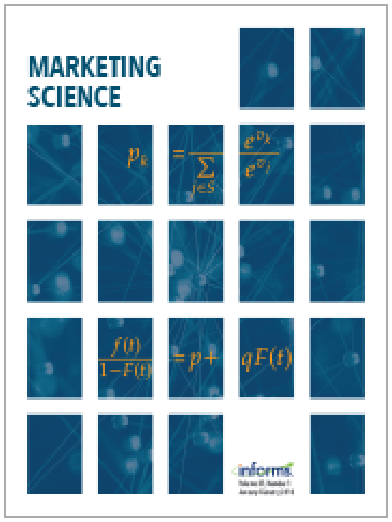

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An Empirical Investigation of Private Label Supply by National Label Producers

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Private labels (PLs) are ubiquitous in several categories, including groceries, apparel, and appliances. However, existing empirical work has not examined the differential impact of various upstream supply arrangements for PL products or the strategic motives for PL supply. To do so requires one to model the interaction between private and national label (NL) products both upstream and downstream while accounting for strategic behavior on the part of manufacturers and retailers and retaining essential differences between NL and PL products. We build a model that satisfies these requirements and lets us answer 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 a vertically integrated supply of PL leads to lower prices for end consumers.

Key words: private labels; structural estimation; distribution channels; counterfactuals
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1. Introduction

We start with some definitions. We 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, we 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 1970s, coinciding with the growth and consolidation of the retail sector. A PL may be produced by an upstream firm (possibly a firm that produces NL products) or else produced internally.[2] We refer to procurement from an upstream firm as a "vertically separated" supply arrangement and production internally as a "vertically integrated" supply arrangement.[3]

Although 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). According to Quelch

[1] Of course, there is no intrabrand 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] Internal supply is equivalent to procurement from an external price-taking contractor, in that both assume marginal cost supply.

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

and Harding (1996), more than 50% of NL consumer packaged goods firms actually produced PL products as well; indeed, NL firms supplied more than 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—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 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 are the upstream and downstream impacts of different PL supply arrangements?

Answering these questions requires us to overcome a fairly significant hurdle at the outset; namely, 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; and (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, we therefore choose to focus on a subset of issues that are most relevant to our research questions.

To start, we abstract away from endogenous PL quality choice—although 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, because the U.S. Department of Agriculture (USDA) grading standards for milk minimize objective quality differences. Second, we do not endogenize the choice of PL supplier. Third, 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. Whereas 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 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, whereas PL products are not. On the other hand, both PL and NL products are branded downstream. In other words, 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.[4] The economics literature suggests a reasonable way of capturing this fundamental conceptual difference in a modeling framework—namely, the use of a Cournot game to model PL supply and the use of a Bertrand game to model NL supply (therefore treating NL as differentiated upstream). In using a Cournot game to model PL supply, we parallel Gilbert and Hastings (2001), who face a similar situation in their examination of vertical foreclosure in the gasoline market. It is important for the validity of the Cournot assumption that there not exist unlimited capacity in the form of fringe producers ready to supply the PL product—this is indeed true in our context.

To sum, we use (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 a 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. Regarding 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. Furthermore, we find that retailers benefit from the presence of PL products. Regarding the second question, we find that given the

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

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 creates a PL monopolist supplier.[5] Our model predicts out-of-sample postdivestiture 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.

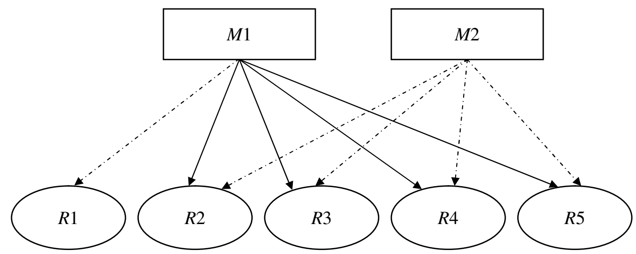
We believe our contributions are fourfold. First, our results pertaining to the impact of PL presence and its supply structure on various constituents (suppliers, retailers, consumers) are likely to be of interest to both managers and policy makers. Second, we believe our tools provide the policy maker a methodology to assess the net effects of alternative vertical supply arrangements, something that has been of much importance to the antitrust 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 industrial organization model with out-of-sample predictions.

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.[6] Two NL firms ($M1$ and $M2$) sell through five retail chains: $R1$, $R2$, $R3$, $R4$, and $R5$, with $R5$ representing a composite residual chain.[7] 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 $M2$.[8] In June 2000, $R1$ divested this plant and began to purchase its PL milk from $M1$.

Figure 1 **Market Structure (as of 1997)**



Notes. Dotted lines: National brand only; solid line: National brand + Private label. $R1$ is vertically integrated in PL supply.

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% at Minyard in Dallas to 99.5% at Safeway in Seattle; see Bonanno and Lopez 2005), which helps us ascertain the market impact of PL goods more sharply.

Second, as already mentioned, USDA milk grading standards minimize objective quality differences across brands, which helps avoid issues such as the 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.

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. 2005). Although few have used the kind of structural modeling we use, these papers provide us with points of comparison as well as points of departure.

2.2. Consumer Demand

Our demand model follows Nair et al. (2005) closely and accounts for both heterogeneous preferences

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

[6] For reasons of confidentiality, we are unable to name the firms involved or the metropolitan area.

[7] 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.

