Horizontal Differentiation with Differential Costs: Retail Prices for Milk by Fat Content

Tian Xia  
Department of Agricultural Economics  
Kansas State University  
E-mail: tianxia@agecon.ksu.edu

Richard J. Sexton  
Department of Agricultural and Resource Economics  
University of California, Davis  
E-mail: rich@primal.ucdavis.edu

DRAFT

Copyright 2007 by Tian Xia and Richard J. Sexton. All rights reserved. Readers may make verbatim copies of this document for non-commercial purposes by any means, provided that this copyright notice appears on all such copies.
Horizontal Differentiation with Differential Costs:  
Retail Prices for Milk by Fat Content

1. Introduction

Differentiated products of a good usually have differential costs. Most studies on product differentiation with differential costs focus on the case of vertical differentiation, that is, when all consumers have the same ordinal preference ranking over attributes of differentiated products, and it is more costly to produce higher ranked products [Mussa and Rosen, Maskin and Riley, Gabszewicz and Thisse, and Shaked and Sutton (1982, 1983)]. But a similar market phenomenon, horizontal differentiation with differential costs, has not received comparable attention. For example, consider fluid milk products, which are differentiated on fat content. Consumers differ in their preferences for fat content of milk. Some consumers prefer skim or low-fat milk because they do not want to consume butterfat, while other consumers like whole milk because it tastes better and/or it is more nutritious. On the other hand, the costs of different types of milk are not the same. The cost of whole milk, which includes the most of the expensive butterfat input, is higher than the cost of low-fat or skim milk. This type of market phenomena can also be found for other goods including foods with differing sugar contents and cars with different engine sizes.

The markets for horizontally differentiated products with differential costs have special features which are quite different from those of the markets for vertically differentiated products with differential costs, such as the typical market in the Mussa-Rosen study. First, in the markets for horizontally differentiated products, the cost difference between differentiated products induces sellers to provide low-cost varieties whenever possible. While in the markets of vertically differentiated products, sellers need to consider both the cost-savings of low-cost
varieties and consumers’ higher willingness to pay for high-cost varieties, which are also of high quality. Second, in the markets with horizontal differentiation, consumers’ disutility of consuming a type of product other than their ideal type encourages sellers to offer their ideal types of products or alternative types which are very close to the ideal types to each consumer. But, in the markets with vertical differentiation, consumers’ identical ordinal preference ranking of products gives sellers an incentive to provide highly-ranked products.

Third, it is the consumers with preferences in the middle of the preference range for the differentiated product attribute that impose the largest negative externalities on a seller’s ability to extract consumer surplus from other consumers in the markets with horizontal differentiation. In contrast, it is the consumers whose preferences are in the lowest range that impose the largest negative externalities in a market with vertical differentiation (Mussa and Rosen). In the markets with horizontal differentiation, the customers whose preferences are in the middle of the range are more likely to be indifferent among different varieties of the good than other consumers. So they are more willing to switch to another type of product if the price of one type is too high. Thus, they impose the strongest restriction on a seller’s ability to extract consumer surplus.

These three features combine to make markets for horizontally differentiated products with differential costs a unique topic worth studying. We develop a basic and an extended model to study grocery retailers’ pricing strategies and market equilibrium for two horizontally differentiated products with predetermined attributes under different competition scenarios. We also conduct an empirical study on retail markets for fluid milk. Data on milk retail prices and costs for 23 U.S. cities are used to study the effects of cost factors on retail prices and market competition.
2. The Basic Model

We consider grocery retailers who sell two horizontally differentiated products of a good, one product with a lower cost and another product with a higher cost, in addition to a large number of other goods.\(^1\) We use subscripts L and H to represent the low-cost and the high-cost product, respectively. We adopt the Hotelling framework to model the products’ horizontally differentiated attribute and consumers’ preferences. The attribute of a product is denoted as \(q_j\), where \(j = L, H\). We set \(q_L = 0\) and \(q_H = 1\) for the low-cost and the high-cost product, respectively. The unit variable procurement and selling cost of the low-cost product is \(C_L = C_0\) and the unit variable procurement and selling cost of the high-cost product is \(C_H = C_0 + (q_H - q_L)c = C_0 + c\), where \(C_0 > 0\) and \(c > 0\). So \(C_0\) is the common cost factor of the low-cost and the high-cost product and \(c\) is the cost difference between the two products.

Consumers are heterogeneous in terms of their preferences for the differentiated attribute of the good. We assume that consumers’ tastes for the attribute, \(\theta\), are uniformly distributed over the range, \([0, 1]\). In the basic model, we assume that the number of consumers with a specific taste value does not depend on the product prices. So, the total number of consumers is constant when the market is covered. The changes of market prices will affect the distribution of consumers between different products, but not the total demand. We set the total number of consumers as \(N = 1\) in the basic model. We will relax this assumption in the extended model in section 3.

A consumer’s utility derived from buying one unit of product \(j\) is

\[
U(\theta, q_j, P_j) = u_0 - r(\theta - q_j)^2 - P_j, \text{ where } r > 0 \text{ is the consumer’s disutility rate of consuming an}
\]

\(^1\) For example, grocery retailers usually carry both skim or low-fat milk and whole or high-fat milk where whole or high-fat milk has a higher cost than skim or low-fat milk due to the expensive input, butterfat.
alternative to his preferred product, $P_j$ is the retail price of product $j$, and $u_o$ is the base utility of consuming other attributes of the product. This utility function shows that a consumer’s utility is reduced by the amount $r(\theta - q_j)^2$ when he consumes a type of product other than his ideal type.

We use a convex function to represent a consumer’s disutility of consuming an alternative type to reflect the likelihood that a consumer’s disutility would be increasing at an increasing rate with the difference between the alternative type and his ideal type of product. A consumer is assumed to either purchase one unit of one product or make no purchase. The reservation utility when a consumer does not purchase is $u = 0$. To make sure the market exists, i.e., some consumers are willing to buy either the high-cost product or the low-cost product at the lowest possible prices—their respective unit variable costs, the condition, $u_o > C_H = C_o + c$, is assumed to hold.

