L} \right) + \beta_H s_H + \beta_G s_G$$

where $p_R$ is raw milk price, uv is units per gallon, and ss is share of skim milk sold. The constant terms, $h_0$, $g_0$, and $l_0$ include the fixed effect of marginal costs of the retailers and manufacturers and wholesale profit margin.

5. Alternative Vertical Market Structures

We also estimate two alternative vertical market structures to determine if they perform better than the bargaining model. The two alternative vertical market structures are vertical integration and vertical Nash pricing. Vertical integration assumes that retailers and manufacturers are fully integrated and maximize their profits jointly:

$$\begin{aligned}\max_{p_i} \pi^T &= \sum_i (p_i - w_i - c_i)s_i M + \sum_i (w_i - mc_i(\omega_i, z))s_i M \\ &= \sum_i (p_i - c_i - mc_i(\omega_i, z))s_i M\end{aligned} \quad ; \quad i = H, G, L$$

The corresponding first order conditions are:

$$p_H = \frac{1}{\beta(1-s_H)} + MC_H - \left(p_L - \frac{s_G MC_G}{1-s_H}\right) - \left(p_H - \frac{s_L MC_L}{1-s_H}\right) \tag{16}$$

$$p_G = \frac{1}{\beta(1-s_G)} + MC_G - \left(p_H - \frac{s_H MC_H}{1-s_G}\right) - \left(p_L - \frac{s_L MC_L}{1-s_G}\right) \tag{17}$$

$$p_L = \frac{1}{\beta(1-s_L)} + MC_L - \left(p_H - \frac{s_H MC_H}{1-s_L}\right) - \left(p_G - \frac{s_G MC_G}{1-s_L}\right) \tag{18}$$

where $MC_H = c_H + mc_H$, $MC_G = c_G + mc_G$, and $MC_L = c_L + mc_L$. The supply side equations for estimation are:

$$\begin{aligned}p_H = \frac{1}{\beta(1-s_H)} + h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H - \left(p_G - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_H}\right) \\ - \left(p_L - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_H}\right)\end{aligned}$$

$$p_G = \frac{1}{\beta(1-s_G)} + g_0 + g_1 p_R + g_2 uv_G + g_3 skim_G - \left( p_H - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_G} \right)$$
$$- \left( p_L - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 skim_L)}{1-s_G} \right)$$
$$p_L = \frac{1}{\beta(1-s_L)} + l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L - \left( p_H - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_L} \right)$$
$$- \left( p_G - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_L} \right)$$

The constant terms, $h_0$, $g_0$, and $l_0$ include the fixed effect of marginal costs of the retailers and manufacturers and wholesale profit margin.

As stated earlier the full vertical integration model is econometrically identical to the vertical bargaining model because wholesale prices cannot be observed. Although they are econometrically identical their estimation results have different interpretations for the supply side equations. In the full vertical integration model only marginal costs are estimated while marginal cost and wholesale profit margins are estimated jointly in the vertical bargaining model.

A vertical Nash game requires that retail price is set such that any change in wholesale price causes one-to-one change in retail price, that is, $\frac{\partial p_i}{\partial w_i} = 1$ and $\frac{\partial p_i}{\partial w_j} = 0$ (Choi, 1991). The market equilibrium is achieved by solving for the unobservable wholesale prices using manufacturers' first order conditions and substituting the wholesale prices in the first order conditions for retailers. The resulting equations that are estimated for each brand are:

$$p_H = \frac{1}{\beta(1-s_H)} + h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H$$
$$- \left( p_G - \frac{s_G}{\beta(1-s_G)(1-s_H)} - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_H} \right)$$
$$- \left( p_L - \frac{s_L}{\beta(1-s_L)(1-s_H)} - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_H} \right)$$

$$p_G = \frac{1}{\beta(1-s_G)} + g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G + p_H$$
$$- \left( p_H - \frac{s_H}{\beta(1-s_H)(1-s_G)} - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_G} \right)$$
$$- \left( p_L - \frac{s_L}{\beta(1-s_L)(1-s_G)} - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_G} \right)$$

$$p_L = \frac{1}{\beta(1-s_L)} + l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L$$
$$- \left( p_H - \frac{s_H}{\beta(1-s_H)(1-s_L)} - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_L} \right)$$
$$- \left( p_G - \frac{s_G}{\beta(1-s_G)(1-s_L)} - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_L} \right)$$

The constant terms, $h_0$, $g_0$, and $l_0$ include the fixed effect of marginal costs of the retailers and manufacturers and wholesale profit margin. Detailed derivation is presented in the appendix.

