Wholesale Price Discrimination: Inference and Simulation*

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ABSTRACT

In this paper we demonstrate a method for making inferences about wholesale price discrimination. This is an important question when there is a policy goal to enforce uniform wholesale price legislation in a variety of markets. We also present a useful procedure to simulate the effects of such uniform wholesale price legislations in the markets. Given a demand and supply model of multiple retailers' and manufacturers' oligopoly-pricing behavior we consider: (i) wholesale price discrimination and (ii) no wholesale price discrimination (via uniform price regulation). We demonstrate how non-nested testing procedures may be used to set up the wholesale price discrimination model specification tests. Finally we indicate how wholesale price legislation simulations may be performed given observed data on retail and input prices and retail quantities sold and not available data on wholesale prices. We illustrate this approach using data on yogurt produced by multiple manufacturers and sold in several stores in a large urban area of the United States, and estimate there to be positive welfare effects from preventing wholesale price discrimination, originating from positive effects on consumer surplus although negligible effects on producer surplus.

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1. Introduction

When price discrimination is allowed, and even enhanced by legislation in the markets, wholesalers will set different prices for the same product if sold to different downstream markets. In particular, a lower price is set in more price sensitive markets and a higher price charged in low price sensitive markets. Economic theory (as in Schmalensee (1981), Varian (1985), Katz (1987) and Ireland (1992)) predicts that, under certain circumstances, retail prices under uniform wholesale price may actually increase relative to the average retail price under price discrimination. In general, whether uniform wholesale pricing leads to higher retail prices and hence to lower welfare is ambiguous and remains an empirical question (see Sole (2001) for a survey). This question is of policy relevance in a variety of markets, such as gasoline[1] and dairy milk markets[2]. In this context this paper provides useful methodological tools relating to the general question of the welfare effects of eliminating wholesale price discrimination in these markets.

In terms of methodology, the first step is to start with the demand side of the market and incorporate multiple manufacturers and retail oligopoly behavior into structural supply side econometric models of sequential vertical-pricing games (as in Brenkers and Verboven, 2004, Goldberg and Verboven 2001, Sudhir, 2001, Mortimer 2002, Villas-Boas and Zhao 2004, Villas-Boas 2005, and Villas-Boas and Hellerstein 2006), but adding two benchmark models to the previous literature: (i) of wholesale price discrimination occuring and (ii) of wholesale price discrimination not occuring. As a second step we outline a testing procedure among the two benchmark models, and in the final and third step we illustrate how one would explicitly simulate uniform wholesale price implementation in the markets, and infer the welfare effects of such legislation given unobservable data on wholesale prices.

To access the fit of the two different benchmark models non-nested testing procedures developed by Smith (1992) are used . In particular we describe how to extend vertical inference under unobserved data on wholesale prices, as presented in Villas-Boas (2005), and set up the wholesale price

[1] A recent debate centers on the fair/uniform wholesale price legislation in retail gasoline industry. See for example in the state of New York, the New York State Motor Fuel Marketing Practices Act (MFMPA) that went into effect last April 2004.

[2] Although the dairy program has undergone several changes (for a survey see Manchester and Blayney, 2001) one of the two main components is the Federal Milk Marketing Order (FMMO), a legal instrument where milk is classified according to use, and minimum prices that processors are required to pay according to use are established. Milk sold to downstream processors of fluid milk, is called Class 1. Class 2 milk is sold to soft manufactured products such as yogurt and ice cream and Class 3 is sold to hard manufactured products such as cheese, butter and powdered milk. The marketing orders set Class 1 price and Class 2 price at given differentials to the lower Class 3 price. The higher wholesale price is charged in the low price sensitive Class 1 fluid milk market and is passed through to retail price to final consumers.

discrimination model specification tests. In terms of policy simulations we start with the benchmark case of no wholesale price discrimination and given demand and supply behavior subject to single wholesale price legislation, we simulate the resulting retail equilibrium prices, again assuming that researchers do not observe data on wholesale prices.

The rest of the paper proceeds as follows. In the next section we introduce the demand and supply economic and econometric models, and derive the equilibrium under the possibility of either wholesale price discrimination or no wholesale price discrimination. In section 3 we set up the inference and policy simulation procedure for uniform wholesale price legislation subject to the lack of observable wholesale price data. In section 4 we illustrate the proposed simple inference and simulation steps with an empirical application using data on yogurt produced by multiple manufacturers and sold in several stores in a large urban area of the United States. Finally, section 5 concludes.

2. The Model

The economic-econometric model for this study is a standard discrete choice demand formulation (see, e.g., McFadden 1984, Berry, 1994, Berry, Levinsohn and Pakes, 1995 and Nevo, 2001) and different alternative models of vertical relationships between manufacturers and retailers. The price-cost margins for the retailers and manufacturers are expressed for each supply model solely as functions of demand substitution patterns. Due to data-set limitations, we do not have wholesale prices or separate data on wholesale and retail costs. This section derives expressions for the total sum of retail and manufacturer price-cost margins as functions of demand substitution patterns for the alternative supply models specified.

2.1. Demand Side

Assume the consumer chooses in each period t among N_t different products sold by several retailers. We define a certain product at the retail-manufacturer level. For example, if product A is sold at retailers 1 and 2 we consider there to be at the consumer level two products, $n = A1, A2$, to chose from. Using the typical notation for discrete choice models of demand, the indirect latent utility of consumer i from buying product j during week t is given by

$$u_{ijt} = d_j + d_t + x_{jt}\beta_i - \alpha_i p_{jt} + \xi_{jt} + \epsilon_{ijt} \tag{1}$$

where d_j represents product (brand-store) fixed effects capturing time invariant product characteristics, d_t are seasonal dummies capturing seasonal unobserved determinants of demand, x_{jt} are the observed product characteristics, p_{jt} is the price of product j, ξ_{jt} identifies the mean across consumers of unobserved (by the econometrician) changes in product characteristics[3] and ϵ_{ijt} represents the distribution of consumer preferences about this mean. The random coefficients β_i are unknown consumer taste parameters for the different product characteristics, and the term α_i represents the marginal disutility of price. These taste parameters are allowed to vary across consumers according to

$$[\alpha_i, \beta_i]' = [\alpha, \beta]' + \Gamma \ D_i + \Upsilon \ v_i \tag{2}$$

where the variable D_i represents observed consumer characteristics such as demographics, while unobserved consumer characteristics are contained in by v_i. The parameters α and β are the mean of the random coefficients described above. The matrix of non-linear demand parameters Γ captures the observed heterogeneity, deviations from the mean in the population of the taste parameters and marginal utility of price due to demographic characteristics D_i. The matrix Υ captures the unobservable heterogeneity due to random shocks v_i.