[8] Note that backward 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 that did occur after June 2000.

and multiple-unit purchases amongst consumers. We define a product as a combination of chain, brand (NL or PL), and type (skim milk 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. Although feasible econometrically, we do not have the minimum data needed to implement this suggestion (at the minimum, we would need data on the customer traffic at each store). Our consumer problem is formulated as

$$\max_{x_{i1t}\cdots x_{iJt}} \quad u = u^*\left(\sum_{j=1}^{J} \psi_{ijt} x_{ijt}, \psi_{izt} z_{it}\right)$$
$$\text{s.t.} \; \sum_{j=1}^{J} p_{ijt} x_{ijt} + z_{it} = y_{it} \quad x_{ijt} \ge 0; z \ge 0, \tag{1}$$
$$i = 1, .., I; \; j = 1, .., J; \; t = 1, .., T,$$

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 nonpricing 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 independent and identically distributed (i.i.d.) extreme value distribution:

$$\varepsilon_{ist} = (\varepsilon_{i1t}, \ldots, \varepsilon_{iJt}) \sim \text{EV}(0, \mu),$$
$$\varepsilon_{izt} \sim \text{EV}(0, \mu).$$

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

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

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

$$E_\varepsilon(x_{ijt}) = \int_{j \text{ is chosen}} x_{ijt}(p_{jt}, \psi_{ijt}, \psi_{izt}, y_t \mid C_{ijt} = 1, I_{it} = 1)\, d\varepsilon$$
$$= -\frac{\mu\alpha_3}{\alpha_i}\frac{y_{it}}{p_{jt}}\left[\frac{\ln(\Pr(I_{it} = 0))}{\Pr(I_{it} = 1)}\right], \tag{2}$$

and the corresponding choice probabilities are

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

where

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

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:

$$\gamma_{ijt} = \gamma_j + L w_{it} \quad \text{such that } w_{it} \sim \text{MVN}(0, I_{J\times 1})$$
$$\text{and} \quad L'L = \Sigma_{J\times J},$$
$$\beta_{it} = \beta + \sigma_\beta \zeta_{it}; \quad \zeta_{it} \sim N(0, 1), \tag{4}$$
$$\alpha_i = \alpha + D_i\theta + \sigma_\alpha \eta_{it}; \quad \eta_{it} \sim N(0, 1),$$

where D_i is the demographic information for consumer i.

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

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

where $\Lambda = (w, \zeta, \eta, D)'$ and $\phi(\cdot)$ denotes the probability density function of the standard multivariate normal distribution. Inserting Equations (2)–(4) into Equation (5), we get

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

where

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

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

$$y_{it} = g(D_i) + \sigma_\tau\tau_{it} \quad v_{it} \sim N(0,1), \tag{7}$$

where $g(\cdot)$ is a prespecified function and σ_τ is the standard deviation of the distribution, both of which are predetermined using external information. Correspondingly, Λ in Equation (6) is defined as $\Lambda = (w, \zeta, \eta, D, \tau)'$, and y_{it} is a random draw given by Equation (7).

2.3. Supply Model

It is crucial on the supply side 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, and 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. We too model competition between PL products upstream as Cournot-Nash, given our context mirrors theirs in important respects (firms competing on capacity and the existence of capacity constraints). 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, because all products (NL and PL) are differentiated, Gilbert and Hastings (2001) model competition between products as Bertrand-Nash. Because this mirrors our case exactly, we model downstream competitive interaction identically to them.

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.[9] 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.[10]

Denote the set of products at retailer r as F_r and the full set of products in the retail market as $F_{\mathrm{R}} = \bigcup F_r$ 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.[11] 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 and superscript 2 denotes whole milk. By definition, $F_{\mathrm{R}} = F_{\mathrm{R}}^n \cup F_{\mathrm{R}}^b$, $F_{\mathrm{R}}^n = F_{\mathrm{R}}^{n1} \cup F_{\mathrm{R}}^{n2}$, and $F_{\mathrm{R}}^b = F_{\mathrm{R}}^{b1} \cup F_{\mathrm{R}}^{b2}$. Finally, we use q_j and p_j to represent the quantity and price, respectively, 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 $F_M^n = \bigcup F_m^n$ 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. Because private labels are homogeneous products in the wholesale market, each manufacturer either supplies F_M^b or does not.[12] Let q_j^n and w_j^n represent the quantity and wholesale price, respectively, for national brands, x_{mi}^b represent the quantity of private label i supplied by manufacturer m, and w_i^b the wholesale price for private label i.[13]

2.3.1. Specifying the Retailer's Problem.[14]

The retailers maximize their category profit (i.e., profit

[9] 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 §4.3.2.

[10] That said, we do not consider nonlinear contracts between upstream and downstream parties. The Cournot model specification for PL products upstream renders this infeasible.

[11] NL and PL products carry the n and b superscripts, respectively.

[12] 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.

[13] 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.

[14] 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 the electronic companion for details).

over the entire fluid milk category),

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

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

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

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

$$\mathrm{PCM}^{\mathrm{R}} = p - w = -(T_{\mathrm{R}} \cdot \Delta_1)^{-1} q, \tag{9}$$

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

$$\Delta_1(i, j) = \frac{\partial q_j}{\partial p_i} \quad \forall\, i,\, j \in F_{\mathrm{R}}.$$

We show how to calculate Δ_1 in the electronic companion to this paper, available as part of the online version that can be found at http://mktsci.pubs.informs.org. T_{R} is an $N_{\mathrm{R}} \times N_{\mathrm{R}}$ matrix indicating the retailer's pricing strategy; in the category maximization case, $T_{\mathrm{R}}(i, j) = 1\ \forall\, i, j \in F_r$. Finally, $T_{\mathrm{R}} \cdot \Delta_1$ is the element by element product of the matrices T_{R} and Δ_1.