## 6. Data, Descriptive Statistics, and Estimation Method

Data for this study are from the University of Connecticut-Food Marketing Policy Center, and was purchased from Information Resources Incorporated (IRI). This IRI database provides four-week period data for the 58 periods from March 1996 to July 2000 on gallons sold, units sold, dollar sales, and prices for Hood, Garelick, and private label whole, 2%, 1%, and skim/low fat milk in Boston. Per capita income data are from Annual Editions of Market Scope. Raw milk price data are from Federal Milk Market Order 1 publications.

Table 1 gives the descriptive statistics for each variable used in the estimation of the models. Hood has the highest average price at $2.96 per gallon. Garelick and private label follow Hood with average retail prices at $2.77 per gallon and $2.49 per gallon respectively. These average price levels are clearly correlated with brand equity. Hood is commonly acknowledged to be the strongest milk brand in New England. When one examines the brand quantities sold one sees that private label's average sales per capita and market share are the highest. Hood has the lowest average sales per capita and market share in the lowest and Garelick is in the middle. This general milk choice and pricing structure is typical for other US urban areas. Private label sells at a significant discount to brands and has a market share above 50%, often as high as 80% in some urban market areas such as Chicago.

Although brand equity explains the observed price structure, some of the reported brand price differential may be due to higher costs. Hood's average units per gallon is the highest. This means that more Hood milk is sold in smallest bottles (0.5 gallons, quarts) than is the case for the other brands. The average price of raw 3.5-butterfat milk is $1.47 per gallon. Its minimum was $1.26 per gallon and its maximum was $1.77 per gallon. This raw milk cost is common to all brands but the butterfat mix varies by brand and the brands that sell more skim milk have lower raw milk costs. The share of private label milk that is skim is higher than that for Garelick and Hood. This may be another reason why private label prices are less than Hood and Garelick milk.

Generalized Method of Moments (GMM) is used to estimate the simultaneous system of 6 equations in all models. GMM estimation brings efficiency gains in the presence of heteroscedasticity, and if the disturbances are homoscedastic, then it is asymptotically the same as 3-stage least square estimation (Greene, 2002).

## 7. Empirical Results

### 7.1 Results for the Bargaining Model

Table 2 shows the demand price coefficient matrix, a 3x3 matrix with nine coefficients, which is constrained to the estimation of one price coefficient that is identical for all three brands. It is negative as hypothesized (-4.0983) and highly significant with a t ratio at -31.33. Per capita income has a positive impact on all three brands and is significant at the 1% level in all cases. The income effect for Hood milk is the largest. This result reasonably reflects Hood's perceived highest quality.

All cost variables in the Logit model have correct signs as hypothesized. When examining the impact of milk costs on prices one finds that all three brands' prices are positively related to raw milk price at 1% significance level. Share of skim milk, a component cost variable, has a negative effect on brand level prices as hypothesized for all three brands and is significant for Garelick and private label at 1% level. The units per gallon coefficient estimates are positive for all three brands and significant for Hood and private label at 1 % level while insignificant for Garelick.

Turning to the most important result for this paper, one can notice that the two bargaining parameters in private label's first order conditions are negative and significant at 1% level. The result suggests the bargaining model is a valid approach to analyzing the Boston fluid milk market and private label indeed seems to be a strategic variable in the bargaining between retailers and processors[7] when they negotiate the division of retail revenues. Garelick brand is more sensitive to private label's price cut. For 1 cent

[7] From this point on, processor means manufacturer because milk bottlers are usually called milk processors.

decrease in private label retail price the retailer can gain 1.7 and 3.3 cents in gross profit margin for Hood and Garelick respectively. This shows that the strategic effect of private label has more effect on Garelick than Hood, that is, Garelick tends to reduce its wholesale price more than Hood. The intuition may be that private label is a better substitute for Garelick than Hood. When private label price reduces it reduces Garelick's market share more than Hood.