In the econometric model, unobserved random consumer characteristics v_i are assumed to be normally distributed, and the observed consumer characteristics D_i have an empirical distribution $\hat{\mathrm{F}}(\mathrm{D})$ from the demographic data. Additionally, an outside good is included in the model, allowing for the possibility of consumer i not buying one of the N_t marketed goods. Its price is not set in response to the prices of the other N_t products. In the outside good we include products sold by smaller retail stores or grocery stores not considered in the analysis. The mean utility of the outside good, δ_{0t}, is normalized to be constant over time and equal to zero. The measure M of the market size is assumed proportional to the population in areas where the retailers are located. The observed market share of product j is given by $s_j = q_j/M$, where q_j are the units sold.

Assuming that consumers purchase one unit of that product among all the possible products available at a certain time t that maximizes their indirect utility then the market share of product j during week t is given by the probability that good j is chosen, that is,

$$s_{jt} = \int_{[(D_i, v_i, \epsilon_{it}) | u_{ijt} \geq u_{iht} \ \forall \ h=0,\dots N_t]} dF(\epsilon) \ dF(v) \ dF(D). \tag{3}$$

If both D and v are fixed and consumer heterogeneity enters only through the random shock where ϵ_{ijt} is distributed i.i.d. with an extreme value type I density, then (3) becomes the Multinomial Logit

[3] In particular, ξ_{jt} includes the (not-seasonal) changes in unobserved product characteristics such as unobserved promotions, changes in shelf display and changes in unobserved consumer preferences.

model. If we assume that ϵ_{ijt} is distributed i.i.d. extreme value and allow consumer heterogeneity to affect the taste parameters for the different product characteristics, this corresponds to the full random coefficients model or mixed Logit model.[4]

2.2. Supply Side

On the supply side let us assume the standard linear pricing model in which M manufacturers set wholesale prices p^w and R retailers follow setting retail prices p. Let retailers' marginal costs be constant and given by $c^r = \beta_r + \gamma_r W_r$, and let manufacturers' marginal cost be constant and given by $c^w = \beta_w + \gamma_w W_w$, where W are cost determinants and β and γ are parameters. We consider two benchmarks: (2.2.1) In the first, and following the example from above, manufacturer A is allowed to set, if he wishes to do so, two different wholesale prices for the same product sold through the two different retailers (that is p^w_{A1} may be chosen to be different from p^w_{A2}); (2.2.2) in the uniform wholesale price model the manufacturer is constrained to set the same wholesale price for product A sold at any retailer (that is p^w_{A1}=p^w_{A2}).

2.2.1. No Uniform Wholesale Pricing

Assume each retailer maximizes his profit function:

$$\pi_r = \sum_{j \epsilon S_r} \left[p_j - p_j^w - c_j^r \right] q_j(p) \quad \text{for} \quad r = 1, ...R. \tag{4}$$

where S_r is the set of products sold by retailer r. The first-order conditions, assuming a pure-strategy Nash equilibrium in retail prices, are:

$$q_j + \sum_{m \epsilon S_r} T_r(m,j) \left[p_m - p_m^w - c_m^r \right] \frac{\partial q_m}{\partial p_j} = 0 \quad \text{for} \quad j = 1, ...N \tag{5}$$

where matrix T_r has the general element $T_r(i,j) = 1$, if the retailer sells both products i and j and equal to zero otherwise. Switching to matrix notation, let us define $[A * B]$ as the element-by-element multiplication of two matrices of the same dimensions A and B. Let Δ_r be a matrix with general element $\Delta_r(i,j) = \frac{\partial q_j}{\partial p_i}$, containing retail level demand substitution patterns with respect to changes in the retail prices of all products. Solving (5) for the price-cost margins for all products

[4]This is a very general model. As shown in McFadden and Train (2000), any discrete choice model derived from random utility maximization can be approximated, with any degree of accuracy, to a Mixed Logit.

in vector notation gives the price-cost margins m_r for the retailers under Nash-Bertrand pricing:

$$\underbrace{p - p^w - c^r}_{m^r} = -[T_r * \Delta_r]^{-1} q(p), \tag{6}$$

which is a system of N implicit functions that expresses the N retail prices as functions of the wholesale prices. If retailers behave as Nash-Bertrand players then equation (6) describes their supply relation.

Manufacturers choose wholesale prices p^w to maximize their profits given by

$$\pi_{wt} = \sum_{j \epsilon S_{wt}} [p^w_{jt} - c^w_{jt}] \ s_{jt}(p(p^w)), \tag{7}$$

where S_{wt} is the set of products sold by manufacturer w during week t and c^w_{jt} is the marginal cost of the manufacturer that produces product j, and knowing that retailers behave according to (6). Solving for the first-order conditions from the manufacturers' profit-maximization problem, assuming again a pure-strategy Nash equilibrium in wholesale prices and using matrix notation, yields:

$$\underbrace{(p^w - c^w)}_{m^w} = -[T_w * \Delta_w]^{-1} q(p), \tag{8}$$

where T_w is a matrix with general element $T_w(i,j) = 1$, if the manufacturer sells both products i and j and equal to zero otherwise, Δ_w is a matrix with general element $\Delta_w(i,j) = \frac{\partial q_j}{\partial p^w_i}$ containing changes in demand for all products when wholesale prices change subject to retail mark-up pricing behavior assumed in (6), and $*$ represents the element-by-element multiplication of both matrices.