If the cost difference, $c$, between two types of products is too large relative to consumers’ disutility rate, $r$, of consuming an alternative type of product, a retailer will offer just one type of product, the low-cost product, to consumers because it is too costly to offer the high-cost product. The market with only one type of product does not have horizontal differentiation, and is not interesting in the context of this study. To make sure that both types of products are offered and purchased in equilibrium, a condition which guarantees that the cost difference is not too large compared to consumers’ disutility rate needs to hold. Based upon the results of the model, this condition is $2r > c$. Thus, we assume $2r > c$ and focus on the case when both types of products are offered.

In the model, the attributes of products are assumed to be predetermined so that the retailer cannot change them. This assumption is quite consistent with many food products, whose attributes are decided by farmers and processors. Retailers choose the optimal prices for two
types of products to maximize their profit. In this paper, we examine three competition scenarios: perfect competition, monopoly, and oligopoly.

2.1. Perfect Competition

When the retail market for these two products is perfectly competitive, any attempt by a retailer to raise retail prices above unit variable procurement and selling costs will cause all of her customers to switch to other retailers. Thus, a retailer’s equilibrium prices for the two types of products are equal to their respective unit variable procurement and selling costs. That is, \( P_L = C_L = C_0 \) and \( P_H = C_H = C_0 + c \). The competitive model of retailer pricing thus predicts that the retail price of each type of product depends on only its own procurement and sales cost and the cost difference between two types of products, \( c \), does not affect the retail price of the low-cost product. Cost changes are reflected fully in changes in the sales price. Consumers’ utility of consuming other attributes of a product \( (u_o) \) and disutility rate \( (r) \) of consuming an alternative type of product have no effect on the retail prices of both types of products.

The taste value \( (\bar{\theta}) \) of consumers who are indifferent between buying the low-cost product and buying the high-cost product is
\[
\bar{\theta} = 1/2 + c/(2r).
\]

This taste value, \( \bar{\theta} \), is also the share of consumers buying the low-cost product (i.e., its market share) and \( 1 - \bar{\theta} \) is the share of consumers buying the high-cost product. The equilibrium taste value is increasing in the cost difference and decreasing in consumers’ disutility rate of consuming an alternative type of product. An increase in the cost difference means an increase in the price difference in the perfect competition scenario. A larger price difference causes more consumers to purchase the low-cost product. A higher disutility rate means consumers are more reluctant to switch from their preferred type of product to the other type. Thus, consumers are
more evenly split between two types of products, which is reflected in a value of $\tilde{\theta}$ closer to 1/2. Therefore, a smaller cost difference and/or higher disutility rate lead to fewer consumers purchasing the low-cost product and the market being more evenly split between the two types of products.

2.2. Monopoly

It is reasonable to consider models where retailers may have market power over consumers due to high concentration in local markets, the spatial dimension of grocery retailing, and efforts among grocery retailers to create “product differentiation” relative to their rivals. Most consumers choose one store to do their regular shopping, depending on various store characteristics and overall price levels of stores. Thus, it may be reasonable to model a retailer as a monopolist in setting the prices for any particular good, if price changes for this good have little or no effect on the number of customers coming to this store.

There are two cases for this type of monopoly market: the case where some consumers do not buy either of the two products at the equilibrium and the case where all consumers buy one type of product or the other. To establish the condition that determines which case will prevail, we consider the hypothetical situations where a retailer carries only one type of product, either the low-cost product or the high-cost one. If a retailer offers only the low-cost product, she will set its retail price at $P_L = (2u_0 + C_0)/3$ to maximize her profit and consumers with $\theta \in \left[0, \sqrt{(u_0 - C_0)/(3r)}\right]$ will buy the low-cost product. If a retailer offers only the high-cost product, she will set its retail price at $P_H = (2u_0 + C_0 + c)/3$ to maximize her profit and consumers with $\theta \in \left(1 - \sqrt{(u_0 - C_0 - c)/(3r)}, 1\right]$ will buy the high-cost product. If the two ranges of consumer tastes do not overlap, that is,
(1) $\sqrt{\left(u_0 - C_0\right)/(3r)} < 1 - \sqrt{\left(u_0 - C_0 - c\right)/(3r)} \Rightarrow 4u_0 < 4C_0 + 2c + c^2/(3r) + 3r,$

the retailer’s profit-maximizing price decisions for the two types of products are not interdependent even if she carries both types of products. Thus, if (1) holds, a retailer sets the prices for the two types of products at the same levels as those prices when she carries only one type of product, and consumers with tastes belonging to $\left[\sqrt{\left(u_0 - C_0\right)/(3r)}, 1 - \sqrt{\left(u_0 - C_0 - c\right)/(3r)}\right]$ do not buy any of the two products. On the other hand, if the two ranges of consumer tastes do overlap, that is,

(2) $\sqrt{\left(u_0 - C_0\right)/(3r)} \geq 1 - \sqrt{\left(u_0 - C_0 - c\right)/(3r)} \Rightarrow 4u_0 \geq 4C_0 + 2c + c^2/(3r) + 3r,$

then the retailer’s profit-maximizing price decisions of two types of products will be interdependent when she carries both types of products. Thus, if (2) holds, all consumers will buy one type of product at the equilibrium.

We now focus on the case where all consumers buy one type of product or the other, that is, the market is covered. The taste for the differentiated attribute of consumers who are indifferent between buying the low-cost product and buying the high-cost product is

(3) $\bar{\theta} = 1/2 + \left(P_{H} - P_{L}\right)/(2r)$.