2.3.2. Specifying the Manufacturers' Problem.[15]

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

$$\operatorname*{Max}_{w_j^n,\, x_{mi}^b} \Pi_m = \sum_{j\in F_m^n} w_j^n q_j^n + \sum_{i\in F_M^b} w_i^b x_{mi}^b - \sum_{j\in F_m^n} c_j^n q_j^n - \sum_{i\in F_M^b} c_i^b x_{mi}^b,$$

where w_j^n is the wholesale price for national brand j, w_i^b is the wholesale price for PL i, c_j^n is the marginal cost for national brand j, and c_i^b is the marginal cost for PL i.

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

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

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

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

$$\frac{\partial \Pi_m}{\partial x_{mk}^b} = \sum_{j\in F_m^n} w_j^n \frac{\partial q_j^n}{\partial x_{mk}^b} + w_k^b + \sum_{i\in F_M^b} \frac{\partial w_i^b}{\partial x_{mk}^b} x_{mi}^b - \sum_{j\in F_m^n} c_j^n \frac{\partial q_j^n}{\partial x_{mk}^b} - c_k^b = 0 \quad \forall\, k \in F_M^b. \tag{10b}$$

In the above,

$$\frac{\partial q_j^n}{\partial w_k^n} = \sum_{l\in F_{\mathrm{R}}} \frac{\partial q_j^n}{\partial p_l} \frac{\partial p_l}{\partial w_k^n},$$

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

Manufacturers Who Do Not Supply Private Labels. These manufacturers maximize profits by choosing prices for their NL products; i.e.,

$$\operatorname*{Max}_{w_j^n} \Pi_m = \sum_{j\in F_m^n} w_j^n q_j^n - \sum_{j\in F_m^n} c_j^n q_j^n.$$

The first-order conditions are obtained from Equation (10a) by setting terms involving w^b to zero:

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

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.

Matrix Expression for Manufacturer Price-Cost Margins. Consider NL products first. It is straightforward to combine Equations (10a) and (11) as

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

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

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

[15] 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 electronic companion for details).

Then, we can write manufacturers' margins on NL as

$$\mathrm{PCM}_M^n = -(T_M^n \cdot \Delta_2^n)^{-1} G_1 \tag{12}$$

where PCM_M^n is an $N_M^n \times 1$ vector of manufacturers' margins on their NL, with $\mathrm{PCM}_M^n(j) = (w_j^n - c_j^n)$ $\forall j \in F_M^n$, Δ_2^n is an $N_M^n \times N_M^n$ matrix with $\Delta_2^n(k, j) = (\partial q_j^n / \partial w_k^n)$ $\forall k,\ j \in F_M^n$, 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, $T_M^n \cdot \Delta_2^n$ 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 (10b) can be written as

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

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

$$\mathrm{PCM}_m^b = -G_{2m} - \Delta_{3m} \mathrm{PCM}_m^n, \tag{13}$$

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

Note that to calculate the manufacturer's margin using Equations (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 electronic companion.

3. Estimation

We perform a sequential estimation; i.e., we first estimate the demand function and use these to obtain the cost parameters (margins) of the supply model. Following Newey and McFadden (1994) and 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.

3.1. Consumer Demand Estimation

We perform the demand estimation in two steps. In step 1, 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 include (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:

$$\begin{aligned} y_i = {} & a_0 + a_{10} * \mathrm{inc} + a_{11} * \mathrm{inc}^2 \\ & + a_{20} * \mathrm{age} + a_{21} * \mathrm{age}^2 + \sigma_\tau \tau_i. \end{aligned} \tag{14a}$$

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

$$\begin{aligned} g(D_i) = {} & a_0 + a_{10} * \mathrm{inc} + a_{11} * \mathrm{inc}^2 \\ & + a_{20} * \mathrm{age} + a_{21} * \mathrm{age}^2. \end{aligned} \tag{14b}$$

In step 2, 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

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

where

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

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

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:

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

Using the value of δ_{jt}, we construct the moment condition $E[\xi_{jt} Z_{jt} \mid Z_{jt}] = 0$, where $\xi_{jt} = \delta_{jt} - [\gamma_j + \alpha_1 \alpha + \beta_i d_{jt} - \alpha \ln(p_{jt})]$. 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

$$mc_{jt} = f_t \tau_j + \psi_{jt}, \tag{15}$$

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 that 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

$$(p_{jt} - \mathrm{PCM}_{jt}) = f_t \tau_j + \psi_{jt}. \tag{16}$$

The τ parameters need to be estimated. We estimate these using ordinary least squares (Petrin 2002). Finally, presaging some of the later discussion, 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, *M*1 produces PL products for *R*2, *R*3, *R*4, and *R*5, whereas *R*1 produces its PL products at an in-house facility, as well as its requirement of *M*2's NL products. In June 2000, *R*1 divested its in-house supply facility and began to purchase its PL products from *M*1. There are two distinct data periods: 152 weeks from July 6, 1997 (week 1) to May 28, 2000 (week 152), and 50 weeks from June 4, 2000 (week 153) to May 20, 2001 (week 203). For our demand estimation, we use the first 152 weeks, reserving the 50 postdivestiture weeks for our out-of-sample validation exercise. 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 *M*2 is the most expensive brand, followed by *M*1 and the various PL products. Second, total PL share exceeds total NL share. Third, skim milk 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 nonprice promotions. *R*3 leads in promotion intensity, followed by *R*2, *R*1, and then *R*4. 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 (Villas-Boas 2007). 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 that input prices, such as the price of raw milk and energy prices, would be correlated with retail prices, whereas they are likely to be uncorrelated with the unobserved ξ term. The latter is reasonable, because it is unlikely that input prices would reflect time-varying shocks such as shelf-space changes and stockouts, which is what the ξ term captures. 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.[16]