The bargaining process is significantly influenced by the presence of private label products sold by retailers. As the retailers reduce the retail prices of private label products, they expect or conjecture that the processors of branded products, Hood and Garelick, to reduce their wholesale price as well[8]. This conjecture in essence lowers the price of private label products and seems to be the key configuration of supply side equations to result in correct signs for the coefficients in the marginal cost functions.

An interesting question to ask is what happens if processors are unwilling to honor a request by retailers for more profit margins. There are two possibilities. One is that retailers accept the current allocation ratio and current equilibrium is retained. Another possibility is that the current bargaining breaks down and the processors and retailers return to double marginalization. In the second possibility both are worse off if processors' total profit is greater than that in the case of double marginalization, for example, vertical Nash. However, the retailers' private label will become even more dominant due to its market integration and increased margin of private label price over brand prices. Therefore, the retailers' loss of profit will be partly, if not entirely,

[8] In a Vertical Nash or full integration model, there is price followship at market equilibrium. However, when prices are at equilibrium, price followship only occurs when there is an exogenous change in marginal cost. In the bargaining model presented in this paper private label expects other milk brands to follow price reduction based on its market leadership position.

compensated by the expansion of private label. For processors this presents a strategic problem because not only they will lose profits, but also they will lose market shares due to widened price gap between private label and factory brands. The fact that factory brands have more to lose both financially and strategically makes private label a credible threat that retailers can use to affect bargaining outcomes to their favor.

### 7.2 Results for the Full Integration Model

Table 3 reports estimation results for the full integration model. The demand coefficient estimate is -5.89 and is significant at 1% level. Income effect is positive and significant at 1% level for Hood milk, the perceived best brand, favored by higher income consumers.

Marginal cost coefficient estimates show a weakness of this specification. Raw milk price, expected to have a positive effect on the wholesale and retail prices since it is the major input for processing fluid milk, is negative but insignificant for Hood, and is positive as expected and significant for Garelick and private label. Share of skim milk is positive and significant at 1% level for Hood although it is negative and significant at 1% level as hypothesized for Garelick and private label. Units per gallon provides another estimate with wrong negative signs that are significant at 1% level for Garelick and private label. However it is positive as hypothesized and significant for Hood at 1% level.

### 7.3 Results for the Vertical Nash Model

Estimation results are presented in Table 4. The single demand coefficient has the correct sign with a value of -8.6548 and is significant at the 1% level with t ratios of

34.53. The income coefficients are positive and significant. Garelick's highest income effect among the three brands is surprising since Hood milk is perceived as the best brand and is also priced so. This may be a sign of model misspecification although the model's overall performance is acceptable.

Estimation results for the cost variables show many wrong signs and thus indicate major model misspecification. Raw milk variable is negative for all three brands and is significant for Hood at 1% level while insignificant for other two brands. The negative signs contradict our hypothesis that raw milk price is positively correlated with wholesale and retail prices. Share of skim milk sold is negative as hypothesized for all three brands and significant at 1% level for Garelick and private label. Units per gallon is positive also as hypothesized and significant at 1% level for all three brands as well. The estimates of raw milk price with wrongs signs for all three brands indicate severe misspecification on the supply side and suggest that vertical Nash pricing may not be an appropriate specification for modeling firm behaviors in the Boston fluid milk market.

## 7.4 Tests to Choose Among the Three Models and Demand Elasticities

We perform three nested SSRD tests for the three models to determine the best model. SSRD test statistics described by Amemiya (1985) is as follows:

$$\mathrm{SSRD} = \frac{N}{S(\alpha)}[S(\tilde{\alpha}) - S(\alpha)]$$

where N is number of observations, $S(\alpha)$ and $S(\tilde{\alpha})$ are minimized objective function values from the estimations of the restricted and unrestricted specifications:

$$S(\alpha) = \frac{1}{N} e' Z(Z'\Sigma Z)^{-1} Z' e$$

where Z is a matrix of instruments and is variance–covariance matrix.  Alternatively, one can also use the test statistic given by Greene (2002):

$$SSRD = NS(\tilde{\alpha}) - TS(\alpha)$$

Test results[9] show that model performances are statistically identical for the three models.  This result indicates that simply based on the measure of model performance one cannot successfully identify the more credible model. Further examination of coefficients estimates or other related measures such elasticities may be necessary to determine the best model.  In this case with the signs of all coefficients as anticipated the bargaining model clearly outperforms the other two models in this regard.