To obtain Δ_w, first note that $\Delta_w = \Delta'_p \Delta_r$, where Δ_p is a matrix of derivatives of all retail prices with respect to all wholesale prices. To get the expression for Δ_p, we start by totally differentiating for a given j equation (5) with respect to all retail prices ($dp_k, k = 1, \cdots, N$) and with respect to a single wholesale price p^w_f, with variation dp^w_f:

$$\sum_{k=1}^{N} \underbrace{[\frac{\partial q_j}{\partial p_k} + \sum_{i=1}^{N} (T_r(i,j) \frac{\partial^2 q_i}{\partial p_j \partial p_k}(p_i - p^w_i - c^r_i)) + T_r(k,j) \frac{\partial q_k}{\partial p_j}]}_{g(j,k)} \ dp_k \ - \ \underbrace{T_r(f,j) \frac{\partial q_f}{\partial p_j}}_{H(j,f)} dp^w_f = 0. \tag{9}$$

Putting all $j = 1,...N$ products together, let G be a matrix with general element $g(j,k)$ and let H_f be an N-dimensional vector with general element $H(j,f)$, as defined in equation (9). Then $G \ dp - H_f \ dp^w_f = 0$. Solving for the derivatives of all retail prices with respect to the wholesale price p_f^w, the f-th column of Δ_p is obtained:

$$\frac{dp}{dp_f^w} = G^{-1} H_f. \tag{10}$$

Stacking all N columns together, $\Delta_p = G^{-1} H$ reflects the derivatives of all retail prices with respect to all wholesale prices. The general element of Δ_p is $(i, j) = \frac{\partial p_i}{\partial p_j^w}$.

2.3. Uniform Wholesale Pricing

Define a N_U by N matrix U that has as many rows, as many different manufactured products (N_U) and has N columns equal to the retail level products, and which element $U(i, j) = 1$ if product i is the same manufactured product as product j and is equal to zero otherwise.

For example, assume three products,$A1$, $A2$ and $B1$, at the consumer level where the first two are produced by manufacturer A and are the same product and product B is sold at retailer 1 and produced by manufacturer B. The matrix U that describes which manufactured products are in fact the same, for the three sets of products above, is a 2 by 3 matrix $U = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$. Following this simple example each of the two retailers, 1 and 2 maximizes the profit function $\pi_1 = [p_{A1} - p_A^w - c_{A1}^r]\, q_{A1}(p) + [p_{B1} - p_B^w - c_{B1}^r]\, q_{B1}(p)$ and $\pi_2 = [p_{A2} - p_A^w - c_{A2}^r]\, q_{A2}(p)$, respectively. Note that the wholesale price for A is the same for both retailers. Solving for optimal price cost margins yields a system that implicitly defines three retail prices as a function of two wholesale prices.

Generally, retailers maximize their profits as given by equation (4) but now the same wholesale price is charged for the same manufactured products regardless of retail outlet. If retailers behave as Nash-Bertrand players then the price-cost margins for all products in vector notation m_r are as in (6) describing retail supply relation.

Manufacturers choose wholesale prices p^w to maximize their profits in (7) knowing that retailers behave according to (6) and subject to U. Manufacturers now only get to choose wholesale prices for N_U products since some manufactured products sold through different retailers are the same and therefore need to be set the same wholesale price.

For example, in the simple example manufacturers maximize their profits with respect to only 2 wholesale prices, respectively, $\pi_A = [p_A^w - c_A^w]\, [q_{A1}(p(p_A^w, p_{B1}^w)) + q_{A2}(p(p_A^w, p_{B1}^w))]$ and $\pi_B = [p_{B1}^w - c_B^w]\, q_{B1}(p(p_A^w, p_{B1}^w))$.

Lets derive now, for the general case, the mark-ups keeping the notation as in the no uniform wholesale price model. Solving for the first-order conditions from the manufacturers' profit-maximization problem, assuming again a pure-strategy Nash equilibrium in wholesale prices and using matrix notation, yields:

$$\underbrace{(p^w - c^w)}_{m_U^w} = -\underbrace{\left[\left(\underbrace{T_w^{Up}}_{N_U \text{ by } N} * \underbrace{\Delta_w^{Up}}_{N_U \text{ by } N}\right) \underbrace{U'}_{N \text{ by } N_U}\right]^{-1}}_{(N_U \text{ by } N_U)} \underbrace{[U\ q(p)]}_{(N_U \text{ by } 1)}, \tag{11}$$

where U is the (N_U by N) matrix defined above, T_w^{Up} and Δ_w^{Up} are (N_U by N) matrices to be derived next, and $*$ represents the element-by-element multiplication of both matrices. What gets to be inverted is the (N_U by N_U) full rank matrix due to uniform wholesale pricing. Note that the derived wholesale mark-ups are denoted by the (N_U by 1) vector m_U^w and that $N - N_U$ products share the same wholesale prices and mark-ups due to uniform wholesale pricing restrictions. If manufacturers behave as Nash-Bertrand players subject to uniform wholesale pricing restrictions then equation (11) describes their supply relation.

To obtain Δ_w^{Up}, first note that $\Delta_w^{Up} = \underbrace{(\Delta_p^{Up})'}_{(N_U \text{ by } N)} \Delta_r$, where Δ_p^{Up} is a matrix of derivatives of all retail prices with respect to all the N_U independent wholesale prices. To get the expression for $\Delta_p^{N_U}$, we start by totally differentiating for a given j equation (5) with respect to all retail prices ($dp_k, k = 1, \cdots, N$) and with respect to a single wholesale price p_f^w, with variation dp_f^w obtaining (9). Putting all $j = 1,...N$ products together, let G be the matrix with general element $g(j,k)$ and let H_f be an N-dimensional vector with general element $H(j,f)$, as defined in equation (9). Note now that we will consider across these equations that $N - N_U$ wholesale price variations are not independent. In terms of matrix notation, when we solve for the derivatives of all retail prices with respect to the wholesale price p_f^w, the f-th column of Δ_p^{Up} is obtained as:

$$\frac{dp}{dp_f^w} = G^{-1} \underbrace{[H_j + ... + H_k]}_{H_f^{Up}}, \text{ where } j, ..., k = f, \text{ are restricted to be the same in } U. \tag{12}$$

Stacking all $N - N_U$ independent-wholesale-price-corresponding columns together, $\Delta_p^{Up} = G^{-1}H^{Up}$ reflects the derivatives of all N retail prices with respect to the N_U wholesale prices, where the general element of Δ_p^{Up} is $(i,j) = \frac{\partial p_i}{\partial p_j^w}$.