4.3. Results

4.3.1. Consumer Demand. Table 3 reports our demand estimates. First, NL brand preference is actually lower than PL, which is not surprising given PL products have almost 60% market share. (Note that NL brand preference is actually the sum of the retailer dummy and the NL manufacturer dummy; for PL, the brand preference is just the retailer dummy. Since NL manufacturer dummies are all negative, it follows that NL brand preference is lower than that for PL products.) 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 whereas age seems to increase it. Third, nonprice promotion has a significant impact. Fourth, although not reported here (see the electronic comapnion), 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 Villas-Boas's (2007) estimates for yogurt. Within-store cross-price elasticities between NL products, and those between NL and PL, are both low (less than one, on average). Finally, cross-price elasticities between stores are also very small, a finding similar to prior work (e.g., 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 §§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)). Before we report marginal cost estimates, however, it is important to observe that we specified and estimated a number of possible competitive interactions and retailer behaviors, and we need to decide the most appropriate "game form" before we proceed further. Whereas

[16] Because 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 four-week lagged measures performed best ($R^2 = 0.88$). We therefore use four-week lagged instrumental variables in our estimations.

Table 1 Descriptive Statistics: Fluid Milk

Chain	Brand	Category	Retail price ($/serving)	Volume (serving)	Nonprice promotion
*R*1	*M*1	Skim	0.1900	649,927	0.1168
*R*1	*M*1	Whole	0.1879	316,914	0.0785
*R*1	*M*2	Skim	0.2000	289,531	0.1499
*R*1	*M*2	Whole	0.2049	148,727	0.0790
*R*1	Private label	Skim	0.1763	1,105,470	0.0890
*R*1	Private label	Whole	0.1809	484,258	0.0524
*R*2	*M*1	Skim	0.1909	353,894	0.2083
*R*2	*M*1	Whole	0.1920	134,007	0.1658
*R*2	*M*2	Skim	0.2019	168, 526	0.2364
*R*2	*M*2	Whole	0.2081	66,699	0.1538
*R*2	Private label	Skim	0.1519	1,491,523	0.0867
*R*2	Private label	Whole	0.1531	822,826	0.0428
*R*3	*M*1	Skim	0.1990	205,707	0.2733
*R*3	*M*1	Whole	0.2023	80,666	0.1705
*R*3	*M*2	Skim	0.2172	92,922	0.2584
*R*3	*M*2	Whole	0.2232	32,192	0.0857
*R*3	Private label	Skim	0.1389	750,821	0.1904
*R*3	Private label	Whole	0.1385	342,957	0.1525
*R*4	*M*1	Skim	0.1813	264,706	0.0773
*R*4	*M*1	Whole	0.1844	122,519	0.0665
*R*4	*M*2	Skim	0.1998	156,358	0.0916
*R*4	*M*2	Whole	0.2031	72,514	0.0472
*R*4	Private label	Skim	0.1863	823,952	0.0822
*R*4	Private label	Whole	0.2028	460,306	0.0208
*R*5	*M*1	Skim	0.1742	325,595	0.3456
*R*5	*M*1	Whole	0.1830	137,733	0.1311
*R*5	*M*2	Skim	0.1944	126,199	0.2590
*R*5	*M*2	Whole	0.2027	51,180	0.0537
*R*5	Private label	Skim	0.1418	695,721	0.1218
*R*5	Private label	Whole	0.1405	353,775	0.0623

Note. Nonprice promotion refers to the percentage of volume sold on nonprice promotion.

Table 2 Descriptive Statistics for Input Prices

Variable	Mean	Std. dev.	Min	Max
FMMO_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

Notes. Variable definition and data sources:

FMMO_price: 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.
*M*1	−0.7232**	0.0770
*M*2	−0.8260**	0.0419
*R*1	−4.4236**	0.1817
*R*2	−2.8487**	0.2604
*R*3	−5.6761**	0.1569
*R*4	−5.5335**	0.1579
*R*5	−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
Nonprice 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
Nonprice promotion		
Std. dev.	0.1592	0.2174

*Significant at 5% level; **significant at 1% level.

prior literature has employed various ways of picking across games, we follow Nevo (2001) and compare the margins predicted by various models with external information on average margins at the retailer and manufacturer levels for a number of milk producers in the same geographical region as our data. We pick 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. We relegate the details to the electronic companion, providing only a brief summary here. The focus 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 different forms of manufacturer and retailer behavior. We find that 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, and (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 4 gives results for the supply cost regression for our best-fitting game. Note that the costs are in dollars per eight-ounce serving—for ease of discussion, we convert this to the more intuitive dollars per gallon (multiplying by 16 achieves the desired conversion). In brief, 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.

Table 4 Supply (Marginal Cost) Estimates

Variable	Coefficient	Std. err.
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		
FMMO_price	0.0123	0.0009
W_Market	−0.0004	0.0000
W_Milk	0.0000	0.0000
W_Grocery	0.0001	0.0000
Gasoline	0.0002	0.0000
E_C_MI	−0.0020	0.0002
E_I_MI	0.0004 n.s	0.0003
Interest rate 1	−0.0059	0.0005
Interest rate 2	0.0001 n.s	0.0005

Notes. All variables significant at 1% level, except those marked "n.s." 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, and (iii) both manufacturers and retailers practice account management; i.e., they separately maximize profits from NL and PL products. The estimates are in dollars per serving (which is eight ounces). Multiplying this by 16 gives costs in dollars per gallon.