Full integration could be as good if one assumes that raw milk price does not affect retail milk price. Obviously this assumption is restrictive and unreasonable. The results of bargaining model are also compared to the two linear models in Tian and Cotterill (2005).  The test statistics for vertical bargaining model vs. fixed premium model and Mills Address model are 10.27 and 12.72 respectively.  Thus the unrestricted model, vertical bargaining model, is the best specification.  Moreover, only the vertical bargaining model gives correct signs on all specified variables, thus making it the most credible econometric model for the Boston fluid milk market.

The own price demand elasticities in the bargaining model for Hood, Garelick and private label are -10.19, -8.16, and -4.04 respectively.  These elasticity estimates are significantly different from those in either studies.  Brand level demand is more elastic at chain level (Cotterill and Dhar, 2002) and less elastic at market level (Tian and Cotterill,

[9] The minimized function values for the bargaining model, full integration model, and vertical Nash model are 0.525, 0.562, and 0.586 respectively.  The SSRD test statistics for the two tests, bargaining model vs. full integration model and vertical Nash model are 4.09 and 6.01.  At 2 degrees of freedom the restricted models cannot be rejected to favor the unrestricted model, the vertical bargaining model.

2005). The estimates of demand elasticities in this work for the Boston fluid milk market suggest that consumers from time to time do switch between brands if not between supermarket chains.

The own price demand elasticities in the full integration model for Hood, Garelick and private label are -14.66, -11.75, and -5.81 respectively. These estimates are significantly smaller than those in vertical Nash pricing model. However they are still significantly higher than those estimated in models in which each brand's profit is maximized separately (Li and Cotterill, 2005).

The own price demand elasticities in the vertical Nash model for Hood, Garelick and private label are -21.51, -17.24, and -8.53 respectively. It is very unusual to observe such elastic demand at aggregated level such as brand level data. They are very much in line with the elasticities in Dhar and Cotterill (2002) in which they estimate demand system at store level and obtained large demand elasticities.

## 8. Concluding Remarks

This chapter empirically studies the impact of private label products in the Boston fluid milk market. It finds empirical support for the theory that private label can provide its retailer strategic power in bargaining with branded products that also sold via the same retailer. In a market with strong private label presence, modeling the private label's strategic effect may be necessary if supply side equations are to be established. The estimation results show that different supply-side structures result in large variation in estimated demand elasticities, which will have significant implications when used for policy analysis. Other interesting findings include that supply side and even demand side specifications may not affect overall performance of a model as shown in the specification tests. In the situation where overall performance cannot be used to statistically select the best model, researchers need additional information. This is usually priori information such as hypothesized sign for or value of coefficients. The models that show correct hypothesized signs or values should be considered more credible than those with wrong signs or values when overall model performances are statistically identical.

Future research needs to focus on obtaining more relevant cost variables for retailers and re-estimate the bargaining model to test its robustness. Another area for further research is to apply the bargaining model to markets with varied private label presence and determine if the strategic effect of private label increase with its presence. It also is interesting to apply the bargaining model to store level data and examine if the model continues to give similar results.

Table 4.1: Descriptive Statistics of Variables

| Variable | Description of Variable | Mean | St. Dev | Minimum | Maximum |
|---|---|---|---|---|---|
| $p_H$ | Price of Hood | 2.97 | 0.19 | 2.69 | 3.36 |
| $p_G$ | Price of Garelick | 2.78 | 0.25 | 2.46 | 3.29 |
| $p_L$ | Price of Private Label | 2.49 | 0.20 | 2.21 | 2.85 |
| $q_H$ | Sales Volume of Hood | 0.84 | 0.21 | 0.52 | 1.18 |
| $q_G$ | Sales Volume of Garelick | 1.78 | 0.31 | 1.20 | 2.41 |
| $q_L$ | Sales Volume of Private Label | 4.26 | 0.36 | 3.45 | 4.90 |
| $p_{RAW}$ | Price of Raw Milk | 1.48 | 0.11 | 1.27 | 1.77 |
| $s_H$ | Market Share of Hood | 0.12 | 0.03 | 0.17 | 0.06 |
| $s_G$ | Market Share of Garelick | 0.24 | 0.03 | 0.30 | 0.20 |
| $s_L$ | Market Share of Private Label | 0.58 | 0.02 | 0.62 | 0.52 |
| Inc | Per Capita Income | 19022 | 2086 | 16509 | 22219 |
| $ug_H$ | Units per Gallon for Hood | 1.67 | 0.15 | 1.50 | 1.97 |
| $ug_G$ | Units per Gallon for Garelick | 1.52 | 0.09 | 1.22 | 1.66 |
| $ug_L$ | Units per Gallon for Private Label | 1.29 | 0.02 | 1.24 | 1.33 |
| $ss_H$ | Share of Skim Milk Sales for Hood | 8.66 | 2.61 | 4.63 | 12.78 |
| $ss_G$ | Share of Skim Milk Sales for Garelick | 18.43 | 1.95 | 14.42 | 22.15 |
| $ss_L$ | Share of Skim Milk Sales for Private Label | 39.09 | 1.53 | 34.89 | 42.43 |