For the simple example, (11) corresponds to $\begin{bmatrix} m_A^w \\ m_{B1}^w \end{bmatrix} = - \begin{bmatrix} \frac{\partial(q_{A1}+q_{A2})}{\partial p_A^w} & 0 \\ 0 & \frac{\partial q_{B1}}{\partial p_{B1}^w} \end{bmatrix}^{-1} \begin{bmatrix} q_{A1}+q_{A2} \\ q_{B1} \end{bmatrix}$ where $\frac{\partial q_i}{\partial p_f^w} = \sum_k (\frac{\partial(q_i}{\partial p_k} \frac{\partial p_k}{\partial p_f^w})$, $k = A1, A2, B1$, and now Δ_p^{Up} is (3 by 2) and gives the responses of the three retail prices with respect to changes in the two upstream wholesale prices, which is constructed from totally differentiating the system of three first order conditions (for the three retail prices) of the two retailers, subject to common wholesale price for the products $A1$ and $A2$.

3. Simulation of Uniform Wholesale Pricing Policy

There are no general theoretical predictions of price (see Thisse and Vives, 1988 and Corts, 1998), profits, consumer surplus and welfare effects resulting from uniform pricing: profits may increase (Holmes, 1989) or decrease if competition becomes more intense ex-post (Armstrong and Vickers, 2001) in the theory models.

Given demand and assuming the model of no uniform pricing (derived in 2.2.1) as starting point, where retail and manufacturer mark-ups are given by (6) and (8), respectively, we recover the marginal costs under such model by

$$\underbrace{c^w + c^r}_{\hat{c}_{2.1}} \;=\; p \;-\Big[\;-[T_r * \Delta_r]^{-1} q(p) - [T_w * \Delta_w]^{-1} q(p)\Big]. \tag{13}$$

Note that we recover the sum or retail and manufacturer marginal costs in (13) without the need to observe wholesale prices, once we have estimated demand (as in Villas-Boas, 2005 and Villas-Boas and Hellerstein, 2006). Then we simulate the equilibrium (N by 1) vector of retail prices under uniform wholesale pricing restrictions as the prices that solve

$$p^* = \hat{c_{2.1}} - (T_r * \Delta_r)^{-1} q(p^*) - \underbrace{[\,(T_w^{Up} * \Delta_w^{Up*})U']^{-1}[U\; q(p^*)]}_{N \text{ by } 1}, \tag{14}$$

again without the need to observe wholesale prices. Note that we expand the wholesale mark-ups under uniform pricing from the (N_U by 1) vector in (11) to the retail level (N by 1) vector of wholesale mark-ups when simulating the retail prices for all products.

We access the changes in the welfare components (consumers', manufacturers' and retailers' surplus) resulting from the changes of the simulated counterfactual equilibrium prices p^* after uniform wholesale pricing from the observed equilibrium prices p with no uniform wholesale pricing. Given the demand model utility maximization primitives, expected consumer i's surplus (Small and Rosen 1981) is defined as $E\left[CS_i\right] = \frac{1}{|\alpha_i|}E\left[max_j(u_{ij}(p)\forall j)\right]$, where α_i denotes the marginal utility of income in (1) that is assumed to remain constant for each household. Given the extreme value distributional assumptions and linear utility formulation, the change in consumer surplus for individual i is computed as

$$\Delta E\left[CS_i\right] = \frac{1}{|\alpha_i|}\left[ln\left(\sum_{j=1}^{N} e^{d_j + x_j\beta_i - \alpha_i p_j^*}\right) - ln\left(\sum_{j=1}^{N} e^{d_j + x_j\beta_i - \alpha_i p_j}\right)\right]. \tag{15}$$

This measure of consumer valuation is computed using the estimated demand model parameters and the simulated counterfactual retail equilibrium prices. Total change in consumer surplus is obtained by averaging this over the individuals. The change in the sum (given that we do not observe wholesale prices) of manufacturers' and retailers' producer surplus is given by

$$\Delta E\left[PS\right] = \left[\sum_{j=1}^{N}\left(\pi_j^r\left(p^*\right) + \pi_j^w\left(p^*\right)\right) - \sum_{j=1}^{N}\left(\pi_j^r\left(p\right) + \pi_j^w\left(p\right)\right)\right]. \tag{16}$$

where we assume that manufacturer and retailer marginal costs remain unchanged. The change in total welfare is the sum of total change in consumer surplus, manufacturers' producer surplus and retailers' producer surplus.

4. Empirical Application to The Yogurt Market

4.1. The Data

The empirical illustration is based on a weekly data set on retail prices, aggregate market shares and product characteristics for 43 products produced by five manufacturers sold at three retailers. Table 1 describes the products considered in the analysis and please note that there although there are 43 products at the retail-consumer level, $N = 43$, there are twenty one $N_U = 21$ products at the manufacturer level (for example products number two and three in Table 1 are the same, Dannon Light Vanilla Yogurt), some sold through different retailers and thus creating the choice set for consumers equal to forty three products. For a more detailed description of the data, for details on the definition of the variables and data sources see Villas-Boas (2005). The price, advertising and market share data come from an Information Resources Inc. (IRI) scanner data set that covers the purchases in three retail stores in a Midwestern urban area during 104 weeks. Summary statistics for prices, quantity sold and shares are presented in Table 2. The combined shares for the products analyzed are on average 34 percent. Quantity sold is defined as servings sold, where one serving corresponds to a 6-ounce yogurt cup. Dannon ranks first in terms of local market shares of its products with an average of 17 percent. General Mills is second in terms of local market share with 9 percent. The private labels is third with 4 percent, and Kraft comes last among the products analyzed with 3 percent. The above IRI data-set is complemented with data on product characteristics, consumer demographics and costs, described in Villas-Boas (2005).