5. What-If Analyses

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

(i) Can an NL firm profit from adding PL sales?

(ii) 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. We 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). We then calculate the share and profit for each product. Table 5 shows these calculations averaged over the 152-week observation period.[17]

5.2. What-If Scenario 1: No Private Labels in the Market

Table 6 presents equilibrium results with no private labels in the market. Comparing this to the base case (Table 5), we can conclude the following.

Total channel profits decline by about 57% when PL is withdrawn. Upstream profits decline by \$204,463, a 56% fall. This fall is mainly driven by $M1$, whose profits fall 62% as a result of 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 6 versus Table 5 confirms this—wholesale margins have increased (by about 1.5¢/gallon[18]), whereas retail margins have declined (by about 34.4¢/gallon). Turning to prices, NL wholesale prices decrease about 14.36¢/gallon, whereas 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 7 reports our results, which we compare to the base case in Table 5. 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 *can gain* by adding PL sales. Notice, however, that total upstream profits decline, driven mainly by $M1$'s fall in profits (\$89,418.50, an approximately 27% decline), which in turn is almost entirely due to a decline in profits from sales of PL products. This is clearly because we have moved toward greater competition in the supply of PL. Total downstream profits, on the other hand, increase by \$121,861.70 (a 15.4% rise), with every retailer gaining substantially except for $R1$. Total channel profits increase by \$63,127.20 (5.4%). To understand these profit changes, consider wholesale and retail price changes.

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 because 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 (because retail margins have actually declined); in fact, downstream volume of PL sold increases by almost 51% (this can be readily seen by comparing serving per person in Tables 5 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 gotten 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.

[17] As mentioned earlier, as a result of the change in $R1$'s supply arrangement in June 2000, we effectively have two distinct data periods—152 weeks from July 6, 1997 (week 1) to May 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.

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

Table 5 Base Case

Retailer							
Retailer	Brand	Product	Retail price ($/serving)	Margin ($/serving)	Serving/person	Profit ($/week)	Total profit ($/week)
*R*1	*M*1	Skim	0.2019	0.0971	0.1576	60,236.60	239,415.50
		Whole	0.2034	0.0965	0.0673	25,596.30	
	*M*2	Skim	0.1800	0.0820	0.0915	29,962.40	
		Whole	0.1839	0.0831	0.0457	15,126.40	
	PL	Skim	0.1770	0.0791	0.2418	76,270.90	
		Whole	0.1812	0.0805	0.1005	32,222.90	
*R*2	*M*1	Skim	0.1842	0.0846	0.0976	32,458.90	203,297.00
		Whole	0.1821	0.0813	0.0402	12,940.90	
	*M*2	Skim	0.1967	0.0861	0.0442	15,068.00	
		Whole	0.1983	0.0852	0.0179	6,027.60	
	PL	Skim	0.1473	0.0598	0.3905	91,741.80	
		Whole	0.1549	0.0627	0.1828	45,059.80	
*R*3	*M*1	Skim	0.1920	0.0606	0.0531	12,757.80	75,064.60
		Whole	0.1972	0.0623	0.0226	5576.80	
	*M*2	Skim	0.2076	0.0645	0.0242	6,221.90	
		Whole	0.2125	0.0660	0.0090	2,374.80	
	PL	Skim	0.1314	0.0440	0.1967	33,801.60	
		Whole	0.1402	0.0480	0.0760	14331.70	
*R*4	*M*1	Skim	0.1716	0.0790	0.0800	24,672.70	188,150.80
		Whole	0.1755	0.0795	0.0343	10,678.80	
	*M*2	Skim	0.1885	0.0836	0.0401	13,397.90	
		Whole	0.1950	0.0859	0.0171	5,884.90	
	PL	Skim	0.1574	0.0699	0.3036	84,341.50	
		Whole	0.1658	0.0736	0.1686	49,175.00	
*R*5	*M*1	Skim	0.1694	0.0522	0.0889	18,381.20	87,390.60
		Whole	0.1744	0.0539	0.0402	8,586.10	
	*M*2	Skim	0.1856	0.0567	0.0324	7,340.50	
		Whole	0.1906	0.0581	0.0139	3,223.20	
	PL	Skim	0.1304	0.0429	0.202	33,803.40	
		Whole	0.1389	0.0467	0.0881	16,056.20	

Manufacturer							
Manufacturer	Chain	Product	Wholesale price ($/serving)	Margin ($/serving)	Serving/person	Profit ($/week)	Total profit ($/week)
*M*1	*R*1	Skim	0.1048	0.0501	0.1576	31,089.60	117,616.80
		Whole	0.1069	0.0494	0.0673	13,107.60	
	*R*2	Skim	0.0996	0.0443	0.0976	17,018.00	
		Whole	0.1008	0.0427	0.0402	6,793.80	
	*R*3	Skim	0.1314	0.0405	0.0531	8,528.30	
		Whole	0.1350	0.0412	0.0226	3,687.80	
	*R*4	Skim	0.0926	0.0427	0.0800	13,331.50	
		Whole	0.0961	0.0433	0.0343	5,814.90	
	*R*5	Skim	0.1172	0.0355	0.0889	12,513.50	
		Whole	0.1205	0.0360	0.0402	5,731.80	
	PL	Skim	0.0875	0.0329	1.0928	141,273.70	211,794.10
		Whole	0.0922	0.0348	0.5157	70,520.40	
*M*2	*R*2	Skim	0.1106	0.0468	0.0442	8,184.30	35,148.00
		Whole	0.1131	0.0465	0.0179	3,288.00	
	*R*3	Skim	0.1430	0.0435	0.0242	4,193.90	
		Whole	0.1465	0.0442	0.0090	1,589.40	
	*R*4	Skim	0.1049	0.0463	0.0401	7,421.00	
		Whole	0.1091	0.0477	0.0171	3,268.70	
	*R*5	Skim	0.1290	0.0387	0.0324	5,018.40	
		Whole	0.1324	0.0394	0.0139	2,184.30	