Consumers whose tastes are in the range, $[0, \bar{\theta}]$, buy the low-cost product and other consumers whose tastes are in the range, $(\bar{\theta}, 1]$, buy the high-cost product. (We assume that indifferent consumers buy the low-cost product.) The retailer’s profit is

(4) $\pi(P_L, P_H) = (P_L - C_0)\bar{\theta} + (P_H - C_0 - c)(1 - \bar{\theta}).$

At the equilibrium, consumers with the taste, $\bar{\theta}$, who are indifferent between buying the low-cost and the high-cost product, are also indifferent between buying either type of product and not buying at all. To prove this argument, suppose at the equilibrium that the utility of consumers
with preferences $\theta$ from purchasing one unit of either type of product, $U(\theta, q_L, P_L) = U(\theta, q_H, P_H)$, is higher than the reservation utility, $u = 0$. Then the retailer can increase her profit by raising both prices by the same amount, $\Delta P$, which is equivalent to the utility difference, $\Delta U = U(\theta, q_L, P_L) - u$. Raising both prices by $\Delta P$ does not affect the value of $\theta$ based on equation (3). Then no consumer will change his purchase decision. But all consumers will pay higher prices. Thus the retailer’s profit is increased. Therefore, at the equilibrium, consumers who are indifferent between the low-cost and the high-cost product are also indifferent between buying and not buying. That is, $U(\theta, q_L, P_L) = U(\theta, q_H, P_H) = u$. Based on this result, we obtain

\begin{align*}
(5) \quad \bar{\theta} &= \sqrt{(u_0 - P_L)/r} \quad \text{and} \\
(6) \quad P_H &= P_L + 2\sqrt{(u_0 - P_L)r - r}.
\end{align*}

Substituting (5) and (6) into (4), we obtain the retailer’s profit as

\begin{align*}
(4') \quad \pi(P_L) &= (P_L - C_0)\sqrt{(u_0 - P_L)/r} + \\
&\quad \left(P_L + 2\sqrt{(u_0 - P_L)r - r - C_0 - c}\right)\left(1 - \sqrt{(u_0 - P_L)/r}\right).
\end{align*}

By solving the first-order condition of equation (4') and substituting the solution for $P_L$ back into (5) and (6), we find the equilibrium retail prices of both types of products,

\begin{align*}
(7) \quad P_L &= u_0 - r(\bar{\theta} - 0)^2 = u_0 - (3r + c)^2/(36r), \quad \text{and} \\
(8) \quad P_H &= u_0 - r(1 - \bar{\theta})^2 = u_0 - (3r + c)^2/(36r) + c/3,
\end{align*}

and the equilibrium value of the taste of indifferent consumers,

\begin{align*}
(9) \quad \bar{\theta} &= 1/2 + c/(6r).
\end{align*}
The equilibrium prices, (7) and (8), show two unique results: the cost difference between the two types of products has a negative effect on the low-cost product price and the common cost factor, $C_o$, surprisingly, has no effect on either product price. We discuss the intuition of these two results below in section 4. The equilibrium prices also show other important results. The high-cost product price is increasing in the cost difference but only partially. Both prices are increasing in consumers’ utility of consuming other attributes because a higher base utility for consumers enables the monopoly retailer to extract more consumer surplus by charging higher prices. The consumers’ disutility rate, $r$, has a negative effect on both product prices. Recall that the retailer wants to cover the whole market when (2) holds. So, the retailer will lower the prices to attract consumers with middle-range tastes to make purchases when a higher disutility rate makes it less attractive for those consumers to buy either type of product.

The taste value, $\theta$, in (9) indicates the market share of the low-cost product, and $1 - \theta$ is the market share of the high-cost product in the monopoly scenario. Compared to perfect competition, fewer consumers purchase the low-cost product and more consumers purchase the high-cost product in the monopoly scenario. The reason is that a monopoly retailer sets the price difference between two types of products less than the price difference under perfect competition. The smaller price difference results in fewer consumers buying the low-cost product and more consumers buying the high-cost product in the monopoly scenario. As in the perfect competition scenario, the market share of the low-cost product is increasing in the cost difference and decreasing in the disutility rate. So a smaller cost difference and/or higher disutility rate will result in fewer consumers buying the low-cost product, more consumers buying the high-cost product, and the market being split more evenly between two types of products.
2.3. Oligopoly

If the level of retail prices of the two products has a significant effect on the number of customers choosing to shop at a store, then a retailer cannot act as a monopoly in setting prices for the products because she knows that some customers will switch to other stores if she sets the prices too high. Nonetheless, a retailer may still enjoy some market power due to the aforementioned factors—horizontal concentration, spatial dimension, and store differentiation. In other words, the retail market for the two products may have the characteristics of an oligopoly.

We consider a simple duopoly market where two retailers, A and B, offer both the low-cost and the high-cost product to N (N is normalized to 1) consumers who do regular shopping in either one of these two stores. The two retailers, A and B, are horizontally differentiated in terms of store location and other store characteristics. The procurement and selling costs and consumers’ taste distribution are the same as those in previous scenarios. The consumers’ preferences for location and other store characteristics are symmetrically distributed between the two stores. A consumer will buy one unit of one product from either store, A or B, or buy nothing at all to maximize his utility. So there are four purchase choices and one no-purchase choice. A consumer’s utility derived from going to store i, where i = A, B, to buy one unit of product j is $V[U(\theta, q_j, P_j), z^i] = V[u_o - \tau(\theta - q_j)^2 - P_j, z^i]$, where $z^i$ is a vector of parameters for the location and other store characteristics of store i.

We do not model the detail choice decision process for each consumer to avoid making stronger assumptions which may cause further losses of generality of the results. Instead, we assume the market share of each of the four purchase choices depends on the retail prices, store locations and other characteristics, and consumers’ disutility rate, $r$, of consuming an alternative type of product. The market share functions are specified as
\[ S^A_L = a_1 - b_{11}(r,z)P^A_L + b_{12}(r,z)P^A_H + b_{13}(r,z)P^B_L + b_{14}(r,z)P^B_H \]
\[ S^A_H = a_2 + b_{21}(r,z)P^A_L - b_{22}(r,z)P^A_H + b_{23}(r,z)P^B_L + b_{24}(r,z)P^B_H \]
\[ S^B_L = a_3 + b_{31}(r,z)P^A_L + b_{32}(r,z)P^A_H - b_{33}(r,z)P^B_L + b_{34}(r,z)P^B_H \]
\[ S^B_H = a_4 + b_{41}(r,z)P^A_L + b_{42}(r,z)P^A_H + b_{43}(r,z)P^B_L - b_{44}(r,z)P^B_H, \]

