AN EMPIRICAL INVESTIGATION OF PRIVATE LABEL SUPPLY BY NATIONAL LABEL PRODUCERS

Xinlei (Jack) Chen
jack.chen@sauder.ubc.ca

Om Narasimhan
naras002@umn.edu

George John
johnx001@umn.edu

Tirtha Dhar
tirtha.dhar@sauder.ubc.ca

This Version: April 12, 2009

Xinlei (Jack) Chen and Tirtha Dhar are Assistant Professors at the Sauder School of Business, University of British Columbia; George John is the Pillsbury-Gerot Chair, and Om Narasimhan is an Associate Professor, both at the Carlson School of Management, University of Minnesota. We are grateful to Prof. Kyle Stiegert and the Food System Research Group, University of Wisconsin for providing us access to the data. We would like to thank Rakesh Niraj and S. Siddarth for helpful comments. The first author gratefully acknowledges support from the Social Sciences and Humanities Research Council of Canada.

AN EMPIRICAL INVESTIGATION OF PRIVATE LABEL SUPPLY BY NATIONAL LABEL PRODUCERS

ABSTRACT

Private labels are ubiquitous in several categories, including groceries, apparel and appliances. In most of the extant work, private label (PL) product suppliers are price-taking fringe firms that do not produce national labels themselves. However, stylized facts suggest that national label (NL) producers themselves supply a large fraction of PL products. Further, the assumption of marginal cost supply in most existing modeling work renders meaningless any examination of the differential impact of various upstream supply arrangements, or of any strategic motives for PL supply. This provides the motivation for our two research questions. First, can an NL firm profit from being an outsourced PL supplier? Second, what are the upstream and downstream impacts of different PL supply arrangements?

We answer these questions by modeling private labels as homogenous products at wholesale, but as differentiated products at retail. In contrast, national label products are differentiated at both wholesale and retail levels. Using structural model estimates for fluid milk in a major metropolitan area, we conduct three counterfactual experiments. We find that both NL producers and retailers profit from adding private labels. We also find that vertically integrated supply of PL leads to lower prices for end consumers.

Keywords: Private labels, structural estimation, distribution channels, counterfactuals.

1. INTRODUCTION

We start with some definitions. Denote a private label (PL) as a brand owned or controlled by a downstream firm (retailer) and sold exclusively at a single retail chain or group. Similarly, denote a national label (NL) as a brand owned by an upstream firm (producer) and typically available at a number of downstream outlets[1]. Kumar and Steenkamp (2007) note that PL products existed over a century ago (e.g., A&P's Eight O'Clock Breakfast Coffee), but that PL presence accelerated in the seventies coinciding with the growth and consolidation of the retail sector. While PL products are most familiar in the grocery sector (e.g., Quelch and Harding 1996), they account for almost half of domestic apparel sales. In the publishing industry, the iconic CliffsNotes study guides competes with Barnes and Noble's own PL (SparkNotes). In financial services, Charles Schwab procures its PL funds from 'white label' [2] suppliers like USB, while it also retails NL funds like Dreyfus. A PL may be produced by an upstream firm (such as an NL firm) or else produced internally[3]. We refer to procurement from an upstream firm as a 'vertically separated' supply arrangement, and procurement internally as a 'vertically integrated' supply arrangement[4].

While there is a large literature on various aspects of PL, most of the theoretical work and all of the empirical work assumes that PL products are procured in perfectly competitive fashion at marginal cost. This is problematic along two dimensions. First, considerable real-world evidence seems to contradict this assumption. As a matter of fact, the outsourcing of PL production to NL firms is pervasive (see Kumar and Steenkamp 2007; Soberman and Parker 2006). According to Quelch and Harding (1996), over 50% of NL consumer packaged goods firms actually produced PL products as well; indeed, NL firms supplied over 60% of PL products (by volume). It is hard to imagine that NL firms with any degree of pricing power would willingly supply PL products at marginal cost. Second, and more substantively, this assumption precludes the asking and answering of a number of questions of interest to marketers.

For instance, the assumption of marginal cost supply renders meaningless any examination of the differential impact of various upstream supply arrangements. If PL products can be procured at marginal cost, the identity of the supplier is irrelevant, as are any strategic motives for PL supply. This

---

[1] Of course, there is no intra-brand competition for an exclusively distributed national label, but its brand ownership resides with the upstream firm. It is useful to point out that the terms 'private label', 'store brand', and 'generic' are often used synonymously – we use the term private label throughout.

[2] In financial and manufacturing sectors, private labels are termed 'white' labels by their producers as a reminder that they are packaged and labeled according to the wishes of the buyer.

[3] As we discuss shortly, internal supply is equivalent to procurement from a price-taking contractor, in that both assume marginal cost supply.

[4] Note that our usage of the terms 'vertically integrated' and 'vertically separated' differs somewhat from the convention in the channels literature. Importantly, this usage *applies only to PL supply* – NL products *always* have a vertically separated channel structure.

leads us to the two questions we seek to answer in this paper. First, can an NL firm profit from being an outsourced PL supplier? Second, what is the upstream and downstream impact of different PL supply arrangements?

Answering these questions requires us to overcome a fairly significant hurdle at the outset, viz. how should one model PL supply in a vertical channel? A complete model of PL supply, one could argue, would address the following issues: i) the choice of PL supplier, upstream; ii) quality positioning of the PL product, upstream and downstream; iii) strategic interaction between NL and PL products, upstream and downstream. In other words, one would have to endogenize the choice of PL supplier and the quality positioning of the products, while accounting for horizontal and vertical strategic interactions between NL and PL products. Unfortunately, incorporating all of these features would result in a prohibitively complex model. As a first step, therefore, we choose to focus on a subset of issues that are most relevant to our research questions. For a start, we abstract away from endogenous PL quality choice; while this is an important issue in itself, it is nevertheless true that across many categories, one rarely finds quality tiers in PL products. Our choice of research context (the fluid milk product category), reflects this decision to abstract away from quality choice, because USDA grading standards for milk minimize objective quality differences. Second, we abstract away from the endogenous choice of PL supplier - we implicitly fold in fringe firm suppliers into the vertically integrated case because the product is procured at marginal cost in both instances. Again, this accords well with our institutional context, because there are no fringe suppliers of PL products in our data. While the above discussion serves to delimit the domain of our inquiry, it is important to emphasize that these features are not idiosyncratic to the milk category; a large number of product categories, especially those with a large PL presence, fit our assumptions (e.g., orange juice).

Even with the caveats above in hand, we are still left with the issue of modeling PL supply as distinct from NL supply. Clearly, the two are distinguished in one very important aspect upstream – NL products are branded, while PL products are not. On the other hand, both PL and NL products are branded downstream. In other words, it is fair to say that PL products are *homogeneous* alternatives at the wholesale level, but *differentiated* alternatives at the consumer level; NL products, on the other hand, are *differentiated* at both wholesale and consumer levels[5]. The economics literature suggests a plausible way of capturing this fundamental conceptual difference in a modeling framework, namely the use of a Cournot game to model PL supply, while using a Bertrand game to model NL products (and therefore treating NL as differentiated upstream). Our use of a Cournot game upstream parallels Gilbert and Hastings (2001), who face a similar situation in their examination of vertical foreclosure in the

[5] Of course, the notion that PL products are homogenous upstream holds only if quality differences between PL products are not an issue.

gasoline market. As in their case, and importantly for the validity of the Cournot assumption, it is true in our context that there does not exist unlimited capacity in the form of fringe producers ready to supply the PL product (if that were the case, one would model perfectly competitive supply at marginal cost, which, as discussed earlier, has been the dominant theoretical treatment of PL supply). More precisely, we model NL and PL products upstream and downstream by using i) Cournot-Nash models to capture the strategic interaction between PL suppliers at the wholesale level, ii) Bertrand-Nash models to capture the strategic interaction between NL products at the wholesale level, and iii) Bertrand-Nash models to capture the strategic interaction between the entire set of products (NL and PL) at the consumer level. Note that this removes the assumption of perfectly competitive supply of PL products upstream, while still retaining essential differences between NL and PL products.

We combine the above supply specification with a demand specification, where heterogeneous consumers choose from a set of differentiated NL and PL products between stores. Importantly, we explicitly model consumers' quantity decisions. All this is considerably more complex than extant work, and requires us to develop estimation procedures that accommodate strategic actors involved in diverse vertical and horizontal channel interactions.

Using the fluid milk product category in a major metropolitan area as our research setting, we estimate the structural model and perform a set of counterfactuals to answer the research questions posed earlier. With regard to our first question, we find that supplying PL products improves the NL firm's profits. Given existing brand preferences, the positive margins earned from PL supply overcome negative competitive pricing effects. Further, we find that retailers benefit from the presence of PL products. With regard to the second question, we find that given the cost differences between suppliers in our data, vertically integrated supply is better for end consumers (in that, prices are lower). Importantly, we validate the conclusions drawn from our model with the help of a natural experiment, namely the divestiture of one retailer's in-house milk processing facility, which subsequently created a PL monopolist supplier[6]. Our model predicts out-of-sample post-divestiture prices quite closely. As far as we know, this is among the first out-of-sample validations of a structural model of a vertically linked market, and adds to the robustness of our conclusions about the strategic behavior of private label suppliers.

We believe our contributions are four-fold. First, our results pertaining to the impact of PL presence and its supply structure on various constituents (suppliers, retailers, consumers) are likely to be of interest to both managers and policy makers. Second, we believe our tools provide the policy maker a methodology to assess the net effects of alternative vertical supply arrangements, something that has

[6] The divestiture occurred in June 2000. In our terminology, PL supply for this retailer moved from 'vertical integration' to 'vertical separation'.

been of much importance to the anti-trust authorities lately (Froeb 2004). Third, we are among the first papers to combine rich supply side modeling with recent techniques that enable the modeling of quantity choice with aggregate data, leading to superior demand side estimates. Fourth, ours is among the few papers to validate a structural empirical IO model with out-of-sample predictions.

The remainder of the manuscript is organized as follows. The rest of this section is devoted to a discussion of the relevant literature. Section 2 presents the model and Section 3 discusses the estimation approach. Section 4 presents the empirical results. Section 5 presents and discusses the what-if scenarios central to our paper. We end with concluding remarks and suggestions for future research in Section 6.

1.1 Literature

The PL phenomenon has spawned an extensive literature in marketing and economics. Here, we review this work selectively with a view to specifying its ramifications for our own work.

Consider first the strand of work on the nature of PL consumer demand. Customers are heterogeneous in their preferences, and PL products differ from NL products in both quality (vertical differentiation) and feature sets (horizontal differentiation) (see Choi and Coughlan 2006 for an extended discussion). Several stylized facts have been documented in this literature, including lower price points for PL products that are essentially lower-quality versions of NL products (Berges-Sennou et al. 2004), and differential sensitivity to promotions (Raju et al. 1995). For our purposes, these results imply that our analysis must accommodate consumers with heterogeneous preferences for products. We do this by using random coefficient logit models to estimate demand.

Another strand of the literature focuses on vertical inter-firm interactions within a PL channel. From this work, we know that PL products (or even a credible threat thereof) increase the retailer's bargaining strength, and thus its share of channel profits vis-à-vis the NL supplier (e.g., Mills 1995; Narasimhan and Wilcox 1998; Scott-Morton and Zettlemeyer 2004). Crucially, these models assume that retailers obtain PL products from a vertically integrated source, or else outsource PL production at fully competitive prices (i.e., at marginal cost) to a contractor that lacks pricing power[7]. As pointed out earlier, this clearly does not fit the stylized fact where NL firms with pricing power nevertheless supply PL products. This suggests that we must carefully model PL vertical supply arrangements, which we do by specifying game theoretic models of these structures.

Finally, a recent strand of the literature uses empirical IO methods to assess strategic considerations in channels while accommodating cost and demand considerations (Kadiyali et al., 2000;

[7] One implication is that NL prices should decrease with more PL product penetration. However, Berges-Sennou et al. (2004) report that the prices of national labels are more likely to *increase* in such situations. This is echoed by Bonanno and Lopez (2005), who find that in the milk category, more PL presence is associated with higher NL prices.

Sudhir, 2001, Villas-Boas and Zhao, 2005; Chu et al. 2007; Chen et al. 2008). We draw on this literature in the formulation of our games upstream and downstream. However, none of this literature has dealt with a mix of homogenous and heterogeneous products, which is central to our analysis. Also, very few papers in this stream have modeled the quantity decision of the consumer, something we accommodate.

2. MODEL

2.1 Preliminary Data Considerations

Our data describe the fluid milk market of a major metropolitan area - Figure 1 illustrates the structure of this market[8]. Two NL firms (*M1* and *M2*) sell through five retail chains: *R1*, *R2*, *R3*, *R4*, and *R5*, with *R5* representing a composite residual chain[9]. Each chain sells its own PL alongside NL products from *M1* and *M2*. Altogether, PL milk accounts for almost 60% of the market. For most of our data period (1997-2000), *M1* supplied PL to *R2, R3, R4* and *R5*, but *R1* was vertically integrated into PL production and its internal requirements of *M2*[10]. In June 2000, *R1* divested this plant and began to purchase its PL milk from *M1*.

The fluid milk product category exhibits several appealing characteristics as a research setting for our questions. First, milk is a category where there is a strong PL presence (a recent study at the supermarket level found penetration rates for PL reduced-fat milk ranging from 24.78% in Dallas to 99.5% at Safeway in Seattle; see Bonanno and Lopez 2005), which helps us ascertain its market impact more sharply.