4.2. Demand Estimation and Results

We estimate the demand parameters, where the individual choice probabilities are given by (3). The demand system contains the common (across consumers) valuation terms for each product j, where ξ_j is the error term representing unobserved product characteristics. Following Berry (1994) and Berry, Levinsohn and Pakes (1995) we set observed market shares equal to predicted market shares and solve the error term ξ_j as a function of the parameters and the data. In the mixed logit model an analytic solution is not available, because consumers are heterogeneous regarding the price and other product characteristics' parameters. The numerical solution uses the contraction mapping suggested by Berry (1994), Berry, Levinsohn and Pakes (1995) and Nevo (2001).

The analysis that follows relies heavily on having consistently estimated demand parameters or, alternatively, demand substitution patterns. The exogenous variation that identifies these substitution patterns is obtained from the relative price variation over time, by observing consumers's choices between different products over time (where a product is perceived as a bundle of attributes among which are prices). Since prices are not randomly assigned, we use manufacturer and retail level input price changes over time that are significant and exogenous to unobserved changes in product characteristics to instrument for prices. We interact the error term ξ_j with a set of instruments to obtain a GMM estimator.

The demand model estimates are presented in Table 3. The first stage R-squared and F-Statistic are high suggesting that the instruments used are important in order to consistently estimate demand parameters. Consumer heterogeneity is investigated by allowing the coefficients on price, store dummy variables and product characteristics to vary across consumers as a function of their income, age and other unobserved consumer characteristics. All the demographic variables that interact with prices and product characteristics are expressed as deviations from the mean. Generalized Method of Moments estimates of the random coefficient specification that allows log of income and age to influence the price coefficient are presented. It appears that age and income do not significantly affect the mean price sensitivity. However, unobservable characteristics in the population seem to affect it significantly. The coefficients associated with the store dummies are interpreted relative to the smaller store one. Unobservable characteristics in the population do not seem to explain why people choose stores two and three over store one. In fact, the positive and significant coefficient associated to the interaction between the store two dummy and age of the population suggests that older people significantly prefer store two over store one. One other possibility is that older people live closer to store two than store one since this model does not control for store distance. The preferences for the larger store two decreases and for store three rises with an increase in income. Perhaps this is due to the location of higher income population around store one. For the average consumer, calories have a negative marginal utility, and calcium content has a positive marginal utility. The estimates for the interactions of demographics with the constant term (that captures consumers' valuation for the outside option) suggest that unobserved characteristics in the population explain significantly and positively how likely or unlikely a consumer is to buy other yogurt not included in the sample.

4.3. Supply Estimation and Results

The demand estimates are used to compute the implied estimated substitution patterns, which in turn are combined with the model of retail and manufacturer behavior to estimate the retail and wholesale margins. In Table 4 the summary statistics for the estimated margins are presented under the models of no uniform wholesale pricing (2.2.1) and of uniform wholesale pricing (2.2.2). Based on the demand estimates and the specification of retail and manufacturer oligopoly pricing with and without uniform wholesale pricing restrictions we recover the sum of retail and manufacturer marginal costs of all products for both models. In uniform pricing model, the average estimated wholesale margins decrease slightly and are less variable than in the model without uniform wholesale pricing. Breaking up the supply estimates by retailers and by manufacturers, and comparing those across both models the conclusions generally appear plausible and conform to intuition. For example, private labels are not significantly affected while national brand manufacturers selling to multiple retailers are (e.g. Dannon), when wholesale price restrictions are in place. Private labels do have no first order impact of such restrictions due to not selling to multiple retailers, and in this empirical application second order effects are very small according to the estimated results.

Looking at the average recovered costs these are larger on average in the uniform wholesale pricing model, which also means that total vertical margins are smaller in the uniform wholesale pricing model overall. In table 4 we further break up the recovered average mark-ups by brands (manufacturers) and across retailers. Yogurt sold in retailer 1 consists of yogurt only from national brands (affected by uniform pricing), and therefore we expect the products to be all affected by the wholesale price restrictions. In fact, it interesting to see that retailer 1's recovered costs is the one that exhibits larger changes when comparing both models, increasing in the uniform wholesale pricing model, which means that total margins decrease on average for retailer 1. For retailers 2 and 3, selling both national and private label brands, they exhibit smaller changes in average recovered marginal costs.

Finally, comparing the column of standard deviations (across brands and time) in Table 4, interestingly and reasonably, in the uniform wholesale pricing case the margins are less variable than in the non uniform wholesale pricing case.

4.4. Inference on Wholesale Pricing Practices and Policy Simulations

Given demand and subsequent supply model estimates, we perform the pair-wise comparison of the models with and without uniform wholesale pricing (see appendix) and conclude that the model of uniform wholesale pricing outperforms the alternative model of no uniform wholesale pricing at any significance level (test estimate of 3.51, versus standard normal critical values of one sided test) and escapes rejection from that alternative model at less than the 5 percent level (test estimate of 2.18).

Next we present estimated effects from simulating uniform wholesale pricing in this market. We do so by starting with the benchmark model of no uniform pricing to recover the marginal costs for each product. Then the simulation analysis consists then in numerically computing the new Nash equilibrium after imposing constraints on uniform wholesale pricing based on the estimates obtained for the demand and marginal cost recovered under no uniform wholesale pricing. Table 5 provides summary information on the general price level changes, price changes by brands and by retailers due to uniform wholesale pricing policy. Looking at simple average price changes or at weighted average price changes, where the weights are given by the product markets shares from the benchmark model of no uniform pricing, yields similar results. Although the average across all products price effect is very small and generally negative, there are brands for which the new retail price falls by approximately 10 cents (18 percent) while there are brands for which the new retail price rises by roughly 4 cents (9 percent). There are no weeks for which all prices do rise or all prices do fall in the sample considered. Breaking down by retailers, the price at retailer one, compared to the other two retailers, is the one that changes the most on average and also has more heterogenous price changes both increasing and decreasing. Note that all products sold at that retailer are affected by the intervention of uniform wholesale pricing, while at the other two retailers, who also sell a large proportion of own store brands, shall be less affected by this intervention. This becomes clearer looking at the breakup of the price effects by manufacturers. Indeed, the private label brands have the smallest simulated price effects compared to the national brands, which is reasonable given that upstream wholesale pricing decisions of private label brands do not get a first order impact of the simulated uniform wholesale pricing policy, but shall get a second oder effect via competitive interactions of the manufacturers and retailers given demand substitution patterns.