Table 6 What-If Scenario 1: No Private Label Sales

Retailer							
Retailer	Brand	Product	Retail price ($/serving)	Margin ($/serving)	Serving/person	Profit ($/week)	Total profit ($/week)
*R*1	*M*1	Skim	0.2016	0.0968	0.1640	62,513.30	136,820.60
		Whole	0.2029	0.0961	0.0708	26,793.40	
	*M*2	Skim	0.1799	0.0819	0.0964	31,511.00	
		Whole	0.1838	0.0829	0.0484	16,002.90	
*R*2	*M*1	Skim	0.1841	0.0844	0.1024	33,995.70	70,215.80
		Whole	0.1823	0.0813	0.0426	13,712.00	
	*M*2	Skim	0.1969	0.0862	0.0470	16,024.80	
		Whole	0.1989	0.0855	0.0191	6,483.30	
*R*3	*M*1	Skim	0.1921	0.0606	0.0542	13,025.30	27,498.30
		Whole	0.1973	0.0623	0.0230	5,685.90	
	*M*2	Skim	0.2077	0.0646	0.0248	6,362.30	
		Whole	0.2126	0.0660	0.0092	2,424.80	
*R*4	*M*1	Skim	0.1711	0.0786	0.0863	26,462.40	59,071.70
		Whole	0.1750	0.0790	0.0376	11,661.30	
	*M*2	Skim	0.1883	0.0835	0.0434	14,493.50	
		Whole	0.1947	0.0857	0.0188	6,454.50	
*R*5	*M*1	Skim	0.1695	0.0523	0.0908	18,762.70	38,308.50
		Whole	0.1744	0.0540	0.0409	8,753.60	
	*M*2	Skim	0.1857	0.0567	0.0331	7,500.30	
		Whole	0.1906	0.0582	0.0142	3,288.90	

Manufacturer							
Manufacturer	Chain	Product	Wholesale price ($/serving)	Margin ($/serving)	Serving/person	Profit ($/week)	Total profit ($/week)
*M*1	*R*1	Skim	0.1047	0.0500	0.1640	32,303.40	122,936.80
		Whole	0.1068	0.0493	0.0708	13,742.00	
	*R*2	Skim	0.0996	0.0444	0.1024	17,873.60	
		Whole	0.1009	0.0428	0.0426	7,223.90	
	*R*3	Skim	0.1315	0.0405	0.0542	8,711.10	
		Whole	0.1350	0.0412	0.0230	3,760.70	
	*R*4	Skim	0.0925	0.0426	0.0863	14,339.40	
		Whole	0.0959	0.0431	0.0376	6,364.70	
	*R*5	Skim	0.1172	0.0356	0.0908	12,775.60	
		Whole	0.1205	0.0360	0.0409	5,842.40	
*M*2	*R*2	Skim	0.1107	0.0469	0.0470	8,721.50	37,158.40
		Whole	0.1134	0.0467	0.0191	3,543.30	
	*R*3	Skim	0.1431	0.0435	0.0248	4,289.10	
		Whole	0.1466	0.0442	0.0092	1,622.80	
	*R*4	Skim	0.1048	0.0463	0.0434	8,037.80	
		Whole	0.1090	0.0476	0.0188	3,587.60	
	*R*5	Skim	0.1290	0.0388	0.0331	5,127.70	
		Whole	0.1325	0.0394	0.0142	2,228.60	

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. Whereas 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—the extent to which the market is saturated and the degree of "closeness" between the two products. The higher each of these