where \( b_{ij} > 0 \) with \( i, j \in \{1, 2, 3, 4\} \), \( z = \{z^A, z^B\} \), superscripts A and B denote store A and B, respectively, and subscripts L and H denotes the low-cost and the high-cost product, respectively. Using the three conditions: the sum of four market shares is equal to 1, the consumer preferences for store characteristics are symmetrically distributed between two retailers in the space of store characteristics, and consumers’ tastes are uniformly distributed, we simplify the market share functions to

\[ S^A_L = 1/4 - b_{11}P^A_L + b_{12}P^A_H + b_{13}P^B_L + (b_{11} - b_{12} - b_{13})P^B_H \]
\[ S^A_H = 1/4 + b_{12}P^A_L - b_{11}P^A_H + (b_{11} - b_{12} - b_{13})P^B_L + b_{13}P^B_H \]
\[ S^B_L = 1/4 + b_{13}P^A_L + (b_{11} - b_{12} - b_{13})P^A_H - b_{11}P^B_L + b_{12}P^B_H \]
\[ S^B_H = 1/4 + (b_{11} - b_{12} - b_{13})P^A_L + b_{13}P^A_H + b_{12}P^B_L - b_{11}P^B_H. \]

The profit functions of retailer A and B are

\[ \pi^A(P^A_L, P^A_H) = (P^A_L - C_0)S^A_L + (P^A_H - C_0 - c)S^A_H \]

and

\[ \pi^B(P^B_L, P^B_H) = (P^B_L - C_0)S^B_L + (P^B_H - C_0 - c)S^B_H. \]

---

\(^2\) We simplify \( b_{ij}(r,z) \) to \( b_{ij} \) in most parts of the text.
Retailer i chooses her prices, \( P_L^i \) and \( P_H^i \), to maximize her profit, \( \pi^i(P_L^i, P_H^i) \), given the prices charged by her rival. By deriving and solving four first-order conditions simultaneously, we find the equilibrium prices,

\[
(10) \quad P_L^* = P_L^A = P_L^B = 1/\left[ 4(b_{11} - b_{12}) \right] + C_0 + \left[ (b_{11} - b_{13}) \right]/\left( 3b_{11} + b_{12} - 2b_{13} \right) c \\
\]

and

\[
(11) \quad P_H^* = P_H^A = P_H^B = 1/\left[ 4(b_{11} - b_{12}) \right] + C_0 + \left[ (2b_{11} + b_{12} - b_{13}) \right]/\left( 3b_{11} + b_{12} - 2b_{13} \right) c .
\]

The equilibrium prices show that the cost difference has a positive effect on the low-cost product under oligopoly, just the opposite of the result of the monopoly scenario. The common cost factor is fully transmitted to both product prices. Unlike in a monopoly scenario, retailers cannot push down the indifferent consumers’ utility of purchasing to their reservation utility in an oligopoly competition. Thus, consumers’ base utility of consuming other attributes does not affect the equilibrium product prices. In the oligopoly scenario, larger values of consumers’ disutility rate reduce the intensity of competition between two differentiated types of products because consumers are more reluctant to switch from their ideal type of product to the other type. Less competition between the two types of products gives retailers more power to charge higher prices. Thus, both prices are increasing with consumers’ disutility rate of consuming an alternative type of product. This is also the opposite of the result in the monopoly scenario.

Substituting (10) and (11) into the market share equations yields the market share of the low-cost product at the equilibrium,

\[
(12) \quad S_L = S_L^L + S_L^A = 1/2 + 2(b_{11} - b_{13})\left( P_H^* - P_L^* \right) \\
\quad = 1/2 + 2(b_{11} - b_{13}) \left[ (b_{11} + b_{12}) \right]/\left( 3b_{11} + b_{12} - 2b_{13} \right) c .
\]

The market share of the low-cost product can also be found through the taste value of the consumers indifferent from consuming the high-cost and the low-cost product. That is,
The market share of the low-cost product in this oligopoly scenario indicated in (12) and (13) is smaller than that under perfect competition and larger than that in the monopoly scenario. Oligopoly retailers have more market power than competitive retailers but less market power than monopoly retailers, so they set the price difference smaller than under perfect competition and larger than under monopoly. The market share of the low-cost product is increasing in the price difference. So the middle-range price difference of the oligopoly scenario results in middle-range market shares for the two types of products. The effects of the cost difference and consumers’ disutility rate on the market shares of two types of products in the oligopoly scenario are the same as those in perfect competition and the monopoly scenario. A smaller cost difference and/or higher disutility rate results in fewer low-cost product buyers, more high-cost product buyers, and a more evenly split market.

3. The Extended Model

We relax two assumptions in this extended model to study a more general case for the markets for horizontally differentiated products with differential cost. First, we relax the assumption about the relationship between the number of consumers with a specific taste value and product prices. The number of consumers with a specific taste value is decreasing in the low-cost and high-cost product price. So the total number of consumers when the market is covered is set to be \( N > 1 \) and \( N \) is decreasing in product prices. Thus, the changes in retail prices of the two products will affect both the total demand and the distribution of consumers between two products. Second, we also relax the assumption of the distribution of consumers’ tastes. In the
extended model, we do not assume any specific distribution form. We only assume that consumers’ tastes are continuously distributed over the range, [0, 1]. Other specifications in the extended model are the same as those in the basic model.

3.1. Perfect Competition

The relaxation of the aforementioned two assumptions in the extended model does not change the results for the perfect competition scenario. The effects of various cost and preference factors on retail prices and market shares in the extended model will be the same as those in the basic model.