In Table 6 we present effects on producer surplus and consumer surplus, and particularly distinguish the estimated effects on manufacturers and retailers' producer surplus from imposing uniform wholesale pricing. We emphasize that we not only are able to estimate the joint effects on retailers and manufacturers surplus but also on the retail-level and manufacturer-level components of the surplus, even though we do not observe data on wholesale prices. The effects from uniform wholesale pricing on manufacturers and retailers joint producer surplus are on average negligible (surplus decreases by 0.02 percent) which may have important implications, namely that the possibility to wholesale price discriminate under the starting model did not by itself contribute to the profits in the benchmark case (since preventing it via uniform wholesale pricing has negligible effects). Note that breaking down by manufacturers and retailers the percent changes in profits are also very small (decreasing 0.04 percent, and increasing 0.02 percent, respectively). Breaking down by individual retailers and manufacturers yields varying effects, some increase some decrease profits, although again, the estimated effects are generally all very small in absolute value. Finally, looking at average changes in consumer surplus measured as the difference in compensating variation identified from the demand model, consumers in the market do on average have a positive estimated impact on their surplus of five dollars a week. Consumer level effects are estimated to be quite larger in magnitude than the estimated effect on overall producer surplus. Extrapolating these weekly dollar average effects for this market, and given that this market's weekly revenues amount to 544 dollars and yearly revenues in the U.S. market are approximately 2 billion dollars, we can do a back of the envelope extrapolation of the estimated welfare effects to a national yearly level. This amounts to yearly national effects on producer surplus of negative three hundred and fifty thousand dollars, while a national yearly increase in consumer surplus of about seventeen million dollars would be associated with such uniform wholesale pricing restrictions. The net welfare effect would be an increase in welfare mostly driven by the resulting increase in estimated consumer surplus.

5. Conclusions

In this paper we develop and analyze an economic model of wholesale pricing in the markets that only requires data at the retail level and at the upstream input price level and that does not require observed data on wholesale prices. We also describe the policy simulation procedure for uniform wholesale price legislation subject to the lack of observable wholesale price data. Given that this is the typical data situation researchers and policy makers face, we derive simple tools to shed light into welfare effects of and as a basis for inference on the existence of uniform wholesale pricing practices in the markets. General theoretical predictions regarding the price, profits, consumer surplus and welfare effects of eliminating price discrimination (via uniform wholesale pricing) in a multiple retailer and manufacturer setting are ambiguous (see Stole, 2001), and remain an empirical question of policy relevance in the markets. We present an illustrative empirical application to motivate researchers to apply this approach to other settings where uniform wholesale price is being considered or enforced. Not only can policy makers access the overall welfare effect of such interventions, without observing wholesale prices, but they may also estimate the effects separately on the retailers and manufacturers involved.

6. References

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Product Number	Manufacturer	Retailer	Product Name	Price Mean	Price Std
1	Kraft	1	Breyer Light Fruit Yogurt	38.94	4.73
2	Dannon	2	Dannon Light Vanilla Yogurt	47.62	3.48
3	Dannon	3	Dannon Light Vanilla Yogurt	42.06	3.07
4	Dannon	1	Dannon Lowfat Plain Yogurt	52.56	3.97
5	Dannon	2	Dannon Lowfat Plain Yogurt	48.19	4.75
6	Dannon	3	Dannon Lowfat Plain Yogurt	46.90	2.48
7	Dannon	1	Dannon Light Fruit Yogurt	57.87	5.01
8	Dannon	2	Dannon Light Fruit Yogurt	54.69	5.09
9	Dannon	3	Dannon Light Fruit Yogurt	47.08	2.33
10	Dannon	2	Dannon Nonfat Plain Yogurt	48.69	4.54
11	Dannon	3	Dannon Nonfat Plain Yogurt	46.56	2.58
12	Dannon	1	Dannon Classic Flavor Fruit Yogurt	52.50	5.53
13	Dannon	2	Dannon Classic Flavor Fruit Yogurt	53.68	7.55
14	Dannon	3	Dannon Classic Flavor Fruit Yogurt	46.96	3.29
15	Dannon	1	Dannon Classic Flavor Vanilla Yogurt	53.31	3.27
16	Dannon	2	Dannon Classic Flavor Vanilla Yogurt	48.82	4.68
17	Dannon	3	Dannon Classic Flavor Vanilla Yogurt	46.38	3.04
18	Dannon	1	Dannon Fruit on the Bottom Yogurt	51.12	6.48
19	Dannon	2	Dannon Fruit on the Bottom Yogurt	53.18	6.47
20	Dannon	3	Dannon Fruit on the Bottom Yogurt	47.31	2.41
21	Store 2	2	Private Label 2 Lowfat Fruit Yogurt	52.17	7.43
22	Store 2	2	Private Label 2 Lowfat Plain Yogurt	30.76	2.00
23	Store 2	2	Private Label 2 Lowfat Vanilla Yogurt	30.13	0.87
24	Store 2	2	Private Label 2 Nonfat Fruit Yogurt	54.63	7.29
25	Store 2	2	Private Label 2 Nonfat Plain Yogurt	54.82	7.35
26	Store 3	3	Private Label 3 Lowfat Fruit Yogurt	35.83	1.01
27	Store 3	3	Private Label 3 Lowfat Plain Yogurt	30.52	2.07
28	Kraft	1	Light N'Lively Nonfat Fruit Yogurt	48.40	4.52
29	Kraft	2	Light N'Lively Nonfat Fruit Yogurt	46.93	4.71
30	Kraft	3	Light N'Lively Nonfat Fruit Yogurt	46.44	3.24
31	Kraft	1	Light N'Lively Lowfat Fruit Yogurt	49.38	4.28
32	Kraft	2	Light N'Lively Lowfat Fruit Yogurt	46.67	5.04
33	Kraft	3	Light N'Lively Lowfat Fruit Yogurt	45.23	4.26
34	General Mills	2	Yoplait Custard Style Lowfat Fruit Yogurt	60.69	5.86
35	General Mills	3	Yoplait Custard Style Lowfat Fruit Yogurt	57.52	4.77
36	General Mills	2	Yoplait Custard Style Lowfat Vanilla Yogurt	63.54	6.58
37	General Mills	3	Yoplait Custard Style Lowfat Vanilla Yogurt	57.06	5.48
38	General Mills	1	Yoplait Fruit Yogurt	57.69	9.47
39	General Mills	2	Yoplait Fruit Yogurt	58.67	4.73
40	General Mills	3	Yoplait Fruit Yogurt	52.62	4.67
41	General Mills	1	Yoplait Light Fruit Yogurt	52.10	10.65
42	General Mills	2	Yoplait Light Fruit Yogurt	56.21	5.61
43	General Mills	3	Yoplait Light Fruit Yogurt	49.15	4.10