Table 7 What-If Scenario 2: *M*2 Adds Private Label Sales

Retailer							
Retailer	Brand	Product	Retail price ($/serving)	Margin ($/serving)	Serving/person	Profit ($/week)	Total profit ($/week)
*R*1	*M*1	Skim	0.2020	0.0972	0.1566	59,878.70	236,816.30
		Whole	0.2035	0.0966	0.0667	25,399.10	
	*M*2	Skim	0.1800	0.0820	0.0907	29,706.50	
		Whole	0.1840	0.0831	0.0452	14,977.70	
	PL	Skim	0.1770	0.0791	0.2383	75,171.70	
		Whole	0.1812	0.0804	0.0988	31,682.60	
*R*2	*M*1	Skim	0.1844	0.0847	0.0965	32,162.30	247,345.60
		Whole	0.1822	0.0814	0.0397	12,785.80	
	*M*2	Skim	0.1968	0.0862	0.0436	14,883.00	
		Whole	0.1983	0.0852	0.0176	5,937.20	
	PL	Skim	0.1199	0.0480	0.6391	121,063.90	
		Whole	0.1247	0.0497	0.3085	60,513.40	
*R*3	*M*1	Skim	0.1921	0.0606	0.0525	12,614.50	97,022.90
		Whole	0.1973	0.0623	0.0223	5,518.00	
	*M*2	Skim	0.2076	0.0645	0.0239	6,147.70	
		Whole	0.2125	0.0660	0.0089	2,348.40	
	PL	Skim	0.1075	0.0356	0.3518	49,287.00	
		Whole	0.1133	0.0383	0.1396	21,107.30	
*R*4	*M*1	Skim	0.1718	0.0791	0.0788	24,356.60	223,250.30
		Whole	0.1757	0.0796	0.0337	10,500.50	
	*M*2	Skim	0.1886	0.0837	0.0395	13,201.40	
		Whole	0.1951	0.0860	0.0168	5,780.80	
	PL	Skim	0.1299	0.0580	0.4613	106,515.90	
		Whole	0.1355	0.0605	0.2619	62,895.10	
*R*5	*M*1	Skim	0.1694	0.0523	0.0879	18,168.50	110,745.10
		Whole	0.1744	0.0540	0.0397	8,492.50	
	*M*2	Skim	0.1856	0.0567	0.0320	7,253.30	
		Whole	0.1906	0.0581	0.0138	3,187.20	
	PL	Skim	0.1068	0.0349	0.3638	49,759.80	
		Whole	0.1124	0.0374	0.1629	23,883.80	
Manufacturer							
Manufacturer	Chain	Product	Wholesale price ($/serving)	Margin ($/serving)	Serving/person	Profit ($/week)	Total profit ($/week)
*M*1	*R*1	Skim	0.1048	0.0501	0.1566	30,896.20	116,432.50
		Whole	0.1070	0.0494	0.0667	13,000.90	
	*R*2	Skim	0.0996	0.0444	0.0965	16,854.30	
		Whole	0.1008	0.0427	0.0397	6,707.60	
	*R*3	Skim	0.1314	0.0405	0.0525	8,426.70	
		Whole	0.1350	0.0412	0.0223	3,647.10	
	*R*4	Skim	0.0927	0.0427	0.0788	13,152.70	
		Whole	0.0961	0.0433	0.0337	5,714.70	
	*R*5	Skim	0.1172	0.0355	0.0879	12,363.60	
		Whole	0.1205	0.0360	0.0397	5,668.70	
	PL	Skim	0.0719	0.0174	1.2133	83,218.70	123,559.90
		Whole	0.0750	0.0176	0.5807	40,341.20	
*M*2	*R*2	Skim	0.1106	0.0468	0.0436	8,080.30	34,669.00
		Whole	0.1131	0.0465	0.0176	3,237.30	
	*R*3	Skim	0.1430	0.0435	0.0239	4,142.40	
		Whole	0.1465	0.0442	0.0089	1,571.30	
	*R*4	Skim	0.1049	0.0463	0.0395	7,310.10	
		Whole	0.1091	0.0477	0.0168	3,210.20	
	*R*5	Skim	0.1290	0.0387	0.0320	4,957.70	
		Whole	0.1324	0.0394	0.0138	2,159.70	
	PL	Skim	0.0719	0.0088	0.6026	20,817.30	31,163.00
		Whole	0.0750	0.0090	0.2922	10,345.70	

factors, the greater 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.[19]

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.

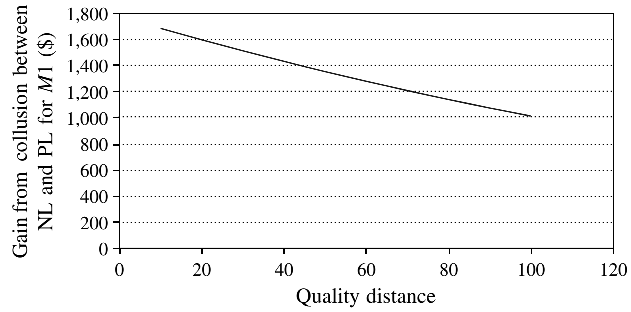
5.4. What-If Scenario 3: Vertically Integrated vs. Vertically Separated PL Supply

To begin, 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 $R5$, namely, 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 8. As before, we compare these outcomes to the base case in Table 5. 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, its 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

[19] As pointed out by an anonymous reviewer, the degree of substitution between products really depends on the correlation between them induced by the estimated heterogeneity parameters. Our discussion should be viewed as an illustrative calculation of the approximate magnitude of the strategic effect.

Figure 2 ***M*1's Gains from Jointly Pricing NL and PL**



Notes. 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, and 0 implies that the two products have the same brand preference parameters.

two sources. First, because $M1$ 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, whereas $M2$'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 vs. 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, because 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, because 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 postdivestiture 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

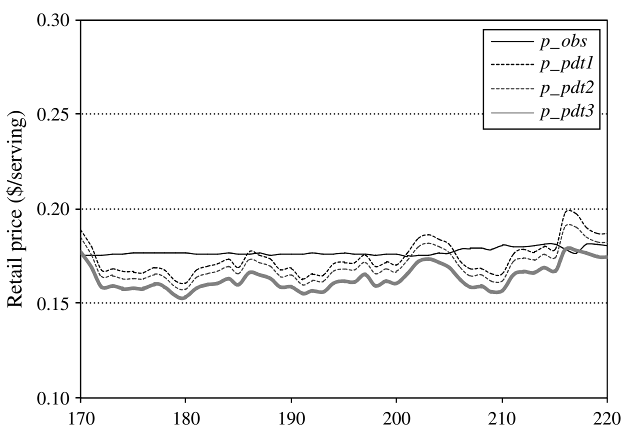
Table 8 What-If Scenario 3: $R1$ Divests Vertically Integrated Facility