Second, USDA milk grading standards minimize objective quality differences across brands – this helps us to identify PL brand effects via store brand constants in our logit models and to abstract away from issues unrelated to the questions at hand (e.g., endogenous positioning of the private label in quality space). Related to this, the milk category does not possess the plethora of quality tiers and product features that characterize other categories, which simplifies our demand analysis greatly.

Third, and perhaps most importantly, this market comports well with our desire to study the ramifications of market power held by both producers and retailers. Transportation costs and government price supports for fluid milk create vertically linked closed oligopoly markets with producers and retailers. Thus, there are no fringe producers supplying PL products at marginal cost, nor is it feasible to ship fluid milk to purchasers outside a region in significant quantities.

[8] For reasons of confidentiality, we are unable to name the firms involved, or the metropolitan area.
[9] It should be noted that the 'national' brands in this category are actually regional brands. Given transportation costs and Federal government programs to support regional production, fluid milk markets are regional in nature.
[10] Note that backwards integration, or vertical integration of *R1* effectively meant that it was getting PL at marginal cost. This is distinct from, say, *M1* supplying PL to *R1*, a situation which did occur after June 2000.

Finally, there is considerable prior empirical work on this category, spanning multiple geographical areas and using a variety of methods (e.g., Bonanno and Lopez 2005; Chidmi et al. 2003). While few have used the kind of structural modeling we use, these papers provide us with points of comparison as well as points of departure.

With the above in mind, it is useful to address one possible drawback. It has been argued in the past that milk is often used as a loss-leader. Since our modeling relies on manufacturers and retailers exhibiting profit-maximizing behavior, loss-leader behavior would be problematic. However, contemporary evidence suggests the lack of prevalence of such behavior. For instance, the Food Marketing Institute (FMI), one of the principal associations representing food retailers and wholesalers, wrote the U.S. General Accounting Office that "major changes in the dairy case and in consumer demand have prompted many retailers to abandon the practice of using milk as a loss-leader" (FMI 2001). Indeed, milk prices at wholesale and retail point to high margins made by downstream agents – in fact, there have been charges of 'gouging' on milk prices, an accusation scarcely consistent with loss-leader behavior[11].

2.2 Consumer Demand

Our demand model follows Nair et al. (2005) closely and accounts for both heterogeneous preferences and multiple unit purchases amongst consumers. We define a product as a combination of chain, brand (NL or PL), and type (skim or whole milk). We model consumer *i* choosing a bundle of products to maximize her utility in each period, subject to a budget constraint. A possible objection to this formulation of the consumer decision is that it is unreasonable to think of consumers picking between chains based on the price of milk. As such, a better formulation would be to 'embed' the chain choice decision somehow, perhaps by assuming that the demand for any brand of milk in a market is the weighted sum of demands within each store, with the weights proportional to the number of consumers in each store[12]. While feasible econometrically, we do not have the minimum data needed to implement this suggestion[13]. Our consumer problem is formulated as:

---

[11] In New York, then Attorney General Elliot Spitzer investigated retail outlets following allegations of price gouging in fluid milk. A number of studies on the issue of 'fair' milk pricing can be found at the University of Connecticut's Food Marketing Policy Center's website, http://www.fmpc.uconn.edu/research/milk/.

[12] We thank the Area Editor for this suggestion.

[13] We would, at the minimum, need data on the customer traffic at each store (chain). That said, our approach is similar, conceptually, to a nested logit model, where the top nest models chain choice and the lower nest models brand/quantity choice conditional on chain choice. Absent any other information, the top nest would consist merely of a chain specific intercept, while the lower nest would be a brand choice regression, with brand dummies and other marketing mix variables as covariates. In essence, this is precisely what we have already.

$$\max_{x_{i1t}\dots x_{iJt}} u = u^*\left(\sum_{j=1}^{J}\psi_{ijt}x_{ijt}, \psi_{izt}z_{it}\right) \quad (1)$$

$$\text{s.t. } \sum_{j=1}^{J} p_{ijt}x_{ijt} + z_{it} = y_{it} \quad x_{ijt} \geq 0\,; z_{it} \geq 0$$

$$i = 1,..,I;\ j = 1,..,J;\ t = 1,..,T$$

where x_{ijt} is the quantity purchased of product j, ψ_{ijt} is the perceived quality-index of product j by consumer i, z_{it} is the numeraire good, p_{ijt} is the price for product j faced by consumer i in week t, and y_{it} is the total basket expenditure of the consumer. The linear subutility over the J products ensures that only a single alternative is chosen. Similar to Chiang (1991) and Chintagunta (1993), we assume the following functional form for the perceived quality index of each product and the outside good:

$$\psi_{ijt} = \exp\left(\frac{\gamma_{ijt} + \beta_{it}d_{jt} + \xi_{jt} + \varepsilon_{ijt}}{\alpha_i}\right)$$

$$\psi_{izt} = \exp\left(\frac{\varepsilon_{izt}}{\alpha_i}\right)$$

where α_i is an individual-specific scale that shifts the perceived quality of products and the outside goods across consumers, γ_{ijt} is consumer i's intrinsic preference for product j at time t, d_{jt} is a deal variable measuring the non-pricing promotion of product j at time t, ξ_{jt} captures unobservable (to the econometrician) demand shocks of product j at time t, and finally the error terms ε_{ijt} and ε_{izt} capture the consumer and product specific unobservable factors affecting consumers' quality perception of the products and the outside good. We assume the error terms follow an i.i.d. Extreme Value distribution:

$$\varepsilon_{ist} = \left(\varepsilon_{i1t},...,\varepsilon_{iJt}\right) \sim EV\left(0,\mu\right)$$

$$\varepsilon_{izt} \sim EV\left(0,\mu\right)$$

As in Chiang (1991), we assume the indirect utility corresponding to (1) has the flexible Homothetic Indirect TransLog (HITL) form. Therefore, the demand function conditional on purchase incidence (I_{it}=1) and product choice (C_{ijt}=1) is:

$$x_{ijt}\left(p_{jt},\psi_{ijt},\psi_{izt},y_t \mid C_{ijt}=1, I_{it}=1\right) = \left(\frac{y_{it}}{p_{jt}}\right)\left[\alpha_1 - \alpha_3 \ln\left(\frac{p_{jt}}{\psi_{ijt}}\right) + \alpha_3 \ln\left(\frac{1}{\psi_{izt}}\right)\right]$$

where α_1 and α_3 are parameters of the HITL indirect utility function (see Pollak and Wales (1992) for further details on the HITL). Therefore, the expected conditional demands are:

$$E_\varepsilon\left(x_{ijt}\right) = \int_{j \text{ is chosen}} x_{ijt}\left(p_{jt},\psi_{ijt},\psi_{izt},y_t \mid C_{ijt}=1, I_{it}=1\right) d\varepsilon \quad (2)$$

$$= -\frac{\mu\alpha_3}{\alpha_i}\frac{y_{it}}{p_{jt}}\left[\frac{\ln\left(\Pr\left(I_{it}=0\right)\right)}{\Pr\left(I_{it}=1\right)}\right]$$

And the corresponding choice probabilities are:

$$\Pr\left(I_{it}=1\right)=\frac{\sum_{j=1}^{J}e^{V_{ijt}}}{1+\sum_{j=1}^{J}e^{V_{ijt}}} \tag{3}$$

$$\Pr\left(C_{ijt}=1,I_{it}=1\right)=\frac{e^{V_{ijt}}}{1+\sum_{j=1}^{J}e^{V_{ijt}}}$$

where $V_{ijt}=\left[\gamma_{ijt}+\frac{\alpha_1\alpha_i}{\alpha_3}+\beta_{it}d_{jt}-\alpha_i\ln\left(p_{jt}\right)+\xi_{jt}\right]\frac{1}{\mu}$.

To control for heterogeneity across consumers, we include random coefficients in the perceived quality index, ψ_{ijt} (Arora et al. 1998). We account for heterogeneity in the following way:

$$\gamma_{ijt}=\gamma_j+Lw_{it}\text{, such that } w_{it}\sim MVN(0,I_{J\times 1})\text{ and } L'L=\Sigma_{J\times J} \tag{4}$$

$$\beta_{it}=\beta+\sigma_\beta\zeta_{it};\ \zeta_{it}\sim N\left(0,1\right)$$

$$\alpha_i=\alpha+D_i\theta+\sigma_\alpha\eta_{it};\ \eta_{it}\sim N\left(0,1\right)$$

where D_i is the demographic information for consumer *i*.

The average quantity purchased per customer for product *j* at time *t* is:

$$\tilde{Q}_{jt}=\int\left[\Pr\left(C_{ijt}=1,I_{it}=1\right)E_\varepsilon\left(x_{it}\right)\right]\phi\left(\Lambda\right)d\Lambda \tag{5}$$

where $\Lambda=\left(w,\zeta,\eta,D\right)'$ and $\phi\left(\bullet\right)$ denotes the pdf of the standard multivariate normal distribution. Inserting equations (2), (3) and (4) into equation (5), we get

$$\overline{Q}_{jt}=\int\frac{\mu\alpha_3 y_{it}}{\alpha_i p_{ijt}}\frac{e^{V_{ijt}}}{\sum_{k=1}^{J}e^{V_{ikt}}}\ln\left(1+\sum_{k=1}^{J}e^{V_{ikt}}\right)\phi\left(\Lambda\right)d\Lambda \tag{6}$$

where

$$V_{ijt}=\left[\gamma_j+\frac{\alpha_1\alpha}{\alpha_3}+\beta_i d_{jt}-\alpha\ln\left(p_{jt}\right)+\xi_{jt}\right]\frac{1}{\mu}+\left[Lw_{it}+\sigma_\beta\zeta_{it}d_{jt}+\left(D_i\theta+\sigma_\alpha\eta_{it}\right)\left(\frac{\alpha_1}{\alpha_3}-\ln\left(p_{jt}\right)\right)\right]\frac{1}{\mu}$$

One difficulty in applying the above model to aggregate data is that we have to know individual level basket expenditure, which is rarely available in combination with aggregate level data. Nair et al. (2005) are able to address this problem because they observe total sales and traffic for a large number of stores of a single retailer chain. They use this to calculate the average basket expenditure for each store in a given week, and assume that the basket expenditure is the same across all customers visiting the same store in the same week. While definitely ignoring some consumer heterogeneity, this still leaves them with enough variation in basket expenditure across stores and weeks to help in identification. Unfortunately, we cannot take recourse to this approach, because we have neither large numbers of stores nor revenue and traffic information for each store. We should stress that our case is not atypical – most data sets available to academic researchers are similar to ours. To the best of our knowledge, there are no data sets that have individual-level consumer information for an entire market as well as information upstream and downstream on all the competitors in that market.

To circumvent this problem, we treat the individual specific basket expenditure, y_{it}, as a function of demographics:

$$y_{it} = g\left(D_i\right) + \sigma_\tau \tau_{it} \qquad \upsilon_{it} \sim N\left(0,1\right) \tag{7}$$

where $g\left(\bullet\right)$ is a pre-specified function and σ_τ is the standard deviation of the distribution, both of which are pre-determined using external information. Correspondingly, Λ in equation 6 is defined as $\Lambda = \left(w, \zeta, \eta, D, \tau\right)'$ and y_{it} is a random draw given by equation 7.

2.3 Supply Model

Recall from our literature review that it was crucial to model vertical structure appropriately. Our problem is complicated by the fact that PL products are *homogeneous* at the wholesale (i.e., upstream) level, but *differentiated* at the retail (i.e., downstream) level. In contrast, NL products are *differentiated at both levels*. This differs significantly from existing vertical structure models in the marketing and economics literature, and poses significant challenges in specification and estimation. The closest model is that employed by Gilbert and Hastings (2001) in their study of NL and PL products in the gasoline market. In their setup, all products are homogeneous at the wholesale level. Given this assumption on products upstream, the authors posit Cournot-Nash competition between producers, i.e., producers simultaneously pick the quantity they wish to produce, and price is determined by market clearing. The Cournot assumption is a natural fit where firms compete on capacity, as in their case with gasoline. Similar to their context, there are capacity constraints in our market, in that there does not exist unlimited capacity in the form of fringe producers ready to supply the PL product, which further justifies the Cournot assumption. We therefore model competition between PL products upstream as Cournot-Nash. It is crucial to emphasize, however, that we do not use the Cournot assumption for NL products upstream. NL products are differentiated upstream, and consequently compete in Bertrand-Nash fashion. Downstream, Gilbert and Hastings model Bertrand-Nash competition between all products (NL and PL), since all products are differentiated downstream. Since this mirrors our case exactly, we model downstream competitive interaction identically to them.

Note that the Gilbert and Hastings (2001) framework, while a useful starting point, needs to be modified significantly for our purposes. First, unlike us, they do not have to deal with a *mix* of differentiated and undifferentiated products upstream. Second, they ignore end consumer heterogeneity as well as quantity considerations (they use a simple linear demand). Their analytical solution strategy becomes infeasible with the more complicated logit demand with heterogeneous preferences that we use. Third, they do not estimate a structural econometric model, which is the main objective of our paper. We now turn to a detailed exposition of our model.

We employ the following two-stage game. In Stage 1, the two NL firms maximize their profits by i) choosing wholesale prices for their NL products in a Bertrand-Nash fashion, and ii) choosing quantities for their PL products in a Cournot-Nash fashion[14]. In Stage 2, conditional on all wholesale prices, retailers choose prices for their NL and PL products, competing in a Bertrand-Nash fashion. Note that manufacturers and retailers could each use a number of possible profit maximization rules, e.g., maximize profits for private labels separately from national brands, maximize profits from all products together, etc.[15]

Denote the set of products at retailer r as F_r, and the full set of products in the retail market as $F_R = \cup F_r$ with measure N_R. Denote the set of national brands and private labels at retail level as F_R^n and F_R^b respectively[16]. Given the two types of fluid milk (skim and whole), denote F_R^{n1} and F_R^{n2} as the sets of these two types of NL products at the retail level, and F_R^{b1} and F_R^{b2} as the corresponding sets of PL products at the retail level. Note that superscript 1 denotes skim while 2 denotes whole milk. By definition, $F_R = F_R^n \cup F_R^b$, $F_R^n = F_R^{n1} \cup F_R^{n2}$, and $F_R^b = F_R^{b1} \cup F_R^{b2}$. Finally, we use q_j and p_j to represent the quantity and price of brand j in the retail market.