3.2. Monopoly

When a retailer is a monopolist in a retail market of the good, the numbers of consumers who will purchase the high-cost and low-cost products are specified as

\[ N_L = a_1 - b_{11}(r)P_L + b_{12}(r)P_H \]

and

\[ N_H = a_2 + b_{21}(r)P_L - b_{22}(r)P_H, \]

where \( b_{ij} > 0 \) for \( i, j = 1 \) and \( 2, \) \( b_{11} > b_{12}, \) \( b_{11} > b_{21}, \) \( b_{22} > b_{21}, \) and \( b_{22} > b_{12}. \) The inequality conditions of model parameters guarantee that the total number of consumers,

\[ N = N_L + N_H = a_1 + a_2 - (b_{11} - b_{21})P_L - (b_{22} - b_{12})P_H, \]

is decreasing in retail prices, \( P_H \) and \( P_L. \)

The retailer’s profit function is \( \pi = N_L (P_L - C_0) + N_H (P_H - C_0 - c). \) The retailer chooses the optimal prices of the low-cost and high-cost product to maximize her total profits. Solve for the equilibrium and we obtain

\[ P_L^* = \alpha_1 + \beta_1 C_0 + \gamma_1 c \]

and

\[ P_H^* = \alpha_2 + \beta_2 C_0 + \gamma_2 c, \]

where
\[ \alpha_1 = \left[ 2a_1 b_{22} + a_2 \left( b_{12} + b_{21} \right) \right] / \left[ 4b_{11} b_{22} - \left( b_{12} + b_{21} \right)^2 \right], \]

\[ \alpha_2 = \left[ 2a_2 b_{11} + a_1 \left( b_{12} + b_{21} \right) \right] / \left[ 4b_{11} b_{22} - \left( b_{12} + b_{21} \right)^2 \right], \]

\[ \beta_1 = \left[ 2 b_{22} \left( b_{11} - b_{21} \right) + \left( b_{22} - b_{12} \right) \left( b_{12} + b_{21} \right) \right] / \left[ 4b_{11} b_{22} - \left( b_{12} + b_{21} \right)^2 \right], \]

\[ \beta_2 = \left[ 2 b_{11} \left( b_{22} - b_{12} \right) + \left( b_{11} - b_{21} \right) \left( b_{12} + b_{21} \right) \right] / \left[ 4b_{11} b_{22} - \left( b_{12} + b_{21} \right)^2 \right], \]

\[ \gamma_1 = b_{22} \left( b_{12} - b_{21} \right) / \left[ 4b_{11} b_{22} - \left( b_{12} + b_{21} \right)^2 \right], \text{ and} \]

\[ \gamma_2 = b_{21} \left( 2 b_{22} - b_{12} - b_{21} \right) / \left[ 4b_{11} b_{22} - \left( b_{12} + b_{21} \right)^2 \right]. \]

It can be shown that \( \alpha_1 > 0, \ \alpha_2 > 0, \ \beta_1 < 1, \ \beta_2 < 1, \ \gamma_1 \approx 0, \text{ and } 0 < \gamma_2 < 1. \)

Some effects of cost and preference factors on prices in the extended model are similar to those in the basic model while other effects are somewhat different. The common cost factor is still transmitted to retail prices of both products, but only partially. The cost difference is still partially transmitted to the high-cost product price. However, the cost difference between two types of products has almost no effect on the retail price of the low-cost product and consumers’ utility of consuming other attributes has no effect on both product prices. The more general specification in the extended model prevents us from deriving analytical results of the effect of the consumers’ disutility rate on product prices and market shares of the two products. Again, a smaller cost difference will result in fewer consumers buying the low-cost product, more consumers buying the high-cost product, and a more evenly split market.

### 3.3. Oligopoly

Two retailers, A and B, offer both the low-cost and the high-cost product to N consumers who do regular shopping in either one of these two stores. The numbers of consumers who will purchase the high-cost and the low-cost products in the two stores are specified as
\[ N^A_L = a_1 - b_{11}(r, z)P^A_L + b_{12}(r, z)P^A_H + b_{13}(r, z)P^B_L + b_{14}(r, z)P^B_H \]
\[ N^A_H = a_2 + b_{21}(r, z)P^A_L - b_{22}(r, z)P^A_H + b_{23}(r, z)P^B_L + b_{24}(r, z)P^B_H \]
\[ N^B_L = a_3 + b_{31}(r, z)P^A_L + b_{32}(r, z)P^A_H - b_{33}(r, z)P^B_L + b_{34}(r, z)P^B_H \]
\[ N^B_H = a_4 + b_{41}(r, z)P^A_L + b_{42}(r, z)P^A_H + b_{43}(r, z)P^B_L - b_{44}(r, z)P^B_H. \]

Because the consumer preferences are symmetrically distributed between two retailers in the space of store characteristics, we obtain \( a_1 = a_3 \) and \( a_2 = a_4 \). By setting \( \sum_{j=i}^{4} b_{ij} - b_{ii} < 0 \) and \( \sum_{j=i}^{4} b_{ji} - b_{jj} < 0 \) for \( i = 1, 2, 3, \) and \( 4 \), we guarantee that the total number of consumers,

\[ N = N^A_L + N^A_H + N^B_L + N^B_H \]
\[ = 2(a_1 + a_2) - (b_{11} - b_{21} - b_{31} - b_{41})P^A_L - (b_{22} - b_{12} - b_{32} - b_{42})P^A_H \]
\[ - (b_{33} - b_{13} - b_{23} - b_{43})P^B_L - (b_{44} - b_{14} - b_{24} - b_{34})P^B_H, \]

is decreasing in retail prices and the number of consumers buying a type of product decreases when all four product prices increase at the same time. The profit functions of the retailers are

\[ \pi^A = N^A_L (P^A_L - C_0) + N^A_H (P^A_H - C_0 - c) \]
and

\[ \pi^B = N^B_L (P^B_L - C_0) + N^B_H (P^B_H - C_0 - c). \]