Prices and income are deflated by Consumer Price Index

Table 2: Empirical Results - Bargaining Model

| | $s_H$ | $s_G$ | $s_L$ | $p_H$ | $p_G$ | $p_L$ |
|---|---|---|---|---|---|---|
| constant | 6.3075*** | 7.9039*** | 8.6170*** | 1.8456*** | 2.2108*** | 1.3708*** |
| | (17.62) | (30.31) | (36.96) | (17.45) | (20.48) | (8.18) |
| $p_H$ | -4.0983*** | -- | -- | -- | -- | -- |
| | (-31.33) | -- | -- | -- | -- | -- |
| $p_G$ | -- | -4.0983*** | -- | -- | -- | -- |
| | -- | (-31.33) | -- | -- | -- | -- |
| $p_L$ | -- | -- | -4.0983*** | -- | -- | -- |
| | -- | -- | (-31.33) | -- | -- | -- |
| Inc | 0.0003*** | 0.0002*** | 0.0002*** | -- | -- | -- |
| | (24.13) | (14.04) | (13.10) | -- | -- | -- |
| $p_{RAW}$ | -- | -- | -- | 0.3088*** | 0.4764*** | 0.4191*** |
| | -- | -- | -- | (3.94) | (5.87) | (5.38) |
| $ss_H$ | -- | -- | -- | -0.0001 | -- | -- |
| | -- | -- | -- | (-0.08) | -- | -- |
| $ss_G$ | -- | -- | -- | -- | -0.0183*** | -- |
| | -- | -- | -- | -- | (-19.86) | -- |
| $ss_L$ | -- | -- | -- | -- | -- | -0.0327*** |
| | -- | -- | -- | -- | -- | (-19.69) |
| $ug_H$ | -- | -- | -- | 0.3059*** | -- | -- |
| | -- | -- | -- | (10.12) | -- | -- |
| $ug_G$ | -- | -- | -- | -- | 0.0428 | -- |
| | -- | -- | -- | -- | (1.16) | -- |
| $ug_L$ | -- | -- | -- | -- | -- | 1.6063*** |
| | -- | -- | -- | -- | -- | (23.56) |

| | | | | | | |
|---|---|---|---|---|---|---|
| $\beta_H$ | -- | -- | -- | -- | -- | -1.7001*** |
| | -- | -- | -- | -- | -- | (-17.65) |
| $\beta_G$ | -- | -- | -- | -- | -- | -3.3131*** |
| | -- | -- | -- | -- | -- | (-35.83) |

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level; t-ratios in parentheses