Upstream, we denote the set of NL products that manufacturer m sells as F_m^n with measure N_m^n, and the full set of NL products as $F_M^n = \cup F_m^n$ with measure N_M^n. Let F_M^b denote the set of PL products supplied in the wholesale market with measure N_M^b. Since private labels are homogeneous products in the wholesale market, each manufacturer either supplies F_M^b or does not[17]. Let q_j^n and w_j^n represent the

[14] Explicitly accounting for a different mode of competition between PL and NL is key to our paper. Given the importance of this specification, we compare our model to one where manufacturers compete Bertrand-Nash on both NL and PL, and find that our model dominates this alternative. We provide further details on this comparison in Section 4.3.2.
[15] That said, we do not consider non-linear contracts between upstream and downstream parties. The Cournot model specification for PL products upstream renders this infeasible.
[16] NL and PL products carry the *n* and *b* superscripts respectively.
[17] We constrain each manufacturer to either supply both whole and skim PL milk, or neither. This reflects our institutional context – no producer in this market focuses on one kind exclusively.

quantity and wholesale price for national brands, x^b_{mi} represent the quantity of private label i supplied by manufacturer m, and w^b_i the wholesale price for private label i.[18]

2.3.1 *Specifying the Retailer's Problem*[19]

The retailers maximize their category profit (i.e., profit over the entire fluid milk category),

$$\underset{p_j, j \in F_r}{Max}\ \Pi_r = \sum_{j \in F_r} (p_j - w_j) q_j(p)$$

where q_j is the quantity and w_j is the wholesale price for product j; p is a vector of retail prices.

The first order conditions are:

$$q_j + \sum_{k \in F_r} (p_k - w_k) \frac{\partial q_k}{\partial p_j} = 0 \qquad \forall\ j \in F_r \tag{8}$$

Written in matrix form, the price-cost margins for all retailers (R) are

$$PCM^R = p - w = -\left(T_R \bullet \Delta_1\right)^{-1} q \tag{9}$$

where p, w, and q are vectors for retail price, wholesale price, and quantity respectively. Δ_1 is an $N_R \times N_R$ matrix of marketing response to retail price, with

$$\Delta_1(i,j) = \frac{\partial q_j}{\partial p_i} \quad \forall i, j \in F_R$$

We show how to calculate Δ_1 in the Technical Appendix. T_R is an $N_R \times N_R$ matrix indicating the retailer's pricing strategy; in the category maximization case, $T_R(i,j) = 1 \ \ \forall i, j \in F_r$. Finally, $T_R \cdot \Delta_1$ is the element by element product of the matrices T_R and Δ_1.

2.3.2 *Specifying the Manufacturers' Problem*[20]

Manufacturers Who Supply Private Labels: These manufacturers maximize profits by choosing prices for NL products and quantities for the PL products they supply:

$$\underset{w^n_j, x^b_{mi}}{Max} \Pi_m = \sum_{j \in F^n_m} w^n_j q^n_j + \sum_{i \in F^b_M} w^b_i x^b_{mi} - c_m Q_m$$

[18] Note that we are implicitly assuming that neither *M1* nor *M2* suffers from capacity constraints, i.e., producing more PL does not force either one to produce less NL. This is not to suggest that the market itself has unlimited capacity in the form of a number of fringe producers willing to supply PL – in fact, that is not the case in our context.

[19] The exposition is for the case where retailers maximize profits for NL and PL products jointly – we do formulate and estimate other forms of retailer conduct (see Table 5 and the Technical Appendix for details).

[20] The exposition is for the case where manufacturers maximize profits for NL and PL products jointly - we do formulate and estimate other forms of manufacturer conduct (see Table 5 and the Technical Appendix for details).

where w_j^n is the wholesale price for national brand j, w_i^b is the wholesale price for PL i, c_m is the marginal cost for manufacturer m, and Q_m is the total quantity produced by manufacturer m, given as:

$$Q_m = \sum_{j \in F_m^n} q_j^n + \sum_{i \in F_M^b} x_{mi}^b .$$

Note that w_i^b is endogenously determined by imposing a market clearing condition, i.e.,

$$\sum_{m \in M} x_{mi}^b = \sum_{j \in F_R^{bi}} q_j^n \left(p\left(w^n, w^b \right) \right) \quad \text{for } i\text{=1,2}$$

Therefore, the PL wholesale prices can be considered as a function of the total quantity of private labels in the wholesale market, and the NL wholesale prices, i.e.,

$$w^b \left(\sum_{m \in M} x_{m1}^b, \sum_{m \in M} x_{m2}^b, w^n \right).$$

Hence, the first order conditions are:

$$\frac{\partial \Pi_m}{\partial w_k^n} = q_k^n + \sum_{j \in F_m^n} w_j^n \frac{\partial q_j^n}{\partial w_k^n} + \sum_{i \in F_M^b} \frac{\partial w_i^b}{\partial w_k^n} x_{mi}^b - c_m \sum_{j \in F_m^n} \frac{\partial Q_m}{\partial q_j^n} \frac{\partial q_j^n}{\partial w_k^n} = 0 \quad \forall\ k \in F_m^n \tag{10a}$$

$$\frac{\partial \Pi_m}{\partial x_{mk}^b} = \sum_{j \in F_m^n} w_j^n \frac{\partial q_j^n}{\partial x_{mk}^b} + w_k^b + \sum_{i \in F_M^b} \frac{\partial w_i^b}{\partial x_{mk}^b} x_{mi}^b - c_m \left[\sum_{j \in F_m^n} \frac{\partial Q_m}{\partial q_j^n} \frac{\partial q_j^n}{\partial x_{mk}^b} + \frac{\partial Q_m}{\partial x_{mk}^b} \right] = 0 \quad \forall\ k \in F_M^b \tag{10b}$$

In the above,

$$\frac{\partial q_j^n}{\partial w_k^n} = \sum_{l \in F_R} \frac{\partial q_j^n}{\partial p_l} \frac{\partial p_l}{\partial w_k^n}$$

$$\frac{\partial q_j^n}{\partial x_{mk}^b} = \sum_{l \in F_R} \frac{\partial q_j^n}{\partial p_l} \sum_{i \in F_M^b} \frac{\partial p_l}{\partial w_i^b} \frac{\partial w_i^b}{\partial x_{mk}^b}$$

<u>*Manufacturers Who Don't Supply Private Labels*</u>: These manufacturers maximize profits by choosing prices for their NL products, i.e.,

$$\underset{w_j^n}{Max} \Pi_m = \sum_{j \in F_m^n} w_j^n q_j^n - c_m Q_m$$

The first order conditions are obtained from equation 10a by setting terms involving w^b to zero:

$$\frac{\partial \Pi_m}{\partial w_k^n} = q_k^n + \sum_{j \in F_m^n} w_j^n \frac{\partial q_j^n}{\partial w_k^n} - c_m \sum_{j \in F_m^n} \frac{\partial Q_m}{\partial q_j^n} \frac{\partial q_j^n}{\partial w_k^n} = 0 \qquad \forall\ k \in F_m^n . \tag{11}$$

With expressions 10a, 10b, and 11 in place, we can now derive the manufacturers' price cost margins for both national brands and private labels, in matrix form.

<u>*Matrix Expression for Manufacturer Price-Cost Margins*</u>: Consider NL products first. It is straightforward to combine equation 10a and 11 as:

$$\sum_{j\in F_m^n}\left(w_j^n - c_m\frac{\partial Q_m}{\partial q_j^n}\right)\frac{\partial q_j^n}{\partial w_k^n} = -\left(q_k^n + \phi(m)\sum_{i\in F_M^b}\frac{\partial w_i^b}{\partial w_k^n}x_{mi}^b\right)$$

where $\phi(m)$ is an indicator function to reflect whether manufacturer *m* supplies PL or not. Define an $N_M^n \times 1$ matrix G_1 as:

$$G_1(k) = q_k^n + \phi(m)\sum_{i\in B}\frac{\partial w_i^b}{\partial w_k^n}x_{mi}^b \qquad \forall\ k \in F_M^n$$

Then we can write manufacturers' margins on NL as:

$$PCM_M^n = -\left(T_M^n \bullet \Delta_2^n\right)^{-1}G_1 \tag{12}$$

where PCM_M^n is an $N_M^n \times 1$ vector of manufacturers' margins on their NL,

with $PCM_M^n(j) = \left(w_j^n - c_m\frac{\partial Q_m}{\partial q_j^n}\right)$ $\forall\ j \in F_M^n$, Δ_2^n is an $N_M^n \times N_M^n$ matrix with $\Delta_2^n(k,j) = \frac{\partial q_j^n}{\partial w_k^n}$ $\forall\ k, j \in F_M^n$, and T_M^n is an $N_M^n \times N_M^n$ matrix indicating manufacturers' pricing strategies for their NL. Note that for the category management case, $T_M^n(i,j) = 1\ \ \forall i, j \in F_m^n$. Finally, $T_M^n \bullet \Delta_2^n$ is the element by element product of the matrices T_M^n and Δ_2^n.

Next, we turn to manufacturers' margins if they supply PL products. Equation 8b can be written as:

$$\left(w_k^b - c_m\frac{\partial Q_m}{\partial x_{mk}^b}\right) = -\sum_{i\in F_m^b}\frac{\partial w_i^b}{\partial x_{mk}^b}x_{mi}^b - \sum_{j\in F_m^n}\left(w_j^n - c_m\frac{\partial Q_m}{\partial q_j^n}\right)\frac{\partial q_j^n}{\partial x_{mk}^b}.$$

Define an $N_M^b \times 1$ matrix G_{2m} as $G_{2m}(k) = \sum_{i\in F_M^b}\frac{\partial w_i^b}{\partial x_{mk}^b}x_{mi}^b$ for $k \in F_M^b$. Therefore manufacturer *m*'s margin from PL products can be written as:

$$PCM_m^b = -G_{2m} - \Delta_{3m}PCM_m^n \tag{13}$$

where PCM_m^b is an $N_M^b \times 1$ matrix with $PCM_m^b(k) = \left(w_k^b - c_m\frac{\partial Q_m}{\partial x_{mk}^b}\right)$ for $k \in F_M^b$. Δ_{3m} is an $N_M^b \times N_m^n$ matrix with $\Delta_{3m}(k,j) = \frac{\partial q_j^n}{\partial x_{mk}^b}$ for $m \in M$, $k \in F_M^b$ and $j \in F_m^n$.

Note that in order to calculate the manufacturer's margin using equation 12 and 13, we need to know Δ_2^n, Δ_{3m}, G_1, and G_{2m}. We show how to calculate each of these in the Technical Appendix.

3. ESTIMATION

There are two preliminary methodological considerations. First, simultaneous estimation of demand and supply appears to be the natural choice; the drawback is that erroneous supply model assumptions will contaminate the estimation for the demand model as well. To avoid this, we follow the recent literature and employ a sequential estimation approach (Chintagunta et al. 2002) as follows. We first estimate the demand function - using the demand estimates, we estimate the cost parameters (margins) of the supply models. This sequential approach generates consistent and efficient estimates for the demand side, and consistent, albeit inefficient, estimates for the supply model. Following Newey and McFadden (1994), and Berto Villas-Boas (2007), we correct the variance-covariance matrix of the supply side estimates, because estimated parameters from the first stage are used in the second stage. Second, price endogeneity, if ignored, biases the price coefficient estimates. We deal with this issue by using instruments for price, as described later.

3.1 Consumer Demand Estimation

We perform the demand estimation in two steps. In step one, we estimate the relationship between budget expenditure and demographics (equation 7) using a unique data set from a retailer located in the same geographical area as the rest of our data. The data includes i) transaction information for one year for each individual using a membership card, and ii) demographic information for each individual. We first select all the individuals with complete information on income and age and calculate the average basket expenditure for each of them. We then estimate the following equation using Maximum Likelihood Estimation.

$$y_i = a_0 + a_{10} * inc + a_{11} * inc^2 + a_{20} * age + a_{21} * age^2 + \sigma_\tau \tau_i \qquad \text{(14a)}$$

From this we get both $g(D_i)$ and σ_τ, where

$$g(D_i) = a_0 + a_{10} * inc + a_{11} * inc^2 + a_{20} * age + a_{21} * age^2 \qquad \text{(14b)}$$

In step two, we estimate equation (6) following Nair et al. (2005). We provide a brief overview of the estimation procedure here, referring the reader to Nair et al. (2005) for details. We can write equation (6) as:

$$\overline{Q}_{jt} = \int \frac{\mu \alpha_3 y_{it}}{\alpha_i p_{ijt}} \frac{e^{\delta_{jt} + \Omega_{ijt}}}{\sum_{k=1}^{J} e^{\delta_{kt} + \Omega_{ikt}}} \ln\left(1 + \sum_{k=1}^{J} e^{\delta_{kt} + \Omega_{ikt}}\right) \phi(\Lambda) d\Lambda$$

where

$$\delta_{jt} = \left[\gamma_j + \frac{\alpha_1 \alpha}{\alpha_3} + \beta_i d_{jt} - \alpha \ln\left(p_{jt}\right) + \xi_{jt} \right] \frac{1}{\mu}$$

$$\Omega_{ijt} = \left[Lw_{it} + \sigma_\beta \zeta_{it} d_{jt} + \left(D_i \theta + \sigma_\alpha \eta_{it}\right) \left(\frac{\alpha_1}{\alpha_3} - \ln\left(p_{jt}\right) \right) \right] \frac{1}{\mu}$$

Similar to Nair et al. (2005), we normalize μ and α_3 to 1 for identification purposes; δ_{jt} can be calculated through a contraction mapping:

$$g\left(\delta\right) = \delta + \ln\left(q\right) - \ln\left[\bar{Q}\left(\delta\right)\right]$$

Using the value of δ_{jt}, we construct the moment condition $E\left[\xi_{jt} Z_{jt} \mid Z_{jt}\right] = 0$, where $\xi_{jt} = \delta_{jt} - \left[\gamma_j + \alpha_1 \alpha + \beta_i d_{jt} - \alpha \ln\left(p_{jt}\right)\right]$. We then estimate our model parameters using a Method of Simulated Moments procedure (Pakes and Pollard 1989).