Each retailer chooses her prices for the two types of products to maximize her total profit given her rival’s prices. We solve four first-order conditions and obtain the equilibrium prices,

\[ P^*_L = P^*_L = P^*_L = \alpha_1 + \beta_1 C_0 + \gamma_1 c \]
and

\[ P^*_H = P^*_H = P^*_H = \alpha_2 + \beta_2 C_0 + \gamma_2 c, \]

where
\[
\alpha_1 = \left[ a_1 (2b_{22} - b_{24}) + a_2 (b_{12} + b_{14} + b_{21}) \right] \\
\left[ (2b_{11} - b_{13})(2b_{22} - b_{24}) - (b_{12} + b_{14} + b_{21})(b_{12} + b_{21} + b_{23}) \right]^{-1},
\]

\[
\alpha_2 = \left[ a_2 (2b_{11} - b_{13}) + a_1 (b_{12} + b_{21} + b_{23}) \right] \\
\left[ (2b_{11} - b_{13})(2b_{22} - b_{24}) - (b_{12} + b_{14} + b_{21})(b_{12} + b_{21} + b_{23}) \right]^{-1},
\]

\[
\beta_1 = \left[ (b_{11} - b_{21})(2b_{22} - b_{24}) + (b_{22} - b_{12})(b_{12} + b_{14} + b_{21}) \right] \\
\left[ (2b_{11} - b_{13})(2b_{22} - b_{24}) - (b_{12} + b_{14} + b_{21})(b_{12} + b_{21} + b_{23}) \right]^{-1},
\]

\[
\beta_2 = \left[ (2b_{11} - b_{13})(b_{22} - b_{12}) + (b_{11} - b_{21})(b_{12} + b_{21} + b_{23}) \right] \\
\left[ (2b_{11} - b_{13})(2b_{22} - b_{24}) - (b_{12} + b_{14} + b_{21})(b_{12} + b_{21} + b_{23}) \right]^{-1},
\]

\[
\gamma_1 = \left[ b_{22} (b_{12} - b_{21} + b_{14}) + b_{21} b_{24} \right] \\
\left[ (2b_{11} - b_{13})(2b_{22} - b_{24}) - (b_{12} + b_{14} + b_{21})(b_{12} + b_{21} + b_{23}) \right]^{-1},
\]

and

\[
\gamma_2 = \left[ b_{22} (2b_{11} - b_{13}) - b_{21} (b_{12} + b_{21} + b_{23}) \right] \\
\left[ (2b_{11} - b_{13})(2b_{22} - b_{24}) - (b_{12} + b_{14} + b_{21})(b_{12} + b_{21} + b_{23}) \right]^{-1}.
\]

It can be shown that \( \alpha_1 > 0, \alpha_2 > 0, 0 < \beta_1 < 1, 0 < \beta_2 < 1, 0 < \gamma_1 < 1, \) and \( 0 < \gamma_2 < 1. \)

The effects of cost factors in this extended model of oligopoly are very similar to the effects in the basic model of oligopoly. The only difference is that the common cost factor is only partially transmitted into the retail prices of both products in the extended model. Again, the effects of the disutility rate on prices and market shares cannot be obtained due to the more general specification in the extended model.

To summarize, in the basic model, the cost difference may reduce the low-cost product price of a monopoly retailer when the market is covered, it can increase the low-cost product price in the oligopoly scenario, and it has no effect on the low-cost product price under perfect
competition. The cost difference is fully transmitted to the high-cost product price in a perfect competition scenario. The transmission is only partial in both the monopoly and the oligopoly scenario. The common cost factor of the two types of products is fully transmitted to both product prices under perfect competition and oligopoly competition. The common cost factor has no effect on both prices in the monopoly scenario when the market is covered. Consumers’ utility from consuming other attributes of a product has a positive effect on both prices in a monopoly scenario when the market is covered but it has no effect on the prices under perfect competition and oligopoly competition. Consumers’ disutility rate of consuming a type of product other than their ideal type reduces both prices in the monopoly scenario but it increases both prices in the oligopoly scenario. It has no effect on the prices under perfect competition. More market power that retailers have, a smaller cost difference, and/or a higher disutility rate will result in fewer consumers purchase the low-cost product, more consumers purchase the high-cost product, and the market is more evenly split between the two products. The effects of cost and preference factors on product prices in the basic model are reported in table 1.

The majority of the results remain the same when we allow for a variable total number of consumers and more general distribution of consumers’ tastes in the extended model. Different results are that, in the extended model, the cost difference has almost no effect on the low-cost product price in the monopoly scenario, the common cost factor is only partially transmitted to both product prices in the monopoly and oligopoly scenario, and consumers’ utility from consuming other attributes of a product has no effect on product prices in the monopoly scenario. The effects of cost and preference factors on product prices in the extended model are reported in table 2.
4. Discussion

Here we discuss the intuition behind the various effects of the cost factors under different competition scenarios. When the market is perfectly competitive, the retail price of a product is only determined by its cost. Thus the cost difference has no effect on the low-cost product price and the common cost factor is fully transmitted to the retail prices of both products.

When the market is characterized as monopoly, a retailer chooses her optimal prices of the two products to maximize her total profit. In the basic model when the total market demand is perfectly inelastic, i.e. it does not decrease in retail prices, the retailer sets the prices of both products high enough so that the consumers indifferent between the low-cost and the high-cost product obtain only their reservation utility. Here, the cost difference between the two types of products has a negative effect on the low-cost product price. The intuition for this striking result is straightforward and interesting. When the cost difference between two types of products increases, it becomes relatively more costly for the retailer to sell the high-cost product. Accordingly, the retailer wants to encourage more consumers to buy the low-cost product instead of the high-cost product. To achieve this goal, she must lower the price ratio between the low-cost and the high-cost product, $\frac{P_L}{P_H}$. Any reduced price ratio that includes an increased or unchanged price for the low-cost product implies that the high-cost product price must be increased. But increasing both prices or keeping $P_L$ unchanged and increasing $P_H$ will result in some consumers, those whose purchases gave them utility equal to or only a little higher than their reservation utility before the price changes, not buying any product with the new prices. So, as long as it is optimal for the retailer to keep the whole market covered, any reduction in the price ratio must involve reducing the low-cost product price.
Second, the common cost factor has no effect on product prices in the monopoly setting. Because the retailer always sets the two product prices such that indifferent consumers’ utility derived from purchasing one type of product is only equal to the level of their reservation utility. Thus, the prices will be determined by the taste value of indifferent consumers and two preference factors, consumers’ disutility rate and consumers’ utility of consuming other attributes. The change of the common cost factor does not change the cost difference between two types of products for the retailer. Thus, if the common cost factor changes, the retailer will not induce any consumer to switch from one type to another type of product by changing the relative prices of these two types. So, the common cost factor cannot change the taste value of indifferent consumers. It cannot affect the two preference factors, either. Therefore, the common cost factor, \( C_0 \), cannot affect the product prices.