Table 1: Information about the 43 Products in Sample-Prices.

Price in cents per serving. One serving is equivalent to 6 ounces of yogurt. First column has the product identification number. Source: IRI.

Description	Mean	Median	Std.Dev.	Max	Min	Brand Variation	Week Variation
Prices (cents per serving)	49	48	9.2	72	24	68.3%	2.4%
Servings sold (1 serving=6 ounces)	246	132	393.3	9538	1	43.6%	4.1%
Share of product within market (%)	0.8	0.4	1.3	32	0.03	43.6%	4.1%
Combined Shares of products (%)	34	37	12.7	75	12		
Combined Shares by Manufacturer (%)	Mean	Median	Std.Dev.	Max	Min		
Dannon	16.8	16.4	7.6	50.0	4.7		
General Mills	8.8	9.0	3.6	31.1	4		
Private Label of Retailer 2	4.1	3.3	4.2	38.5	0.6		
Kraft	3.4	3.1	1.6	13.6	1.1		
Private Label of Retailer 3	1.3	1.2	0.5	3.7	0.6		
Combined Shares by Retailer (%)	Mean	Median	Std.Dev.	Max	Min		
Retailer 1	2.3	2.3	1.0	9.2	1		
Retailer 2	19.8	20.5	9.2	57.6	1.2		
Retailer 3	13.6	13.5	3.4	24.3	6.7		

Table 2: Prices, Servings Sold and Market Shares of Products in Sample: Summary Statistics. Source IRI.

		Estimates (standard errors)			Estimates (standard errors)
Mean	Constant	3.28 (0.25)	Interact	Constant	0.01 (0.53)
	Price	−8.25 (4.71)	With	Price	1.40 (0.84)
	Store 2	−0.35 (0.04)	Income	Store 2	−1.56 (0.40)
	Store 3	−1.02 (0.04)		Store 3	−0.43 (0.31)
	Calories	0.06 (0.01)		Calories	0.00 (0.00)
	Calcium	2.06 (0.13)		Calcium	0.42 (0.16)
Std dev	Constant	0.25 (0.08)	Interact	Constant	0.52 (1.40)
	Price	0.92 (0.18)	With	Price	−2.55 (2.11)
	Store 2	0.07 (0.13)	Age	Store 2	1.04 (0.55)
	Store 3	0.15 (0.15)		Store 3	0.55 (0.59)
	Calories	0.00 (0.00)		Calories	0.00 (0.00)
	Calcium	0.28 (0.11)		Calcium	0.25 (0.41)
First Stage					
F- statistic	16.24				
R2	0.82				
R2 min.dist	0.75				

Table 3: Results from Random Coefficient Model of Demand.
GMM estimates and Newey-West heteroscedasticity- and autocorrelation-consistent simulation corrected standard errors are in parenthesis. Source: Author's calculations.

Wholesale (W), Retail (R) and Total (T) Price Cost Margins (PCM)	Mean	Std	Min	Max
Model 2.2.1: No Uniform Wholesale Pricing: T-PCM	68.75%	14.96%	37.58%	171.36%
Model 2.2.1: No Uniform Wholesale Pricing: R-PCM	37.03%	8.58%	20.43%	100.56%
Model 2.2.1: No Uniform Wholesale Pricing: W-PCM	31.72%	7.18%	16.63%	84.73%
W-PCM Average by Manufacturer				
Kraft	31.71%	6.60%	21.27%	78.17%
Dannon	32.87%	6.29%	19.92%	84.73%
Private Label 2	32.31%	9.74%	19.08%	72.14%
Private Label 3	40.45%	5.29%	31.60%	58.60%
General Mills	27.50%	5.24%	16.63%	58.73%
Model 2.2.2: Uniform Wholesale Pricing: T-PCM	68.25%	14.85%	38.65%	175.63%
Model 2.2.2: Uniform Wholesale Pricing: R-PCM	37.03%	8.58%	20.43%	100.56%
Model 2.2.2: Uniform Wholesale Pricing: W-PCM	31.22%	7.00%	17.23%	89.00%
W-PCM Average by Manufacturer				
Kraft	31.08%	6.62%	20.38%	78.27%
Dannon	32.21%	5.92%	21.72%	89.00%
Private Label 2	32.31%	9.74%	19.08%	72.14%
Private Label 3	40.45%	5.29%	31.60%	58.60%
General Mills	27.04%	4.87%	17.23%	61.25%
Recovered Retail and Wholesale Costs	Mean	Std	Min	Max
Model 2.2.1: No Uniform Wholesale Pricing	0.1653	0.0889	−0.1713	0.4403
Average by Manufacturer				
Kraft	0.1378	0.0642	−0.1593	0.2817
Dannon	0.1623	0.0670	−0.1713	0.3384
Private Label 2	0.1446	0.1262	−0.1007	0.3472
Private Label 3	0.0345	0.0391	−0.0784	0.1097
General Mills	0.2268	0.0796	−0.0866	0.4403
By Retailer				
Store 1	0.1682	0.0756	−0.1332	0.4081
Store 2	0.1864	0.1022	−0.1713	0.4403
Store 3	0.1381	0.0708	−0.0784	0.3322
Model 2.2.2: Uniform Wholesale Pricing	0.1680	0.0885	−0.1815	0.4336
Average by Manufacturer				
Kraft	0.1410	0.0649	−0.1586	0.2897
Dannon	0.1658	0.0659	−0.1815	0.3345
Private Label 2	0.1446	0.1262	−0.1007	0.3472
Private Label 3	0.0345	0.0391	−0.0784	0.1097
General Mills	0.2294	0.0781	−0.0927	0.4336
By Retailer				
Store 1	0.1804	0.0775	−0.1334	0.4281
Store 2	0.1829	0.1013	−0.1815	0.4336
Store 3	0.1418	0.0712	−0.0784	0.3387