3.2 Supply Model Estimation

The principal outputs sought are the marginal costs for products across suppliers. We follow prior work, and use our pricing equations to estimate marginal costs (e.g., Besanko et al. 1998). Recall that each game leads to a certain implied price-cost margin, which can be calculated once we have estimates of the demand-side parameters in place. We combine this calculation of the price-cost margin with observed prices to back out costs. We then regress these costs on a set of cost characteristics. Formally, we assume that the marginal cost for a product of brand *j* at time *t* is:

$$mc_{jt} = f_t \tau_j + \psi_{jt}, \qquad (15)$$

where τ is a vector of input prices, such as wage rates (for the retailer) and raw milk (for the manufacturer), as well as brand and size dummies, and *f* is the vector of coefficients associated with these characteristics. The cost characteristics thus consist of a set τ which is observed to the econometrician, and an unobserved portion ψ. Denoting the price cost margin as PCM_{jt}, we obtain the pricing equation we actually estimate as:

$$(p_{jt} - PCM_{jt}) = f_t \tau_j + \psi_{jt} \qquad (16)$$

The τ parameters need to be estimated. We estimate these using OLS (Petrin 2002). Finally, presaging some of the discussion later, we use the estimated marginal costs across various games, coupled with external information, to pick the most appropriate game form.

4. EMPIRICAL ANALYSIS

4.1 Data

Our data are from Information Resources Inc. (IRI), and include weekly retail marketing and price information for each brand of fluid milk at each of the four largest supermarket chains in this market from July 6, 1997 to May 20, 2001, a total of 203 weeks. The remainder of the retail sector is combined into a fifth retail chain termed the “Residual Chain.” As shown in Figure 1, *M1* produces PL products for *R2*, *R3*, *R4* and *R5*, while *R1* produces its PL products at an in-house facility, as well as its requirement of *M2*’s NL products. In June 2000, *R1* divested its in-house supply facility and began to purchase its PL products from *M1*. There are two distinct data periods – 152 weeks from 07/06/1997 (week 1) to 05/28/2000 (week 152), and 50 weeks from 06/04/2000 (week 153) to 05/20/2001 (week 203). For our demand estimation we use the first 152 weeks, reserving the 50 post-divestiture weeks for our out-of-sample validation exercise.

We aggregate the various reduced fat milk products into an overall skim product. We exclude some very low share fluid milk brands from our analysis; in all these constitute less than 1% market share. We also exclude fluid milk derivatives such as milk shakes, flavored milk and eggnog, and milk substitutes such as soymilk. Finally, we use the population of the metropolitan area in our data (around 4 million people in 2000), as the measure of our customer base.

Table 1 provides some descriptive statistics. Observe that *M2* is the most expensive brand, followed by *M1* and the various PL products. Second, total PL share exceeds total NL share. Third, skim sells more than whole milk, with the difference being higher for NL products. Fourth, there are some differences across retail chains in their use of non-price promotions. *R3* leads in promotion intensity, followed by *R2*, *R1*, and *R4*. Finally, skim milk is generally promoted more often than whole milk.

4.2 Instruments

Recall that the ξ_{jts} terms in equation 1 represent unobserved time varying features or demand shocks, which are highly likely to be correlated with observed prices, thus creating a potential endogeneity bias. We account for the endogeneity of prices by using lagged input prices multiplied by the product dummy as instruments for price (Berto Villas-Boas 2007; Chintagunta et al. 2002). Input prices include the raw milk price, the average daily wage for workers in the milk sector, electricity prices, and interest rates. The logic behind these specific instruments is as follows: i) input prices, such as the price of raw milk and energy prices, would be correlated with retail prices (the link with wholesale prices is easier to see, and retail prices are very highly correlated with wholesale prices), and ii) they are likely to be uncorrelated with the unobserved ξ term. This seems reasonable, if one thinks of some of the time-varying effects ξ captures, e.g., shelf space changes and stock-outs. It is very unlikely that input prices would reflect these shocks. The multiplication with product dummies ensures variation across products in the instruments, and allows different products to use inputs differently.

Table 2 describes the instruments, along with their descriptive statistics. Since we do not know, a priori, the proper lag to use for input prices, we regressed retail price on the instrumental variables for various lags and found that 4-week lagged measures performed best ($R^2 = 0.88$). We therefore use 4-week lagged instrumental variables in our estimations.

4.3 Results

4.3.1 *Consumer Demand*

Table 3 reports our demand estimates. First, NL products possess larger brand constants than PL products, as one would expect (and in spite of the fact that PL products in this category have almost 60% market share). Second, the mean price coefficient is significantly negative (–0.28) and heterogeneous (standard deviation of price = 0.12, significant at 1%), indicating differential price sensitivity across customers. Turning to observed heterogeneity, higher income seems to reduce price sensitivity while age seems to increase it. Third, non-price promotion has a significant impact.

Table 4 describes the price elasticity matrix for skim milk calculated from our demand estimates. The own-price elasticities range from about -2 to -3.5, which is in the range of elasticity for similar products (e.g., for yogurt see Sudhir 2001). PL own-price elasticity is not very different from NL own-price elasticity, a pattern similar to Berto Villas-Boas's (2007) estimates for yogurt.

Second, within-store cross-price elasticities between NL products, and those between NL and PL, are both low (less than 1, on average). Finally, cross-price elasticities between stores are also very small, a finding similar to prior works (e.g., Berto Villas-Boas 2007).

4.3.2 *Supply Model and Game Picking*

We employ the demand parameters reported above to calculate price-cost margins, as described in Sections 2.3.1 and 2.3.2. These margins are used along with observed prices to obtain the impact of a vector of covariates on marginal cost (equation 15).

Now, recall that we had specified and estimated a number of possible competitive interactions and retailer behaviors. It is important at this stage to decide the most appropriate 'game form'. Prior literature has employed various ways of picking across games, including i) a conduct parameter approach, with estimated values of the conduct parameter suggesting the appropriate game (Bresnahan 1989; Kadiyali et al. 2000); ii) statistical fit tests, such as the Vuong (1989) or Smith (1992) tests (e.g., Sudhir 2001); iii) data patterns that pin down the nature of the game form (Porter 1983); and iv) a comparison of the margins/costs predicted by various models with those obtained externally (Nevo 2001). The key issue is whether there is sufficient information in the data to pin down *both* the nature of competitive interaction (and hence the price-cost margins) and the marginal cost. As Reiss and Wolak (2007) point out, this is almost never the case. With regard to the first alternative, various authors have suggested fundamental problems with the interpretation of the conduct parameters, and with the data requirements for identification in differentiated product markets (Corts 1999; Nevo 1998). Statistical testing is also problematic – among other issues, these tests are not transitive, which means that we can have a situation where model A dominates model B, model B dominates model C, but model C dominates model A. Finding data patterns to identify the nature of the game is extremely hard in practice. This leaves the last alternative, which is in many ways the most attractive, but one that requires valid external information.

Fortunately, we do have access to external information on average margins at the retailer and manufacturer level for a number of milk producers in the same geographical region as our data. We therefore follows Nevo (2001) closely, comparing the predicted margins from each of the possible game forms we estimate to these external numbers, and picking the game that gives us numbers closest to the external value.

Because of the complexity of the vertical and horizontal interactions that we model, the comparison of estimated margins to actual margins is fairly involved. To recap, the focus here is on comparing our *proposed model*, where PL products are homogenous upstream (Cournot-Nash) and differentiated downstream (Bertrand-Nash), with the *alternative model* where PL products are differentiated both upstream and downstream (Bertrand-Nash). In addition, we wish to distinguish between three possible forms of manufacturer and retailer behavior. Before we proceed, it is useful to set some nomenclature. We define a 'product' upstream as consisting of the identity of the manufacturer (*M1*, *M2*), the 'brand' (NL, PL), and the type (skim, whole). Downstream the definition is similar, except that the identity of the retailer is also relevant for PL products. Examples of upstream products include: NL skim milk from *M2*, PL whole milk from *M1*, etc. Equivalent downstream products, at say *R2*, would be NL skim milk from *M1* and *M2*, and PL whole milk.

With this in place, we outline the three possible forms of manufacturer and retailer behavior. i) *Product management*, wherein the manufacturer (retailer) maximizes profits separately for each 'product' in his portfolio. ii) *Account management*, wherein the manufacturer (retailer) maximizes profits for NL products (viewed as one account) separately from PL products (viewed as a different account). As an example, upstream, *M1* would maximize profits for its NL skim and whole milk jointly, but separate from its PL skim and whole milk. Downstream, retailer *R2* would maximize profits jointly for NL products such as *M1* skim and whole, and *M2* skim and whole, but separate from its own PL skim and whole milk products. iii) *Category management*, wherein the manufacturer (retailer) maximizes joint profits across all products.

This gives us a total of 18 games to pick from – nine for the proposed model and identically nine for the alternative. For each game we estimate three margins (total, retailer, and manufacturer) giving us a total of 54 margins (18 x 3). Table 5 displays all the estimated margins, along with confidence intervals. Cells where the true value of the margin falls within the estimated confidence interval are bolded, to highlight that this mode of conduct is indistinguishable statistically from the 'true' behavior. Note that there is only one game for which all three margins are bolded – this is the proposed model with both manufacturers and retailers practicing account management. To reiterate, the best fitting game is one where i) PL products compete Cournot-Nash upstream and Bertrand-Nash downstream; ii) NL products compete Bertrand-Nash both upstream and downstream; iii) both manufacturers and retailers practice account management, i.e., they separately maximize profits for NL and PL products. This is the game we use in all subsequent analyses.

Table 6 gives results for the supply cost regression for our best fitting game. Note that the costs are in dollars per 8 oz. serving. Multiplying this by sixteen gives costs in $/gallon. Briefly, of the two NL firms, *M2* is the higher cost producer; note that *R1*, which is vertically integrated in PL supply, produces at a cost higher than either of the NL firms. The production cost difference between PL and NL products is quite small (0.432 $/gallon); the five retailers have similar costs, except for *R3*, whose cost is considerably lower. Whole milk costs very slightly more to produce than skim milk varieties (0.044 $/gallon). Finally, the price of raw milk is the biggest determinant of cost.

5. WHAT-IF ANALYSES

We now proceed to the substantive questions at the heart of our effort:

a) Can an NL firm profit from adding PL sales?
b) What are the upstream and downstream effects of vertically integrated versus vertically separated PL supply structures?

These questions are examined through three counterfactual policy experiments. We proceed as follows. Conditioning on the estimated demand function and cost structure, we calculate the equilibrium price, volume, and profit for each product for the best-fitting as-is model. Denote this as the *base case*. We then calculate the equilibrium price, volume, and profit for each product under the revised industry model for each what-if scenario, and compare them to the base case.

Our first counterfactual experiment describes the overall impact of private labels. Thus, in this market is it in the retailers' interest to carry PL products? Is it in the NL producers' interest? We address this by simulating a market without private labels. Comparing this with the base case gives us a first look at our main questions, and quantifies the overall impact of private labels on upstream and downstream outcomes. Note, however, that this counterfactual does not help parcel out the magnitudes of the incentives that an NL producer faces, or help examine the impact of differing upstream supply arrangements on outcomes.

Our second counterfactual experiment examines the gain to an NL firm from adding PL sales to its portfolio. Recall that in the base case, *M2* does not supply PL. As such, we envision a what-if structure where *M2* competes with *M1* for PL sales to *R2*, *R3*, *R4* and *R5*. *R1* remains with its vertically integrated supply arrangement. By comparing this to our base case we isolate the impact of the PL addition on *M2*'s profits.

Our third counterfactual experiment compares the impact of changing PL supply from a vertically integrated arrangement to a vertically separated arrangement with an NL firm. Recall that in the base case, *R1* was vertically integrated into PL supply. As such, we envision a what-if structure where *R1* switches to a vertically separated arrangement with *M1*. By comparing this to our base case, we isolate the impact of this change on outcomes. Crucially, we are also able to validate our structural estimates because this switch actually occurred in June 2000 with the divestiture by *R1* of its vertically integrated facility.

5.1 Base Case Results

Given our estimate of the manufacturer's cost, we solve for i) retail prices at each chain for both NL and PL products, ii) NL wholesale prices, and iii) PL quantities and wholesale price (from each manufacturer, as needed). In principle, given Cournot competition upstream for PL supply, solving for quantity uniquely identifies wholesale price. However, this is possible only if one is able to express the inverse demand function of wholesale price in terms of quantities demanded downstream. The complexity of our demand function prevents us from obtaining this kind of analytical expression. We therefore solve for *both* wholesale price and quantity of PL products. After solving for the unknowns, we calculate the share and profit for each product. Table 7 shows these calculations averaged over the 152-week observation period[21].