In the monopoly scenario in the extended model and the oligopoly scenario in both models, a retailer will set the optimal prices of two products at the level where the marginal benefit of a price increase equals the marginal cost. The marginal benefit of an increase in the low-cost product price consists of two parts: (1) extra revenue due to the higher price from all sales of the low-cost product of this retailer and (2) profit earned from additional sales of the other product, the high-cost product, of the same retailer because some consumers switch from the low-cost to the high-cost product in the same store due to a higher \( P_L \). We use MB1 and MB2 to denote the first and second part of the marginal benefit, respectively. The marginal cost (MC) of the price increase of the low-cost product is the profit loss due to reduced sales of the product. The effects of cost factors on product prices depend on the directions and magnitudes of their effects on MB1, MB2, and MC of a price change. The same analysis of marginal benefit and cost also apply to the high-cost product.
In the extended model of monopoly, a retailer can no longer set prices to cause the indifferent consumers between the two products to obtain only the reservation utility. Now the retailer needs to consider the negative effect of product prices on total number of consumers in determining optimal pricing strategies. An increase in the cost difference will reduce the MC of an increase in \( P_H \), which then results in a higher equilibrium price of the high-cost product. A higher \( P_H \) means that the market share of the low-cost product is larger so that the MB1 of an increase of \( P_L \) is larger. Although \( P_H \) is higher, the equilibrium per-unit profit of selling the high-cost product will be lower because the retailer will absorb part of the cost increase. The lower per-unit profit of selling the high-cost product results in a smaller MB2 of the price increase of the low-cost product. Because there is only one retailer, the magnitude of the increase of MB1 depends on how much \((b_{12})\) the demand for the low-cost product increases when \( P_H \) increases. The magnitude of the decrease of MB2 depends on how much \((b_{21})\) the demand for the high-cost product increases when \( P_L \) increases. The two magnitudes are likely equal to each other if the consumers’ tastes are continuously distributed between the quality attributes of the low-cost and the high-cost product, i.e. over the range \([0, 1]\). So, the effects of an increase of the cost difference on MB1 and MB2 are of opposite directions but similar magnitudes. The cost difference does not affect the MC of the price increase of the low-cost product. Therefore, the cost difference likely has no effect on the equilibrium price of the low-cost product.

On the other hand, an increase in the common cost factor will reduce the MC and the MB2 of a price increase of the low-cost product. But the magnitude of the MC decrease is greater than that of the MB2 decrease because a unit increase of \( P_L \) causes more demand decrease for the low-cost product than the demand increase for the high-cost product when some consumers switch from buying the low-cost product to not buying. So, an increase in the common cost
factor will result in higher equilibrium price of the low-cost product. The similar analysis and result apply to the case of the high-cost product price. The transmission of the change of the common cost factor into retail prices in the extended model for monopoly is partial because the total market demand decreases in retail prices and the retailer needs to absorb part of a cost increase.

When the market is characterized by oligopoly competition, multiple retailers sell both the low-cost and the high-cost product. Retailers choose the prices of the differentiated products to maximize their respective profit. Similar to the situation in the extended model of monopoly, an increase of the cost difference will result in a higher $P_h$. Again, the cost difference increases MB1 and decreases MB2. But, the positive effect on MB1 in the oligopoly scenario is stronger than the negative effect on MB2 because the higher prices of the high-cost product in a retailer’s own store and competing stores will increase MB1 but only the lower per-unit profit of selling the high-cost product in one store, the retailer’s own store, will reduce MB2. So, the total MB of price increase will be larger and the equilibrium price of the low-cost product will be higher.

Similar to the extended model of monopoly, an increase of the common cost factor will reduce the MC and the MB2 of the price increase of the low-cost product in the extended model of oligopoly. The magnitude of the MC decrease is greater than that of the MB2 decrease. So, an increase in the common cost factor will lead to a higher equilibrium price of the low-cost product. The similar analysis and results apply to the case of the high-cost product. The change of the common cost factor is fully transmitted into both $P_h$ and $P_L$ in the basic model for oligopoly because the total market demand is perfectly inelastic so that retailers do not need to absorb part of a cost increase to prevent sales from falling. The transmission of the common cost
factor is partially in the extended model for oligopoly when the total market demand decreases in retail prices so that retailers need to absorb part of a cost increase.

5. The Empirical Study

The conceptual models provide many testable results about the effects of various cost and preference factors on the prices and market shares of horizontally differentiated products under the three competition scenarios. The estimated signs and magnitudes of these effects can also be used to distinguish the forms of competition of a market. We obtained weekly retail milk prices, city-level average household income, and average household size from Information Resource Incorporated’s Infoscan™ scanner data set for 23 U.S. cities for the period from 1997 through 1999.³ Milk is horizontally differentiated by fat content. Grocery retailers usually carry four types of milk based upon butterfat content: skim milk, 1% milk, 2% milk, and whole milk that has about 3.5% butterfat. The cost of milk products is increasing in the percentage of the butterfat content because butterfat is the most expensive ingredient of raw milk.

To study the retail milk market, we extend the conceptual models from the 2-product case to a 4-product case. The results in the 4-product cases are very similar to those in the 2-product cases. The effects of the cost and preference factors on retail prices of four types of milk are reported in table 3. According to the conceptual results in table 3, the cost difference, the common cost factor, consumers’ utility of other attributes (non-fat contents of milk), and consumers’ disutility rate will have different effects on the prices of skim milk, 1% milk, 2%

---

³ The 23 cities are Atlanta, Boston, Cedar Rapids (Iowa), Chicago, Denver, Detroit, Eau Claire (Wisconsin), Grand Junction (Colorado), Houston, Kansas City, Los Angeles, Memphis, Midland (Texas), Minneapolis/St. Paul, New York, Philadelphia, Pittsburgh, Pittsfield (Massachusetts), San Francisco/Oakland, Seattle/Tacoma, St. Louis, Tampa/St. Petersburg, and Visalia (California).
milk, and whole milk under the three different competition scenarios.\(^4\) However, because the data on those preference factors are not available, we have no way to estimate and test the effects of the two preference factors, consumer’s utility of consuming non-fat contents and consumers’ disutility rate of purchasing a type of milk other than their ideal type. Therefore, we focus the empirical study on the effects on retail milk prices of the two cost factors, the cost difference and the common cost factor (for which good data are available) and reveal competition characteristics of retail milk markets based on those estimated effects.