Table 3: Empirical Results - Full Integration Model

| | $s_H$ | $s_G$ | $s_L$ | $p_H$ | $p_G$ | $p_L$ |
|---|---|---|---|---|---|---|
| Constant | 9.7892*** | 9.9919*** | 10.9783*** | 1.7628*** | 3.4631*** | 5.4794*** |
| | (25.36) | (31.23) | (41.69) | (11.40) | (22.37) | (22.89) |
| $p_H$ | -5.8984*** | -- | -- | -- | -- | -- |
| | (-30.82) | -- | -- | -- | -- | -- |
| $p_G$ | -- | -5.8984*** | -- | -- | -- | -- |
| | -- | (-30.82) | -- | -- | -- | -- |
| $p_L$ | -- | -- | -5.8984*** | -- | -- | -- |
| | -- | -- | (-30.82) | -- | -- | -- |
| Inc | 0.0004*** | 0.0004*** | 0.0003*** | -- | -- | -- |
| | (21.96) | (13.74) | (15.00) | -- | -- | -- |
| $p_{RAW}$ | -- | -- | -- | -0.0897 | 0.1870** | 0.1410* |
| | -- | -- | -- | (-1.15) | (2.78) | (1.93) |
| $ss_H$ | -- | -- | -- | 0.0200*** | -- | -- |
| | -- | -- | -- | (9.25) | -- | -- |
| $ss_G$ | -- | -- | -- | -- | -0.0513*** | -- |
| | -- | -- | -- | -- | (-27.71) | -- |
| $ss_L$ | -- | -- | -- | -- | -- | -0.0261*** |
| | -- | -- | -- | -- | -- | (-17.05) |
| $ug_H$ | -- | -- | -- | 0.4501*** | -- | -- |
| | -- | -- | -- | (10.06) | -- | -- |
| $ug_G$ | -- | -- | -- | -- | -0.1893*** | -- |
| | -- | -- | -- | -- | (-6.13) | -- |
| $ug_L$ | -- | -- | -- | -- | -- | -2.0333*** |
| | -- | -- | -- | -- | -- | (-15.19) |

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level; t-ratios in parentheses

Table 4: Empirical Results - Vertical Nash Model

| | $s_H$ | $s_G$ | $s_L$ | $p_H$ | $p_G$ | $p_L$ |
|---|---|---|---|---|---|---|
| Constant | 14.9308*** | 13.2747*** | 14.5836*** | 1.2315** | 1.3453*** | 0.2471 |
| | (25.76) | (31.80) | (41.78) | (2.58) | (2.89) | (0.59) |
| $p_H$ | -8.6548*** | -- | -- | -- | -- | -- |
| | (-36.63) | -- | -- | -- | -- | -- |
| $p_G$ | -- | -8.6548*** | -- | -- | -- | -- |
| | -- | (-36.63) | -- | -- | -- | -- |
| $p_L$ | -- | -- | -8.6548*** | -- | -- | -- |
| | -- | -- | (-36.63) | -- | -- | -- |
| Inc | 0.0005*** | 0.0006*** | 0.0005*** | -- | -- | -- |
| | (18.09) | (15.12) | (16.07) | -- | -- | -- |
| $p_{RAW}$ | -- | -- | -- | -0.5476* | -0.4301 | -0.452 |
| | -- | -- | -- | (-1.73) | (-1.34) | (-1.43) |
| $ss_H$ | -- | -- | -- | -0.003 | -- | -- |
| | -- | -- | -- | (-1.55) | -- | -- |
| $ss_G$ | -- | -- | -- | -- | -0.0125*** | -- |
| | -- | -- | -- | -- | (-12.03) | -- |
| $ss_L$ | -- | -- | -- | -- | -- | -0.0121*** |
| | -- | -- | -- | -- | -- | (-8.71) |
| $ug_H$ | -- | -- | -- | 0.2672*** | -- | -- |
| | -- | -- | -- | (11.44) | -- | -- |
| $ug_G$ | -- | -- | -- | -- | 0.1271*** | -- |
| | -- | -- | -- | -- | (5.17) | -- |
| $ug_L$ | -- | -- | -- | -- | -- | 1.0017*** |
| | -- | -- | -- | -- | -- | (12.52) |

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level; t-ratios in parentheses

## APPENDIX: DERIVATION OF SUPPLY SIDE EQUATIONS FOR VERTICAL NASH LOGIT SPECIFICATION

We develop the supply side equations for a vertical Nash Logit specification. A retailer's profit maximization problem is restated:

$$\max_{p_i} \pi^R = \sum_i (p_i - w_i - c_i) s_i M \,; \qquad i = H, G, L$$

where $p_i$ is the retail price, $w_i$ is the wholesale price, $s_i$ is the market share of brand i, $c_i$ is the retailer's marginal cost for brand i, and M is the market size (total expenditure) of fluid milk sold in supermarkets. H, G, and L stand for Hood, Garelick and private label brands.

A manufacturer maximizes its profit by setting its wholesale price:

$$\max_{w_i} \pi^W = \sum_i (w_i - mc_i(\omega_i, z)) s_i M \,; \qquad i = H, G, L$$

where $mc_i$ is marginal cost as a function of $\omega_i$, brand i's cost of raw coffee and $z_i$ costs of other input factors.