[21] As mentioned earlier, thanks to the change in *R1*'s supply arrangement in June 2000, we effectively have two distinct data periods – 152 weeks from 07/06/1997 (week 1) to 05/28/2000 (week 152), and 50 weeks from week 153 to week 203. The base case we calculate refers to the first period of the data. For evaluating the impact of the change, which we do in the third counterfactual, we use both the first and second data periods.

5.2 What-if Scenario #1: No Private Labels in the Market

Our first counterfactual directly addresses the impact of PL products. Table 8 presents equilibrium results with no private labels in the market. Comparing this to the base case (Table 7) we can conclude the following.

Total channel profits decline by about 57% when PL is withdrawn. Upstream profits decline by $204463, a 56% fall. This fall is mainly driven by *M1*, whose profits fall 62%, due entirely to its not supplying the PL anymore. Interestingly, profits from NL rise for *M1* by 4.52% and for *M2* by 5.7%. This suggests that if the NL producer were not previously supplying PL (similar to *M2* in our context), then he is made better off without any PL at all in the market.

Downstream, total profits decline by 58% when PL is withdrawn, with every retail chain seeing a decline in profits, ranging from 42% to 68%. A quick look at the wholesaler and retailer margins displayed in Table 8 versus Table 7 confirms this – wholesale margins have increased (by about 1.5¢/gallon[22]) while retail margins have declined (by about 34.4¢/gallon). Turning to prices, NL wholesale prices decrease about 14.36¢/gallon, while retail prices decrease about 81.36¢/gallon. To conclude, this counterfactual tells us that *retailers benefit from the presence of PL, and that NL manufacturers benefit from the supply of PL.* This is similar to the findings of Bonnano and Lopez (2005) who found an increase in the price of NL after the introduction of PL.

5.3 What-if Scenario #2: NL Manufacturer Adds PL Sales

In the base case, *M1* is the sole incumbent supplier of private label milk to all retail chains, except *R1*, which used its in-house facility. In this experiment, we introduce *M2* as a competitor to *M1* for PL supply. To summarize, *M1* and *M2* supply national labels to all five chains, and they compete to supply PL products to four chains. As before, *R1* maintains its in-house facility.

Table 9 reports our results, which we compare to the base case in Table 7. Consider *M2*. Adding PL sales raises its total profits by 87%, despite a small decline in its NL profits. This provides an unambiguous answer to our first research question - an NL firm <u>can gain</u> by adding PL sales. Notice, however, that total upstream profits decline, driven mainly by *M1*'s fall in profits ($89,418.5, an approximately 27% decline), which in turn is almost entirely due to a decline in profits from sales of PL products. This is clearly due to the fact that we have moved towards greater competition in the supply of PL. Total downstream profits, on the other hand, increase by $121,861.7 (a 15.4% rise), with every retailer gaining substantially, except for *R1*. Total channel profits increase, by $63,127.2 (5.4%). To understand these profit changes, consider wholesale and retail price changes.

[22] The numbers in the tables are dollars per serving (8 ounces). Multiplying by 16 gives dollar estimates per gallon.

The entry of *M2* intensifies PL competition upstream with wholesale PL prices declining by about 26.24¢/gallon on average. Retail PL prices decrease by a substantial 43.2¢/gallon. (The one exception is *R1*, whose wholesale and retail prices remain almost unchanged on account of its vertically integrated PL supply.) Interestingly, neither wholesale nor retail NL prices show any change – this is what we would expect, given the relatively small cross-price elasticities between the products. Clearly, the increase in profits downstream is coming almost entirely from increases in volume sold (since retail margins have actually declined); in fact, downstream volume of PL sold increases by almost 51% (this can be readily seen by comparing servings/person in Tables 9 and 7).

To sum, an NL producer can gain from adding PL sales, despite the enhanced competition between undifferentiated products at wholesale. It is important to emphasize that we could not have got this conclusion if we had modeled PL suppliers as marginal cost producers, as seen in the minuscule changes impacting *R1*, which is in effect a marginal cost producer because of its vertically integrated facility.

Disentangling the incentives facing the NL firm: There are two incentives in our model for an NL producer to supply PL products; i) the increased profit from making a positive margin on the private label, and ii) the 'strategic' gains from joint pricing of the national label and private label. While the magnitude of the first incentive is clear from our counterfactual, we have not yet addressed the second incentive. We quantify this with a back of the envelope calculation.

The 'strategic effect' from joint pricing depends crucially on the magnitude of the cross-price elasticities between NL and PL products. A higher cross-price elasticity suggests that the products are close substitutes for each other, and that there would be greater gains to 'collusive' pricing for the products. The magnitude of the cross-price elasticity, in turn, depends on two major factors (basically, factors that affect the estimated price coefficient) – the extent to which the market is saturated, and the degree of 'closeness' between the two products. The higher each of these factors, the greater is the cross-elasticity between the products. We focus attention on the second factor and examine its impact. We use the difference between the estimated brand preference parameters for NL and PL products as a measure of the closeness between them. In particular, given identical marketing mix factors, a difference of zero in the brand preference parameters would suggest that the two products are perfect substitutes[23].

[23] An anonymous reviewer pointed out two important issues. First, the 'strategic gain' is bound to be small, since we have already found the best fitting game to be one where the producer maximizes profits from NL and PL products separately. Second, the degree of substitution between products really depends on the correlation between them induced by the estimated heterogeneity parameters. While acknowledging the merit of both these points, we nevertheless present the discussion as an illustration of a way to calculate the approximate magnitude of the 'strategic effect', which might well be large in some contexts.

We calculate *M1*'s profits under two scenarios: i) joint profit maximization of its NL and PL, and ii) separate profit maximization of its NL and PL. The difference between i) and ii) measures gains from joint pricing. In each case we solve for equilibrium outcomes assuming all other upstream and downstream factors remain the same (i.e., upstream private label supply arrangements and retailer conduct). Figure 2 plots this difference for various values of the 'closeness'. In particular, we let the closeness range from zero to the value in our demand estimates (which we designate 100). We see that current gains from collusive pricing are fairly low, but that these gains rise as the difference in brand preference parameters narrows. In this market, the maximum gain from such collusive pricing would be $1,800 per week, which is about 0.5% of *M1*'s profits, a fairly small amount, but not surprising given the very low cross elasticity between products.

5.4 What-if Scenario #3: Vertically Integrated versus Vertically Separated PL Supply

To begin with, recall that we construed marginal cost PL supply to be equivalent to backward vertical integration by a retailer, as is the case with *R1* in this market. In this experiment, we change *R1*'s arrangement to that used by *R2*, *R3*, *R4* and *R5*; viz. vertically separated supply from *M1*. *M2* remains out of the PL supply market. It should be noted that exactly this event occurred in June 2000, when *R1* divested its vertically integrated facility. Because we wish to perform out-of-sample validation of our estimates later, we only use data *prior* to June 2000 for this experiment.

The results are shown in Table 10. As before, we compare these outcomes to the base case in Table 7. Looking at profits first, upstream profits increase by about 15.73%. Not surprisingly, *M1* gains considerably from its newly minted PL monopoly – its PL profits increase by 12%. Interestingly, it's NL profits change negligibly (0.6%). However, *M2*'s profits from its NL increase substantially, by 34%. These change in upstream profits are easy to explain, and come from two sources. First, since *M1* was making considerable margins on its PL supply, it is no surprise that it sees a large increase in profits from supply to *R1*, which no longer makes PL. Second, *M2* also sees a profit increase because its NL product is no longer sourced internally by *R1*. Downstream, there is a profit decrease of about 5.78% overall.

Turning to prices, there is an interesting pattern of changes. At the wholesale level, there is almost no change in *M1*'s NL prices, while *M2*'s prices increase by about 9¢/gallon (6%) on average. PL prices show a sharp increase of about 16¢/gallon (11%). This has a perceptible effect on downstream quantity sold, which declines by about 8.7%. Overall, consumers seem to be worse off after the divestiture.

5.5 Validating the Vertically Integrated versus Vertically Separated PL Supply Experiment

Recall that *R1* actually divested its in-house facility in June 2000, mirroring our experiment described above. In the previous section we calculated the impact of *R1*'s divestiture using data prior to the actual event. Here, we use 50 weeks of real data *after* this exact divestiture to perform an out-of-sample validation of our model's predictions. There are two major, interrelated dimensions that we wish to examine in this validation exercise. First, since the raison d'être of a structural model is its ability to provide estimates that are impervious to policy changes, it is important to examine how well our model actually performs when confronted with a structural change. Second, since the assumption of homogenous PL goods upstream, and the consequent Cournot modeling is fairly central to our analysis, it is important to examine how well this assumption works in comparison to alternatives.

We perform our out-of-sample validation by comparing actual post divestiture prices with prices predicted by three different models: i) the main model in this paper, i.e., upstream Cournot PL competition, upstream NL Bertrand competition, and Bertrand competition between PL and NL downstream; ii) a model identical to the prior one, but assuming no divestiture has taken place; and iii) a model that assumes Bertrand competition between PL and NL upstream and Bertrand competition between PL and NL downstream, i.e., PL products are *not homogeneous* upstream. Note that these comparisons address both dimensions of interest. Thus, comparing actual prices to those predicted by our model versus those predicted by the model without divestiture, serves to test the predictive ability of our model in the presence of a structural change. Comparing actual prices to those predicted by our model versus a model which does not make the Cournot assumption on PL products upstream, serves as an indirect test of the validity of the upstream PL homogeneity assumption. Figure 3 shows the results of the comparison. We find that the model proposed in this paper outperforms the other models using a Mean Squared Error criterion.

5.6 Summing up the What-if Analyses

The overall message from our counterfactual experiments is that i) NL producers benefit from the supply of, and retailers benefit from the presence of PL products, and ii) vertically integrated PL supply is better for consumers than procurement from NL producers. Relative to the first takeaway, the key insight is that an NL producer makes positive margins from adding PL products, which improves his overall profits, despite the attendant cannibalization. Relative to the second takeaway, the key insight is that downstream prices increase for most retailers, because the shift away from vertical integration increases PL wholesale prices, which are then passed on in the form of higher retail prices. Of course, both these takeaways apply only to situations where NL producers themselves are the source of PL products.

6. CONCLUSIONS AND FUTURE RESEARCH

We started from the observation that many NL producers also supply PL products, which is not consistent with the assumption in earlier work that retailers obtain PL products at marginal cost from price-taking (fringe) suppliers. We proposed a model whereby NL producers compete as homogenous product suppliers upstream for PL products, which are then differentiated across retailers downstream. NL products, on the other hand, are differentiated at both wholesale and retail levels. This is captured via Cournot and Bertrand competition upstream, and Bertrand competition downstream. The specification poses significant challenges, both analytically and in estimating the parameters econometrically on real-world data.

We estimate our model with data on fluid milk products from all producers and retailers in a major metropolitan area. We find that retailers benefit from the presence of PL products, and NL producers benefit from supplying PL products, despite competing on an undifferentiated basis for wholesale PL sales. We find that vertically separated PL supply hurts consumers, in that prices are higher relative to vertically integrated PL supply.

Our paper makes a number of contributions. From a methodological standpoint, this is the first structural empirical effort to model upstream competition in PL and NL products, while acknowledging the differences between the two, i.e., PL products are homogenous upstream and differentiated downstream; NL products are differentiated upstream and downstream. The resulting game we specify is new to the literature. Given the ubiquity of oligopoly competition in vertically linked markets involving homogenous and differentiated products, we believe our methodology is an important step in the direction of greater realism. In addition, ours is among the first papers to tractably specify and estimate a model that incorporates a variety of vertical and horizontal channel interactions, along with a rich demand specification that takes quantity choices into account.

Managerially, our findings suggest that it makes sense for firms who are NL producers in their own right to add PL products, particularly when they do not face competition from fringe suppliers. We support Soberman and Parker’s (2006) position that the widely held intuition that NL producers resist supplying PL products is essentially incorrect if we account for heterogeneous consumers.

From a public policy standpoint, we show that the structure of upstream competition amongst PL suppliers matters greatly to downstream outcomes. Our analysis is of immediate relevance to anti-trust authorities because it provides a methodology to analyze vertical structure changes that reshape competition between national labels and private labels. Such tools are quite lacking today. For instance, the government argued in an recent amicus brief that the Supreme Court should not review a 3rd Circuit decision that[24] joint pricing of NL and PL products constituted exclusionary conduct in the transparent tape market. According to the government, there is insufficient academic work to provide guidance to the Court on this issue. On this point, the utility of our model is quite clear. Contrary to the 3rd Circuit decision, we are able to provide empirical support for the conclusion that joint pricing of NL and PL products by a full-line supplier in our fluid milk market is benign.

Needless to say, the paper suffers from a number of limitations that offer directions for future research. For a start, it would be useful to replicate our analysis in other categories where PL penetration is much lower. Recall that the absence of fringe suppliers in our market enables us to focus on NL suppliers, but the large market share of PL products also changes the magnitude of the incentives facing upstream and downstream agents. In our theoretical model, upstream firms have an incentive to raise downstream PL prices, with a view to shifting demand to the NL products. This is muted in our data because the firms' NL margins are not that much higher than their PL margins. Second, there are a number of other issues we have not considered, of which two stand out from the recent literature – endogenous PL quality choice and endogenous PL supplier choice by the retailer. While our institutional context rules out their relevance to the current analysis, they do define the boundary conditions that apply to our takeaways and are thus of considerable interest in follow-on work. Further factors that serve to delimit the boundary conditions of our work, and are fruitful grounds for further research are i) the presence of non-linear pricing contracts between manufacturers and retailers; ii) the presence of exclusive contracts governing manufacturer/retailer interactions; and iii) endogenous sunk costs as important drivers of cost differences between manufacturers[25].