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	60,692.30	183,297.20
		Whole	0.2034	0.0965	0.0679	25,804.00	
	$M2$	Skim	0.3316	0.1517	0.0242	14,633.10	
		Whole	0.3358	0.1524	0.0122	7,386.70	
	PL	Skim	0.2403	0.1074	0.1231	52,559.30	
		Whole	0.2449	0.1087	0.0514	22,221.80	
$R2$	$M1$	Skim	0.1843	0.0846	0.0982	32,695.00	201,348.00
		Whole	0.1822	0.0814	0.0405	13,041.20	
	$M2$	Skim	0.1971	0.0863	0.0444	15,179.90	
		Whole	0.1987	0.0854	0.0180	6,074.60	
	PL	Skim	0.1511	0.0615	0.3703	89,378.90	
		Whole	0.1561	0.0633	0.1809	44,978.40	
$R3$	$M1$	Skim	0.1921	0.0606	0.0532	12,773.80	73,416.00
		Whole	0.1973	0.0623	0.0226	5,582.90	
	$M2$	Skim	0.2076	0.0645	0.0243	6,228.30	
		Whole	0.2125	0.0660	0.0091	2,377.10	
	PL	Skim	0.1347	0.0451	0.1833	32,298.60	
		Whole	0.1413	0.0484	0.0746	14,155.30	
$R4$	$M1$	Skim	0.1716	0.0790	0.0808	24,915.00	187,462.60
		Whole	0.1755	0.0795	0.0346	10,794.10	
	$M2$	Skim	0.1888	0.0838	0.0404	13,531.40	
		Whole	0.1953	0.0860	0.0173	5,946.90	
	PL	Skim	0.1612	0.0716	0.2915	82,905.00	
		Whole	0.1670	0.0742	0.1681	49,370.20	
$R5$	$M1$	Skim	0.1694	0.0522	0.0890	18,401.10	85,704.40
		Whole	0.1744	0.0539	0.0402	8,594.70	
	$M2$	Skim	0.1856	0.0567	0.0325	7,347.60	
		Whole	0.1906	0.0581	0.0139	3,226.00	
	PL	Skim	0.1336	0.0441	0.1882	32,276.60	
		Whole	0.1400	0.0471	0.0865	15,858.40	

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	31,326.70	118,374.70
		Whole	0.1069	0.0494	0.0679	13,213.00	
	$R2$	Skim	0.0996	0.0444	0.0982	17,147.10	
		Whole	0.1008	0.0427	0.0405	6,848.40	
	$R3$	Skim	0.1315	0.0405	0.0532	8,538.10	
		Whole	0.1350	0.0412	0.0226	3,691.50	
	$R4$	Skim	0.0926	0.0427	0.0808	13,466.90	
		Whole	0.0961	0.0433	0.0346	5,879.30	
	$R5$	Skim	0.1172	0.0355	0.0890	12,526.30	
		Whole	0.1205	0.0360	0.0402	5,737.40	
	PL	Skim	0.0982	0.0350	1.1566	158,960.80	237,230.30
		Whole	0.1015	0.0355	0.5616	78,269.50	
$M2$	$R1$	Skim	0.1798	0.0818	0.0242	7,889.60	47,295.10
		Whole	0.1834	0.0825	0.0122	4,001.30	
	$R2$	Skim	0.1108	0.0470	0.0444	8,262.40	
		Whole	0.1133	0.0467	0.0180	3,319.90	
	$R3$	Skim	0.1431	0.0435	0.0243	4,198.30	
		Whole	0.1466	0.0442	0.0091	1,590.90	
	$R4$	Skim	0.1051	0.0465	0.0404	7,513.10	
		Whole	0.1093	0.0479	0.0173	3,310.00	
	$R5$	Skim	0.1290	0.0387	0.0325	5,023.30	
		Whole	0.1325	0.0394	0.0139	2,186.30	

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 (and hence how well our model reflects the new set of vertical interactions). Comparing actual prices to those predicted by our model versus a model that 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 (MSE) error criterion. Note, however, that our model predicts a much higher variation in prices than that actually observed. Interestingly, the actual variation in prices (in the raw data) is much higher predivestiture than post. This suggests that there are other changes that have taken place, postdivestiture, that are not in our model. To the extent that the predictions of our model are better than those of the alternatives, we can say that (i) the principal assumption underpinning our model still holds, i.e., that PL products are homogenous upstream and differentiated downstream; and (ii) our model captures the vertical structure postdivestiture reasonably well.

Figure 3 Comparing Predicted with Observed Prices (PL Only)



Notes. All prices are for PL milk, aggregated across chains. *p_obs:* Observed prices. *p_pdt1*: Predicted prices using proposed model (MSE = 0.00008). *p_pdt2*: Predicted prices using a model assuming PLs are differentiated at the wholesale level (MSE = 0.00011). *p_pdt3*: Predicted prices using proposed model without taking into consideration the vertical divestiture (MSE = 0.00023).

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 with 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 and 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. 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 antitrust authorities because it provides a methodology to analyze vertical structure changes that reshape competition between national labels and private labels. For instance, the government argued in an recent amicus brief that the Supreme Court should not review a circuit court decision[20] that joint pricing of NL and PL products constituted exclusionary conduct in the transparent tape market. On this point, the utility of our model is quite clear. Contrary to the circuit court 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, this paper suffers from a number of limitations that offer directions for future research. To start, it would be useful to replicate our analysis in other categories where PL penetration is much lower, changing the magnitude of the incentives facing upstream and downstream agents. 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. Although 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-up 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 nonlinear 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.[21]

7. Electronic Companion

An electronic companion to this paper is available as part of the online version that can be found at http://mktsci.pubs.informs.org/.

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

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

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