Table 4: Price-Cost Margins and Recovered Costs for Models 2.2.1 and 2.2.2. PCM=$(p-c)/p$ where p is price and c is marginal cost. Recovered Costs=$p - epcm$ where p is retail price and $epcm$ are the estimated margins. Std: Standard deviation. Source: Author's calculations.

	Average Change	Std	Minimum	Maximum
Changes in Retail Price (in cents)				
Overall	−0.30	1.24	−9.80	4.30
By Retailer				
Retailer 1	−1.32	1.74	−9.80	2.80
Retailer 2	0.32	0.67	−2.10	4.30
Retailer 3	−0.37	0.84	−5.30	2.70
By Manufacturer				
Kraft	−0.33	1.20	−6.10	4.10
Dannon	−0.39	1.44	−9.80	3.30
Private Label 2	−0.07	0.10	−0.40	0.10
Private Label 3	0.02	0.05	−0.10	0.20
General Mills	−0.29	1.28	−7.20	4.30

Table 5: Estimated Price Effects from Simulation of Uniform Wholesale Pricing.
Prices are expressed in cents and average product price before simulation is 50 cents. Source: Author's calculations.

Change in Producer Surplus	Average	Percent	
All Retailers	−0.1066	−0.0440	
Retailer 1	3.0600	4.6884	
Retailer 2	−6.0840	−1.9196	
Retailer 3	4.9320	1.8281	
All Manufacturers	0.0050	0.0024	
Kraft	−0.2077	−0.1653	
Dannon	−0.2102	−0.0890	
Private Label 2	1.1772	0.6730	
Private Label 3	−0.3193	−0.2029	
General Mills	0.0421	0.0184	
			US/ year extrapolation$^{(\star)}$
	Average	Percent	Average
Overall Change Producer Surplus	−0.0950	−0.0212	−349
Change in Consumer Surplus	4.6237	0.0506	16999
Change Welfare	4.5287	1.0114	16649

Table 6: Welfare Estimates from Simulation of Uniform Wholesale Pricing.
Effects are expressed in dollars per week, while US/Year extrapolations ($\star$) are expressed in thousands of dollars. Source: Author's calculations.

APPENDIX

7. Specification Tests on Uniform Wholesale Pricing

Under each supply model, given the demand parameters $\theta = [\ \alpha\ \beta\ \Gamma\ \Upsilon\ ]$, the price-cost margins implied by the different models 2.2.1 and 2.2.2 can be computed: $m^r(\theta)$ for the retailers and $m^w(\theta)$ for the manufacturers. In the econometric supply model the supply pricing equation is obtained by specifying the supply-side residual ϵ^s that contains unobserved components of marginal cost,

$$p = c\ \gamma + m^r(\theta)\ \lambda^r + m^w(\theta)\ \lambda^w + \epsilon^s, \tag{i}$$

where $c = [\ W_r\ W_w\ ]$ is a matrix of observed cost side variables such as input prices, γ is a vector of coefficients associated with cost-side variables, λ^r and λ^w are N-dimensional vectors of coefficients associated with the implied price-cost margins of the retailers and the manufacturers, respectively, and measure empirically departures from those margins.[5] Determining the consistency of these structural models with the data requires non-nested testing procedures, because the uniform wholesale pricing and the no uniform wholesale pricing models's mark-ups cannot be nested into one another. Therefore, pairwise non-nested Cox-type testing procedures as proposed by Smith (1992) are used. In the basic framework consider the two competing regression models $g = 2.2.1$ and $h = 2.2.2$ as

$$\begin{aligned} M_g: \quad & p = c\ \gamma_g + m^r_g(\theta)\ \lambda^r_g + m^w_g(\theta)\ \lambda^w_g + \epsilon^s_g, \quad \lambda^r_g = \lambda^w_g = 1 \\ M_h: \quad & p = c\ \gamma_h + m^r_h(\theta)\ \lambda^r_h + m^w_h(\theta)\ \lambda^w_h + \epsilon^s_h, \quad \lambda^r_h = \lambda^w_h = 1. \end{aligned} \tag{ii}$$

Let y be the difference in retail price and price-cost margins. The two competing regression models, M_g and M_h are defined, respectively, as $M_g : y_g = c\gamma_g + \epsilon^s_g$ and $M_h : y_h = c\gamma_h + \epsilon^s_h$. In the model, c is a matrix of input prices, and γ_g and γ_h are parameters to be estimated by GMM. To compare each pair of models, the Cox-type statistic is constructed by examining the difference of the estimated GMM criterion functions for model M_h and for the alternative model M_g. Normalized, standardized and compared to a standard normal critical value, a large positive statistic in this one-sided goodness of fit test leads to rejection of the null model M_h against M_g. The intuition behind the non-nested pair-wise comparisons is to see how the price-cost margins of alternative

[5]For each model specification test the null hypothesis is that all the coefficients in λ^r and λ^w are not significantly different from one, implying that retailers and manufacturers mark-ups do not differ significantly from the ones assumed in the underlying model to be tested (see also Villas-Boas and Hellerstein (2006) on identification of vertical models of retail and manufacturer oligopoly behavior).

models explain the residual (unobserved determinants of price) of the null model. This residual is obtained by subtracting the computed price-cost margins and estimated marginal costs from retail prices under the null model being considered.