The first order conditions for the retailer's profit maximization problem are:

$$p_H = \frac{1}{\beta(1-s_H)} + MC_H - \left( p_G - \frac{s_G(w_G + c_G)}{1-s_H} \right) - \left( p_L - \frac{s_L(w_L + c_L)}{1-s_H} \right) \qquad \text{(A1)}$$

$$p_G = \frac{1}{\beta(1-s_G)} + MC_G - \left( p_H - \frac{s_H(w_H + c_H)}{1-s_H} \right) - \left( p_L - \frac{s_L(w_G + c_L)}{1-s_H} \right) \qquad \text{(A2)}$$

$$p_L = \frac{1}{\beta(1-s_L)} + MC_L - \left( p_H - \frac{s_H(w_H + c_H)}{1-s_L} \right) - \left( p_G - \frac{s_G(w_G + c_G)}{1-s_L} \right) \qquad \text{(A3)}$$

where $MC_H = c_H + mc_H$, $MC_G = c_G + mc_G$, and $MC_L = c_L + mc_L$.

The first order conditions for each manufacturer's profit maximization problems are:

$$w_H = \frac{1}{\beta(1-s_H)} + mc_H \tag{A4}$$

$$w_G = \frac{1}{\beta(1-s_G)} + mc_G \tag{A5}$$

$$w_L = \frac{1}{\beta(1-s_L)} + mc_L \tag{A6}$$

Substituting these equations into the solutions to the retailer's profit maximization problem gives the supply side equations:

$$\begin{aligned} p_H = \frac{1}{\beta(1-s_H)} + MC_H - \left( p_G - \frac{s_G}{\beta(1-s_G)(1-s_H)} - \frac{s_G MC_G}{1-s_H} \right) \\ - \left( p_L - \frac{s_L}{\beta(1-s_L)(1-s_H)} - \frac{s_L MC_L}{1-s_H} \right) \end{aligned} \tag{A7}$$

$$\begin{aligned} p_G = \frac{1}{\beta(1-s_G)} + MC_G - \left( p_H - \frac{s_H}{\beta(1-s_H)(1-s_G)} - \frac{s_H MC_H}{1-s_G} \right) \\ - \left( p_L - \frac{s_L}{\beta(1-s_L)(1-s_G)} - \frac{s_L MC_L}{1-s_G} \right) \end{aligned} \tag{A8}$$

$$\begin{aligned} p_L = \frac{1}{\beta(1-s_L)} + MC_L - \left( p_H - \frac{s_H}{\beta(1-s_H)(1-s_L)} - \frac{s_H MC_H}{1-s_L} \right) \\ - \left( p_G - \frac{s_G}{\beta(1-s_G)(1-s_L)} - \frac{s_G MC_G}{1-s_L} \right) \end{aligned} \tag{A9}$$

Substituting cost functions into the three supply side equations gives the econometric equations for the supply side:

$$p_H = \frac{1}{\beta(1-s_H)} + h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H - \left( p_G - \frac{s_G}{\beta(1-s_G)(1-s_H)} - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_H} \right) - \left( p_L - \frac{s_L}{\beta(1-s_L)(1-s_H)} - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_H} \right) \tag{A10}$$

$$p_G = \frac{1}{\beta(1-s_G)} + g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G + p_H - \left( p_H - \frac{s_H}{\beta(1-s_H)(1-s_G)} - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_G} \right) - \left( p_L - \frac{s_L}{\beta(1-s_L)(1-s_G)} - \frac{s_L(l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L)}{1-s_G} \right) \tag{A11}$$

$$p_L = \frac{1}{\beta(1-s_L)} + l_0 + l_1 p_R + l_2 uv_L + l_3 ss_L - \left( p_H - \frac{s_H}{\beta(1-s_H)(1-s_L)} - \frac{s_H(h_0 + h_1 p_R + h_2 uv_H + h_3 ss_H)}{1-s_L} \right) - \left( p_G - \frac{s_G}{\beta(1-s_G)(1-s_L)} - \frac{s_G(g_0 + g_1 p_R + g_2 uv_G + g_3 ss_G)}{1-s_L} \right) \tag{A12}$$

The constant terms, $h_0$, $g_0$, and $l_0$ include the fixed effect of marginal costs of the retailers and manufacturers and wholesale profit margin.

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