[24] LePage's Inc. vs. 3M 324 F.3rd 141 (3rd Cir. 2003) *cert. denied*, 124 S. Ct. 2932 (2004).

[25] We thank an anonymous reviewer for suggesting these boundary conditions.

Table 1: Descriptive Statistics: Fluid Milk

Chain	Brand	Category	Retail Price ($/Serving)	Volume (Serving)	Non-Price Promotion
R1	M1	Skim	0.1900	649927	0.1168
R1	M1	Whole	0.1879	316914	0.0785
R1	M2	Skim	0.2000	289531	0.1499
R1	M2	Whole	0.2049	148727	0.0790
R1	Private label	Skim	0.1763	1105470	0.0890
R1	Private label	Whole	0.1809	484258	0.0524
R2	M1	Skim	0.1909	353894	0.2083
R2	M1	Whole	0.1920	134007	0.1658
R2	M2	Skim	0.2019	168526	0.2364
R2	M2	Whole	0.2081	66699	0.1538
R2	Private label	Skim	0.1519	1491523	0.0867
R2	Private label	Whole	0.1531	822826	0.0428
R3	M1	Skim	0.1990	205707	0.2733
R3	M1	Whole	0.2023	80666	0.1705
R3	M2	Skim	0.2172	92922	0.2584
R3	M2	Whole	0.2232	32192	0.0857
R3	Private label	Skim	0.1389	750821	0.1904
R3	Private label	Whole	0.1385	342957	0.1525
R4	M1	Skim	0.1813	264706	0.0773
R4	M1	Whole	0.1844	122519	0.0665
R4	M2	Skim	0.1998	156358	0.0916
R4	M2	Whole	0.2031	72514	0.0472
R4	Private label	Skim	0.1863	823952	0.0822
R4	Private label	Whole	0.2028	460306	0.0208
R5	M1	Skim	0.1742	325595	0.3456
R5	M1	Whole	0.1830	137733	0.1311
R5	M2	Skim	0.1944	126199	0.2590
R5	M2	Whole	0.2027	51180	0.0537
R5	Private label	Skim	0.1418	695721	0.1218
R5	Private label	Whole	0.1405	353775	0.0623

Note: *Non-Price Promotion* refers to the percentage of volume sold on non-price promotion.

Table 2: Descriptive Statistics for Input Prices

Variable	Mean	S.D.	Min	Max
Coop Price ($/Gallon)	1.4842	0.1414	1.2611	1.8593
W_Market ($/Day)	66.3298	2.7796	59.5143	73.6071
W_Milk ($/Week)	627.5500	32.5060	572.4200	687.7200
W_Grocery ($/Week)	281.7891	14.1566	257.5400	310.3800
Gasoline (₵/Gallon)	122.5389	19.7902	88.9000	162.6000
E_C_MI (¢/KwH)	9.7798	1.3569	6.9300	13.8500
E_I_MI (¢/KwH)	8.5436	1.0725	5.8600	11.8100
Interest rate 1 (%)	5.0849	1.1461	1.6300	6.8500
Interest rate 2 (%)	5.0863	1.1970	1.6000	6.6200

Variable Definition and Data Sources:
Price Coop: Federal Milk Market Order Class-I milk price.
W_Market: Average daily wage in market (Bureau of Labor Statistics).
W_Milk: National average weekly earnings of production workers: fluid milk (Bureau of Labor Statistics).
W_Grocery: National average weekly earning of production workers: Grocery stores (Bureau of Labor Statistics).
Gasoline: Regional Regular All Formulations Retail Gasoline Prices (Energy Information Administration).
E_C_MI: Average Revenue Per KWH -Commercial (¢/KwH), MI(Energy Information Administration).
E_I_MI: Average Revenue Per KWH –Industrial (¢/KwH), MI (Energy Information Administration).
Interest rate 1: Federal funds effective rate (Federal Reserve).
Interest rate 2: Commercial Paper 3 month (Federal Reserve).

Table 3: Demand Estimates

Parameter	Estimate	Std. Err
M1	-0.7232**	0.0770
M2	-0.8260**	0.0419
R1	-4.4236**	0.1817
R2	-2.8487**	0.2604
R3	-5.6761**	0.1569
R4	-5.5335**	0.1579
R5	-6.2386**	0.1712
Skim	0.5159**	0.0543
1st quarter	0.0201	0.0230
2nd quarter	-0.0710**	0.0239
3rd quarter	-0.0547*	0.0218
Non-price Promotion	1.0068**	0.1631
-ln(price)	0.2822**	0.0170
α_1	-4.6820**	0.1376
Heterogeneity		
-ln(price)		
Income ($'000)	-0.0180**	0.0005
Age	0.0712**	0.0026
Std. dev.	0.1203**	0.0244
Non-price Promotion		
Std. dev.	0.1592	0.2174

Note: **: significant at 1% level; *: significant at 5% level

Table 4: Price Elasticity Matrix

		R1			R2			R3			R4			R5		
		M1	**M2**	**P**	**M1**	**M2**	**P**	**M1**	**M2**	**P**	**M1**	**M2**	**P**	**M1**	**M2**	**P**
R1	**M1**	-2.0878	0.0160	0.0333	0.0273	0.0085	0.0262	0.0018	0.0004	0.001	0.0174	0.0057	0.0228	0.0014	0.0003	0.0007
	M2	0.0363	-2.1981	0.0475	0.0163	0.0091	0.0343	0.0009	0.0002	0.0006	0.0131	0.0093	0.0389	0.0008	0.0002	0.0004
	P	0.0251	0.0158	-2.2460	0.0132	0.0090	0.0551	0.0005	0.0001	0.0005	0.0135	0.0099	0.0623	0.0004	0.0001	0.0003
R2	**M1**	0.0545	0.0143	0.0350	-2.182	0.0085	0.0359	0.0018	0.0005	0.0024	0.0169	0.0058	0.0308	0.0016	0.0004	0.002
	M2	0.0341	0.0160	0.0476	0.0170	-2.289	0.0478	0.0011	0.0004	0.0029	0.0140	0.0089	0.0480	0.0011	0.0003	0.0025
	P	0.0155	0.0090	0.0434	0.0107	0.0071	-2.4823	0.0006	0.0003	0.0102	0.0110	0.0071	0.0582	0.0007	0.0003	0.0085
R3	**M1**	0.0062	0.0014	0.0022	0.0031	0.0009	0.0035	-3.1775	0.0238	0.0432	0.0015	0.0003	0.0007	0.0828	0.0320	0.0461
	M2	0.0030	0.0007	0.0011	0.0017	0.0007	0.0038	0.0483	-3.2206	0.0474	0.0007	0.0002	0.0003	0.0830	0.0334	0.0508
	P	0.0013	0.0003	0.0008	0.0016	0.0010	0.0229	0.0167	0.0090	-3.0021	0.0003	0.0001	0.0002	0.0270	0.0113	0.0598
R4	**M1**	0.0462	0.0154	0.0477	0.0226	0.0093	0.0492	0.0011	0.0003	0.0006	-2.1753	0.008	0.0511	0.0009	0.0002	0.0004
	M2	0.0265	0.0192	0.0616	0.0135	0.0104	0.0555	0.0004	0.0001	0.0002	0.0141	-2.2557	0.0647	0.0003	0.0001	0.0002
	P	0.0193	0.0145	0.0699	0.0131	0.0102	0.0827	0.0002	0.0000	0.0001	0.0162	0.0117	-2.2766	0.0001	0.0000	0.0001
R5	**M1**	0.0032	0.0008	0.0012	0.0018	0.0006	0.0026	0.0540	0.0267	0.0456	0.0007	0.0002	0.0003	-3.2598	0.0360	0.0489
	M2	0.0016	0.0004	0.0007	0.0011	0.0005	0.0029	0.0529	0.0272	0.0485	0.0004	0.0001	0.0002	0.0912	-3.2828	0.0523
	P	0.0009	0.0002	0.0007	0.0014	0.0009	0.0202	0.0188	0.0102	0.0630	0.0002	0.0000	0.0002	0.0305	0.0129	-3.0458

Note:

1. The matrix is for skim milk only. The complete matrix for skim and whole milk is available from the authors.
2. An element in the *i*th row and *j*th column represents the percentage change in *i*'s quantity as a result of a 1% change in *j*'s price.

Table 5: Supply Model Selection

		M_C	M_A	M_P
Proposed Model				
R_C	Total	**62.7 (62.1,63.5)**	62.4 (61.7,63.2)	61.9 (61.2,62.8)
	Retailer	**40.5 (39.9,41.1)**	**40.5 (39.9,41.1)**	**40.5 (39.9,41.1)**
	Manufacturer	22.3 (22.1,22.4)	21.9 (21.7,22.1)	21.5 (21.2,21.8)
R_A	Total	**63.1 (62.5,63.9)**	***62.8 (62.2,63.7)***	62.3 (61.6,63.2)
	Retailer	**40.1 (39.6,40.8)**	***40.1 (39.6,40.8)***	**40.1 (39.6,40.8)**
	Manufacturer	23.0 (22.8,23.1)	***22.7 (22.6,22.9)***	22.2 (22.0,22.4)
R_P	Total	**63.2 (62.6,64.0)**	**63.0 (62.3,63.8)**	62.2 (61.4,63.0)
	Retailer	39.9 (39.3,40.5)	39.9 (39.3,40.5)	39.9 (39.3,40.5)
	Manufacturer	23.3 (23.2,23.5)	**23.1 (22.9,23.3)**	22.3 (22.1,22.5)
Alternative Model				
R_C	Total	**63.1 (62.3,63.7)**	**62.6 (61.7,63.4)**	62.1 (61.4,63.0)
	Retailer	**40.5 (39.9,41.1)**	**40.5 (39.9,41.1)**	**40.5 (39.9,41.1)**
	Manufacturer	22.6 (22.4,22.6)	22.1 (21.9,22.3)	21.7 (21.4,22.0)
R_A	Total	**63.5 (62.8,64.3)**	**63.2 (62.6,64.0)**	**62.4 (61.7,63.3)**
	Retailer	**40.1 (39.6,40.8)**	**40.1 (39.6,40.8)**	**40.1 (39.6,40.8)**
	Manufacturer	23.3 (23.2,23.5)	23.1 (23.0,23.2)	22.3 (22.1,22.5)
R_P	Total	**63.7 (63.0,64.5)**	**63.2 (62.5,64.0)**	**62.9 (62.2,63.7)**
	Retailer	39.9 (39.3,40.5)	39.9 (39.3,40.5)	39.9 (39.3,40.5)
	Manufacturer	23.8 (23.6,23.9)	23.3 (23.2,23.5)	23.0 (22.8,23.1)

i) Proposed Model: PL products homogeneous upstream and differentiated downstream; NL differentiated upstream and downstream.
Alternative Model: PL products differentiated both upstream and downstream; NL differentiated upstream and downstream.
ii) M: manufacturer; R: retailer; C: category management; A: account management; P: product management.
iii) Reported numbers are median margins, with the 95% confidence interval in parenthesis.
iv) Numbers are bolded when the confidence interval covers the observed value from external data. The best fitting game has values italicized and bolded.
v) Observed average margins (external data): Total 63.3%, Retailer 40.6%; Manufacturer 22.7%.

Table 6: Supply Estimates

Variable	Coefficient	Std. error
Producer		
R1	0.1148	0.0044
M1	0.0715	0.0044
M2	0.0801	0.0044
Brand Dummy (PL vs. NL)		
Private Label Dummy	-0.0271	0.0003
Chain*National Label Dummy		
R1	-0.0269	0.0003
R2	-0.0264	0.0003
R3	0.0093	0.0003
R4	-0.0317	0.0003
Product Type Dummy		
Skim	-0.0028	0.0002
Input Price		
Coop Price	0.0123	0.0009
Wage Market	-0.0004	0.0000
Gasoline	0.0002	0.0000
Electricity (Commercial) MA	-0.0020	0.0002
Electricity (industrial) MA	0.0004[n.s]	0.0003
Wage (Milk Industry)	0.0000	0.0000
Wage (Grocery)	0.0001	0.0000
Interest Rate 1	-0.0059	0.0005
Interest Rate 2	0.0001[n.s]	0.0005

Note: All variables significant at 1% level, except those marked 'n.s'.
1. Estimates are for the game where: i) PL products compete Cournot Nash upstream and Bertrand Nash downstream; ii) NL products compete Bertrand Nash upstream and downstream; iii) both manufacturers and retailers practice account management, i.e., they separately maximize profits from NL and PL products.
2. The estimates are in dollars per serving (which is 8 ounces). Multiplying this by 16 gives costs in $/gallon.

Table 7: Base Case

Retailer							
Retailer	Brand	Product	Retail Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
R1	M1	Skim	0.2019	0.0971	0.1576	60236.6	239415.5
		Whole	0.2034	0.0965	0.0673	25596.3	
	M2	Skim	0.18	0.082	0.0915	29962.4	
		Whole	0.1839	0.0831	0.0457	15126.4	
	PL	Skim	0.177	0.0791	0.2418	76270.9	
		Whole	0.1812	0.0805	0.1005	32222.9	
R2	M1	Skim	0.1842	0.0846	0.0976	32458.9	203297
		Whole	0.1821	0.0813	0.0402	12940.9	
	M2	Skim	0.1967	0.0861	0.0442	15068	
		Whole	0.1983	0.0852	0.0179	6027.6	
	PL	Skim	0.1473	0.0598	0.3905	91741.8	
		Whole	0.1549	0.0627	0.1828	45059.8	
R3	M1	Skim	0.192	0.0606	0.0531	12757.8	75064.6
		Whole	0.1972	0.0623	0.0226	5576.8	
	M2	Skim	0.2076	0.0645	0.0242	6221.9	
		Whole	0.2125	0.066	0.009	2374.8	
	PL	Skim	0.1314	0.044	0.1967	33801.6	
		Whole	0.1402	0.048	0.076	14331.7	
R4	M1	Skim	0.1716	0.079	0.08	24672.7	188150.8
		Whole	0.1755	0.0795	0.0343	10678.8	
	M2	Skim	0.1885	0.0836	0.0401	13397.9	
		Whole	0.195	0.0859	0.0171	5884.9	
	PL	Skim	0.1574	0.0699	0.3036	84341.5	
		Whole	0.1658	0.0736	0.1686	49175	
R5	M1	Skim	0.1694	0.0522	0.0889	18381.2	87390.6
		Whole	0.1744	0.0539	0.0402	8586.1	
	M2	Skim	0.1856	0.0567	0.0324	7340.5	
		Whole	0.1906	0.0581	0.0139	3223.2	
	PL	Skim	0.1304	0.0429	0.202	33803.4	
		Whole	0.1389	0.0467	0.0881	16056.2	
Manufacturer							
Manufacturer	Chain	Product	Wholesale Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
M1	R1	Skim	0.1048	0.0501	0.1576	31089.6	117616.8
		Whole	0.1069	0.0494	0.0673	13107.6	
	R2	Skim	0.0996	0.0443	0.0976	17018	
		Whole	0.1008	0.0427	0.0402	6793.8	
	R3	Skim	0.1314	0.0405	0.0531	8528.3	
		Whole	0.135	0.0412	0.0226	3687.8	
	R4	Skim	0.0926	0.0427	0.08	13331.5	
		Whole	0.0961	0.0433	0.0343	5814.9	
	R5	Skim	0.1172	0.0355	0.0889	12513.5	
		Whole	0.1205	0.036	0.0402	5731.8	
	PL	Skim	0.0875	0.0329	1.0928	141273.7	211794.1
		Whole	0.0922	0.0348	0.5157	70520.4	
M2	R2	Skim	0.1106	0.0468	0.0442	8184.3	35148
		Whole	0.1131	0.0465	0.0179	3288	
	R3	Skim	0.143	0.0435	0.0242	4193.9	
		Whole	0.1465	0.0442	0.009	1589.4	
	R4	Skim	0.1049	0.0463	0.0401	7421	
		Whole	0.1091	0.0477	0.0171	3268.7	
	R5	Skim	0.129	0.0387	0.0324	5018.4	
		Whole	0.1324	0.0394	0.0139	2184.3	

Table 8: What-if Scenario #1: No Private Label Sales

Retailer							
Retailer	Brand	Product	Retail Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
R1	M1	Skim	0.2016	0.0968	0.164	62513.3	
		Whole	0.2029	0.0961	0.0708	26793.4	
	M2	Skim	0.1799	0.0819	0.0964	31511	
		Whole	0.1838	0.0829	0.0484	16002.9	136820.6
R2	M1	Skim	0.1841	0.0844	0.1024	33995.7	
		Whole	0.1823	0.0813	0.0426	13712	
	M2	Skim	0.1969	0.0862	0.047	16024.8	
		Whole	0.1989	0.0855	0.0191	6483.3	70215.8
R3	M1	Skim	0.1921	0.0606	0.0542	13025.3	
		Whole	0.1973	0.0623	0.023	5685.9	
	M2	Skim	0.2077	0.0646	0.0248	6362.3	
		Whole	0.2126	0.066	0.0092	2424.8	27498.3
R4	M1	Skim	0.1711	0.0786	0.0863	26462.4	
		Whole	0.175	0.079	0.0376	11661.3	
	M2	Skim	0.1883	0.0835	0.0434	14493.5	
		Whole	0.1947	0.0857	0.0188	6454.5	59071.7
R5	M1	Skim	0.1695	0.0523	0.0908	18762.7	
		Whole	0.1744	0.054	0.0409	8753.6	
	M2	Skim	0.1857	0.0567	0.0331	7500.3	
		Whole	0.1906	0.0582	0.0142	3288.9	38308.5
Manufacturer							
Manufacturer	Chain	Product	Wholesale Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
M1	R1	Skim	0.1047	0.05	0.164	32303.4	
		Whole	0.1068	0.0493	0.0708	13742	
	R2	Skim	0.0996	0.0444	0.1024	17873.6	
		Whole	0.1009	0.0428	0.0426	7223.9	
	R3	Skim	0.1315	0.0405	0.0542	8711.1	
		Whole	0.135	0.0412	0.023	3760.7	
	R4	Skim	0.0925	0.0426	0.0863	14339.4	
		Whole	0.0959	0.0431	0.0376	6364.7	
	R5	Skim	0.1172	0.0356	0.0908	12775.6	
		Whole	0.1205	0.036	0.0409	5842.4	122936.8
M2	R2	Skim	0.1107	0.0469	0.047	8721.5	
		Whole	0.1134	0.0467	0.0191	3543.3	
	R3	Skim	0.1431	0.0435	0.0248	4289.1	
		Whole	0.1466	0.0442	0.0092	1622.8	
	R4	Skim	0.1048	0.0463	0.0434	8037.8	
		Whole	0.109	0.0476	0.0188	3587.6	
	R5	Skim	0.129	0.0388	0.0331	5127.7	
		Whole	0.1325	0.0394	0.0142	2228.6	37158.4

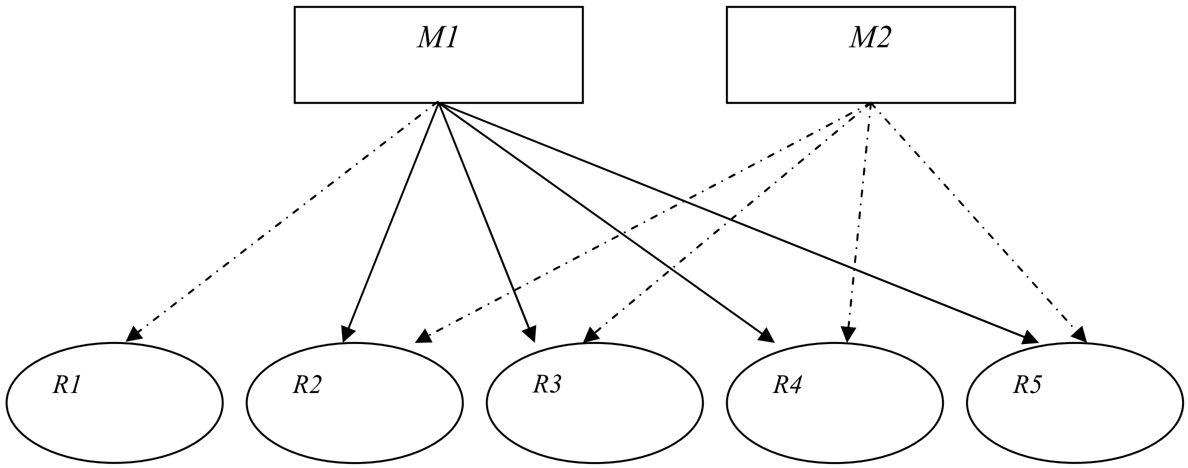
Table 9: What-if Scenario #2: *M2* adds Private Label Sales

			Retailer				
Retailer	Brand	Product	Retail Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
R1	M1	Skim	0.202	0.0972	0.1566	59878.7	236816.3
		Whole	0.2035	0.0966	0.0667	25399.1	
	M2	Skim	0.18	0.082	0.0907	29706.5	
		Whole	0.184	0.0831	0.0452	14977.7	
	PL	Skim	0.177	0.0791	0.2383	75171.7	
		Whole	0.1812	0.0804	0.0988	31682.6	
R2	M1	Skim	0.1844	0.0847	0.0965	32162.3	247345.6
		Whole	0.1822	0.0814	0.0397	12785.8	
	M2	Skim	0.1968	0.0862	0.0436	14883	
		Whole	0.1983	0.0852	0.0176	5937.2	
	PL	Skim	0.1199	0.048	0.6391	121063.9	
		Whole	0.1247	0.0497	0.3085	60513.4	
R3	M1	Skim	0.1921	0.0606	0.0525	12614.5	97022.9
		Whole	0.1973	0.0623	0.0223	5518	
	M2	Skim	0.2076	0.0645	0.0239	6147.7	
		Whole	0.2125	0.066	0.0089	2348.4	
	PL	Skim	0.1075	0.0356	0.3518	49287	
		Whole	0.1133	0.0383	0.1396	21107.3	
R4	M1	Skim	0.1718	0.0791	0.0788	24356.6	223250.3
		Whole	0.1757	0.0796	0.0337	10500.5	
	M2	Skim	0.1886	0.0837	0.0395	13201.4	
		Whole	0.1951	0.086	0.0168	5780.8	
	PL	Skim	0.1299	0.058	0.4613	106515.9	
		Whole	0.1355	0.0605	0.2619	62895.1	
R5	M1	Skim	0.1694	0.0523	0.0879	18168.5	110745.1
		Whole	0.1744	0.054	0.0397	8492.5	
	M2	Skim	0.1856	0.0567	0.032	7253.3	
		Whole	0.1906	0.0581	0.0138	3187.2	
	PL	Skim	0.1068	0.0349	0.3638	49759.8	
		Whole	0.1124	0.0374	0.1629	23883.8	
			Manufacturer				
Manufacturer	Chain	Product	Wholesale Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
M1	R1	Skim	0.1048	0.0501	0.1566	30896.2	116432.5
		Whole	0.107	0.0494	0.0667	13000.9	
	R2	Skim	0.0996	0.0444	0.0965	16854.3	
		Whole	0.1008	0.0427	0.0397	6707.6	
	R3	Skim	0.1314	0.0405	0.0525	8426.7	
		Whole	0.135	0.0412	0.0223	3647.1	
	R4	Skim	0.0927	0.0427	0.0788	13152.7	
		Whole	0.0961	0.0433	0.0337	5714.7	
	R5	Skim	0.1172	0.0355	0.0879	12363.6	
		Whole	0.1205	0.036	0.0397	5668.7	
	PL	Skim	0.0719	0.0174	1.2133	83218.7	123559.9
		Whole	0.075	0.0176	0.5807	40341.2	
M2	R2	Skim	0.1106	0.0468	0.0436	8080.3	34669
		Whole	0.1131	0.0465	0.0176	3237.3	
	R3	Skim	0.143	0.0435	0.0239	4142.4	
		Whole	0.1465	0.0442	0.0089	1571.3	
	R4	Skim	0.1049	0.0463	0.0395	7310.1	
		Whole	0.1091	0.0477	0.0168	3210.2	
	R5	Skim	0.129	0.0387	0.032	4957.7	
		Whole	0.1324	0.0394	0.0138	2159.7	
	PL	Skim	0.0719	0.0088	0.6026	20817.3	31163
		Whole	0.075	0.009	0.2922	10345.7	

Table 10: What-if Scenario #3: *R1* divests vertically integrated facility

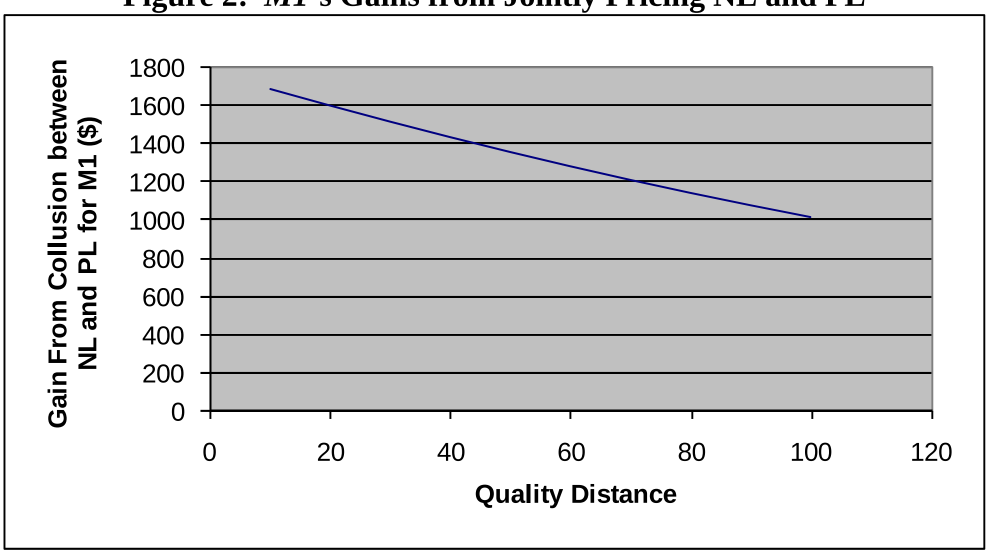
Retailer							
Retailer	Brand	Product	Retail Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
R1	M1	Skim	0.2019	0.0971	0.1588	60692.3	
		Whole	0.2034	0.0965	0.0679	25804	
	M2	Skim	0.3316	0.1517	0.0242	14633.1	
		Whole	0.3358	0.1524	0.0122	7386.7	
	PL	Skim	0.2403	0.1074	0.1231	52559.3	
		Whole	0.2449	0.1087	0.0514	22221.8	183297.2
R2	M1	Skim	0.1843	0.0846	0.0982	32695	
		Whole	0.1822	0.0814	0.0405	13041.2	
	M2	Skim	0.1971	0.0863	0.0444	15179.9	
		Whole	0.1987	0.0854	0.018	6074.6	
	PL	Skim	0.1511	0.0615	0.3703	89378.9	
		Whole	0.1561	0.0633	0.1809	44978.4	201348
R3	M1	Skim	0.1921	0.0606	0.0532	12773.8	
		Whole	0.1973	0.0623	0.0226	5582.9	
	M2	Skim	0.2076	0.0645	0.0243	6228.3	
		Whole	0.2125	0.066	0.0091	2377.1	
	PL	Skim	0.1347	0.0451	0.1833	32298.6	
		Whole	0.1413	0.0484	0.0746	14155.3	73416
R4	M1	Skim	0.1716	0.079	0.0808	24915	
		Whole	0.1755	0.0795	0.0346	10794.1	
	M2	Skim	0.1888	0.0838	0.0404	13531.4	
		Whole	0.1953	0.086	0.0173	5946.9	
	PL	Skim	0.1612	0.0716	0.2915	82905	
		Whole	0.167	0.0742	0.1681	49370.2	187462.6
R5	M1	Skim	0.1694	0.0522	0.089	18401.1	
		Whole	0.1744	0.0539	0.0402	8594.7	
	M2	Skim	0.1856	0.0567	0.0325	7347.6	
		Whole	0.1906	0.0581	0.0139	3226	
	PL	Skim	0.1336	0.0441	0.1882	32276.6	
		Whole	0.14	0.0471	0.0865	15858.4	85704.4
Manufacturer							
Manufacturer	Chain	Product	Wholesale Price ($/Serving)	Margin ($/Serving)	Serving/ Person	Profit ($/week)	Total Profit ($/week)
M1	R1	Skim	0.1048	0.0501	0.1588	31326.7	
		Whole	0.1069	0.0494	0.0679	13213	
	R2	Skim	0.0996	0.0444	0.0982	17147.1	
		Whole	0.1008	0.0427	0.0405	6848.4	
	R3	Skim	0.1315	0.0405	0.0532	8538.1	
		Whole	0.135	0.0412	0.0226	3691.5	
	R4	Skim	0.0926	0.0427	0.0808	13466.9	
		Whole	0.0961	0.0433	0.0346	5879.3	
	R5	Skim	0.1172	0.0355	0.089	12526.3	
		Whole	0.1205	0.036	0.0402	5737.4	118374.7
	PL	Skim	0.0982	0.035	1.1566	158960.8	
		Whole	0.1015	0.0355	0.5616	78269.5	237230.3
M2	R1	Skim	0.1798	0.0818	0.0242	7889.6	
		Whole	0.1834	0.0825	0.0122	4001.3	
	R2	Skim	0.1108	0.047	0.0444	8262.4	
		Whole	0.1133	0.0467	0.018	3319.9	
	R3	Skim	0.1431	0.0435	0.0243	4198.3	
		Whole	0.1466	0.0442	0.0091	1590.9	
	R4	Skim	0.1051	0.0465	0.0404	7513.1	
		Whole	0.1093	0.0479	0.0173	3310	
	R5	Skim	0.129	0.0387	0.0325	5023.3	
		Whole	0.1325	0.0394	0.0139	2186.3	47295.1

Figure 1: Market Structure (as of 1997)



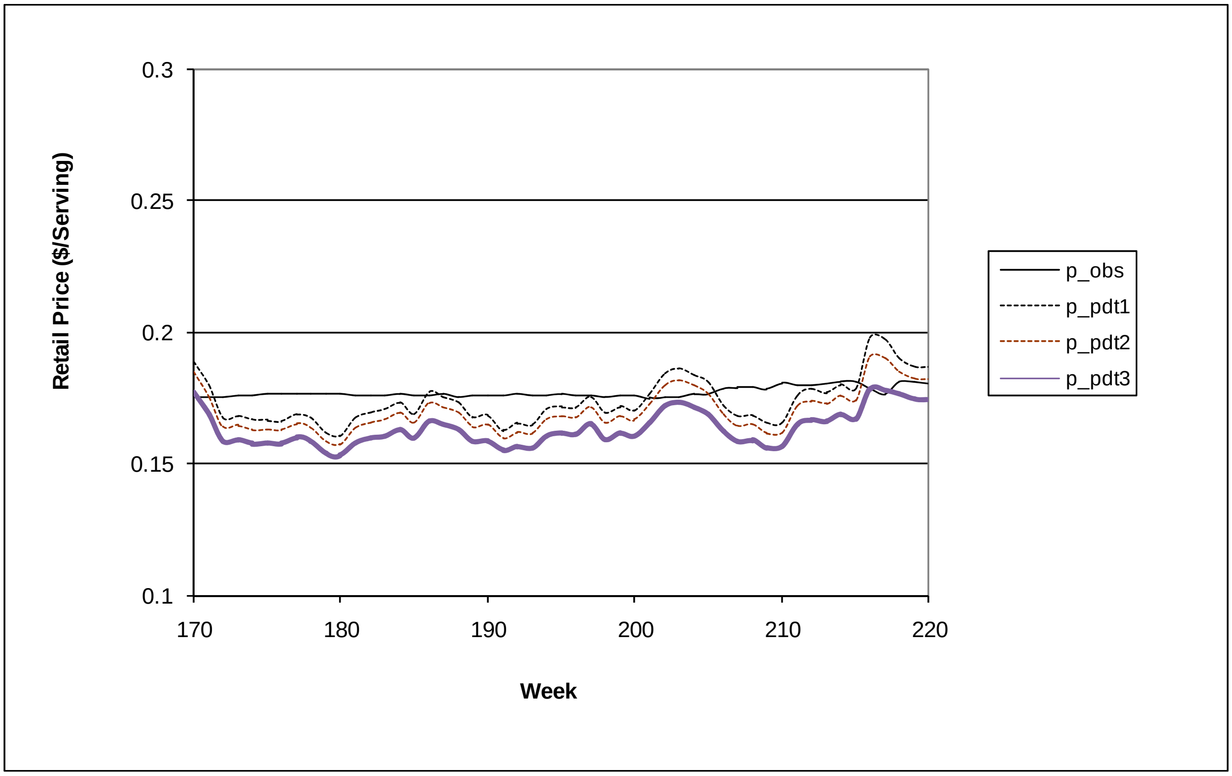
Note:
1. Dotted lines: National brand only; Solid line: National brand + Private label
2. R1 is vertically integrated in PL supply.

Figure 2: *M1*'s Gains from Jointly Pricing NL and PL



Note: The x-axis measures the distance between the brand preference parameters of NL and PL products for *M1*. A value of 100 represents the distance between the values actually estimated in the data, while 0 implies that the two products have the same brand preference parameters.

Figure 3: Comparing Predicted with Observed Prices



Note:
1. p_obs: Observed prices
2. p_pdt1: Predicted prices using proposed model (MSE=0.00008).
3. p_pdt2: Predicted prices using a model assuming PLs are differentiated at the wholesale level (MSE=0.00011).
4. p_pdt3: Predicted prices using proposed model without taking into consideration the vertical divestiture (MSE=0.00023).

REFERENCES

Arora, N., G.M. Allenby and J.L. Ginter (1998), "A Hierarchical Bayes Model of Primary and Secondary Demand," *Marketing Science*, 17, pp. 29-44.

Bergès-Sennou, Fabian, Philippe Bontems and Vincent Réquillart (2004), "Economics of Private Labels: A Survey of Literature", *Journal of Agricultural & Food Industrial Organization*, 2, p. 5.

Berto Villas-Boas, Sofia (2007), "Vertical Contracts between Manufacturers and Retailers: Inference With Limited Data", *Review of Economic Studies*, 74 (2), 625-652.

Besanko, D., S. Gupta and D. Jain (1998), "Logit Demand Estimation Under Competitive Pricing Behavior: An Equilibrium Framework," *Management Science*, Nov., 1533-1547.

Bonanno, Alessandro and Rigoberto Lopez (2005), "Private Label Expansion and Supermarket Milk Prices, *Journal of Agriculture and Food Industrial Organization*, vol. 3, article 2.

Bresnahan, T.F. (1989), "Empirical Methods for Industries with Market Power," R. Schmalensee and R. Willig, eds., Handbook of Industrial Organization, vol. 2, North Holland, Amsterdam.

Chen, Xinlei, George John and Om Narasimhan (2008), "Assessing the Effects of a Channel Switch," *Marketing Science*, 27 (3), 398-416.

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

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

Chintagunta, Pradeep K., Andre Bonfrer, and Inseong Song (2002), "Investigating the Effects of Store-Brand Introduction on Retail Demand and Pricing Behavior," *Management Science*, 48 (October), 1242-1267.

Chidmi, B., R.W. Lopez, and R.W. Cotterill (2003), "Retail Oligopoly Power and Fluid Milk Prices in Boston," Paper presented at the American Agricultural Economics Association Annual Meetings, Montreal, Canada.

Choi Chan S. and Anne T. Coughlan (2006), " Private Label Positioning: Quality versus Feature Differentiation from the National Brand," *Journal of Retailing*, 82 (2), 79-93.

Chu, Junhong , Pradeep K. Chintagunta and Naufel J. Vilcassim (2007), "Assessing the Economic Value of Distribution Channels: An Application to the Personal Computer Industry," *Journal of Marketing Research*, 44(1), pp. 29-41.

Corts, Kenneth (1999), "Conduct Parameters and the Measurement of Market Power," *Journal of Econometrics*, 88(2), 227-250.

Froeb, Luke (2004), "Antitrust Enforcement, R&D: Mergers and Vertical Restraints," Talk at King's College, London (available at http://www.ftc.gov/speeches/froeb/041203londonkingscollege.pdf).

Gilbert, Richard and Justine Hastings (2001), "Vertical Integration in Gasoline Supply: An Empirical Test of Raising Rivals' Costs", *Working Paper*, University of California at Berkeley.

Gilbert, Richard and Justine Hastings (2005), "Market Power, Vertical Integration, and the Wholesale Price of Gasoline," *Journal of Industrial Economics*," 53(4), 469-92.

Kadiyali, Vrinda, Pradeep Chintagunta, and Naufel Vilcassim (2000), "Manufacturer-Retailer Channel Interactions and Implications for Channel Power: An Empirical Investigation of Pricing in a Local Market," *Marketing Science*, 19 (Spring), 127-148.

Kumar, Nirmalya and Jan Benedict Steenkamp (2007), Private Label Revolution: What Retailers And Manufacturers Should Know About Store Brands, 1st Edition, Harvard Business School Press, Cambridge, MA.

Mills, David E (1995), “Why Retailers Sell Private Labels”, *Journal of Economics and Management Strategy*, 1995, 4(3), 509-28.

Nair, H., J.P. Dube and P.K. Chintagunta (2005), “Accounting for Primary and Secondary Demand Effects with Aggregate Data, *Marketing Science*, 24(3), pp. 444-460.

Narasimhan C. and R. Wilcox (1998), “Private Labels and the Channel Relationship: A Cross-Category Analysis”, *Journal of Business*, 71, 573-600.

Nevo, Aviv (2000), “A Practitioner’s Guide to Estimation of Random Coefficients Logit Models of Demand,” *Journal of Economics & Management Strategy*, 9 (Winter), 513-548.

________ (2001): Measuring Market Power in the Ready-to-eat Cereal Industry, *Econometrica*, 69(2), 307-42.

Newey, W. and D. McFadden (1994), “Large Sample Estimation and Hypothesis Testing,” R.F. Engle and D. McFadden eds., Handbook of Econometrics, Vol. 4, 2211-2245, North Holland, Amsterdam.

Pakes, A. and D. Pollard (1989), “Simulation and the Asymptotics of Optimization Estimators,” *Econometrica*, 57, p. 1027-1058.

Petrin, Amil (2002), “Quantifying the Benefits of New Products: The Case of the Minivan,” *Journal of Political Economy*, 110:705-729, 2002.

Pollak, R.A. and T.J. Wales (1992), *Demand System Specification and Estimation*, Oxford University Press.

Porter, Robert (1983), “A Study of Cartel Stability: The Joint Executive Committee, 1880-1886, *The Bell Journal of Economics*, 14(2), 301-14.

Quelch, John A. and David Harding (1996), “Brands Versus Private Labels: Fighting to Win,” *Harvard Business Review*, Jan-Feb, pp. 99- 109.

Raju Jagmohan S., Raj Sethuraman and Sanjay K. Dhar (1995), “The Introduction and Performance of Store Brands”, *Management Science*, 41(6), 957-78.

Reiss, Peter C. and Wolak, Frank A. (2007) “Structural Econometric Modeling: Rationales and Examples from Industrial Organization,” *Handbook of Econometrics*, Volume 6A, (James J. Heckman and Edward E. Leamer eds.), 4277-4415.

Scott-Morton, Fiona and Florian Zettlemeyer (2004), “The Strategic Positioning of Store Brands in Retailer-Manufacturer Negotiations”, *Review of Industrial Organization*, 24, 161-194.

Smith, Richard (1992), “Non-nested Tests for Competing Models Estimated by Generalized Method of Moments,” *Econometrica*, 60, 973-980.

Soberman, David A. and Philip M. Parker (2006), “The Economics of Quality-equivalent Store Brands,” *International Journal of Research in Marketing*, 23, 125-39.

Sudhir, K. (2001), “Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer,” *Marketing Science*, 20 (Summer), 973-980.

Villas-Boas, J. Miguel, and Ying Zhao (2005), “Retailers, Manufacturers, and Individual Consumers: Modeling the Supply Chain in the Ketchup Marketplace”, *Journal of Marketing Research*, 42 (1), 83-95.

Vuong, Q.H. (1989), “Likelihood Ratio Tests for Model Selection and Non-Nested Hypotheses”, *Econometrica*, 57(March), 307-333.