The supply of fluid milk involves farmers, processors, and retailers. Depending on the form of competition in retail markets, retail milk prices may be affected by four cost and preference factors, the cost difference between different types of milk, the common cost factor, consumers’ utility of non-fat contents, and the disutility rate. In addition, milk retail prices are also affected by other demand-shift and cost-shift variables, such as consumer income, household demographics, seasonal demand change, retailers’ costs for labor, energy for cooling, etc. In our econometric model, retail milk prices are regressed on the cost difference, the common cost factor, household income, household sizes, seasonal dummies for June, July, and August, and a linear and a quadratic time trend variable. The trend variables are used to capture the effects of changes in consumers’ utility for non-fat contents, the disutility rate, and other demand shifters and cost shifters. We conducted a fixed effect panel data analysis for the milk retail markets in 23 U.S. cities for the period from January 1, 1997 to December 31, 1999. In the model, the intercept is city specific to capture the heterogeneity among cities. We examine the effects of the

\(^4\) We define the cost difference variable, \(c\), as the cost difference between skim milk and whole milk. Due to the content of components in the four types of milk, the cost difference between any two types of milk can be approximately represented by the product of a constant and the defined cost difference variable, \(c\). For example, the cost difference between skim milk and 1% milk is equal to \((1/3.5)\times c\) and the cost difference between 2% milk and whole milk is equal to \((1.5/3.5)\times c\). Defining only one cost difference variable also simplifies our analysis.
two cost factors on retail milk prices and compare the effects with the conceptual results to characterize the competition for retail milk markets in these cities.

Three of the 23 cities are in California, which has its own stabilization and marketing plans for market milk for both northern California and southern California marketing areas. These plans set minimum monthly milk prices and milk components prices for various classes of milk. Fluid milk belongs to Class I. We obtained these minimum farm prices of Class I milk components from various issues of the *California Dairy Information Bulletin*. Using these milk component prices and federal component standards of milk for California, we calculated the minimum farm prices of the four types of milk for the three Californian cities. Each of the 20 non-California cities is in one of the 31 federal milk marketing order areas. Each federal milk marketing order sets minimum farm milk prices and milk components prices for various classes. We obtained Class I whole milk farm prices and Class I butterfat farm prices from the annual summary of Federal Milk Order Marketing Statistics. We calculated Class I farm prices for the other 3 types of milk using Class I whole milk prices, butterfat farm prices, and federal component standards of milk for those federal milk marketing order areas. An over-order premium is a fee for milk sold above the regulated minimum price and is usually related to services provided by milk marketing cooperatives. We use the over-order premiums from Federal Milk Order Marketing Statistics and add them to the federal minimum farm milk prices to obtain more accurate measures for the milk prices that farmers received.

Retailers’ costs of fluid milk products include wholesale prices paid to processors and selling cost. When the wholesale milk market is perfectly competitive, wholesale prices are the sum of farm prices and processing costs. By assuming the wholesale milk market is competitive, retailers’ cost of skim milk is equal to the sum of farm price of skim milk, processing cost, and
selling cost. By definition, the common cost factor is equal to retailers’ cost of skim milk. So the common cost factor is equal to the skim milk farm price plus processing and selling costs. Due to lack of data on processors’ processing cost and retailers’ selling cost, we used the farm price of skim milk to represent the common cost factor, $C_o$, and then the effects of differences in processing costs and selling costs are captured by both the intercepts and the trend variables.

During processing, raw milk is first separated by component and then various components are re-assembled according to different content formulas to make the final products, such as different types of fluid milk. So it is reasonable to think that processing cost of skim milk is the same as those of the other three types of milk. Also retailers’ selling costs for skim milk and whole milk are likely the same. Thus, retailers’ cost difference, $c$, between skim milk and whole milk is equal to the difference between the skim milk farm price and whole milk farm price. We calculate the farm price difference between skim milk and whole milk and use it to represent the cost difference, $c$.

We obtain the regional consumer price index (CPI) for all items less food for all urban consumers, not seasonally adjusted, where 1982 is the base year, from the Bureau of Labor Statistics. The CPI is used to deflate all prices of milk and average household income. The summary statistics of the data of the cost difference, the common cost factor, and retail prices of the four types of milk are reported in table 4. There are significant variations in the two cost factors and four retail milk prices.

We estimated the fixed effect panel model for each of the four retail milk prices. The estimation results are reported in table 5. The model fits the data very well for each of the four retail milk prices. Most parameter estimates are statistically significant and the adjusted $R^2$ statistics are high, ranging from 0.84 in the model for 1% milk price to 0.94 in the model for
skim milk price. The current and one past (1-week lag) values of the cost difference have statistically significant and positive effects on the retail price of skim milk. The long-run permanent effect of the cost difference on the skim milk retail price is $0.23+0.22=0.45$, which is between 0 and 1. This long-run permanent effect is consistent with the conceptual result of oligopoly scenarios but inconsistent with the conceptual results of perfect competition or monopoly scenarios. The cost difference has similar statistically significant and positive effects on the retail price of the other three types of milk. The coefficient estimates of the current and past (1-week and/or 2-week lag) values of the common cost factor in the models of the four types of milk are statistically significant and positive. We find out that the long-run permanent effect of the common cost factor on retail price is between 0 and 1 for all four types of milk. So, the common cost factor was partially transmitted to the retail prices of all four milk products. This empirical result is consistent with the conceptual results of either oligopoly or monopoly scenario in the extended model but not consistent with the conceptual results of other competition scenarios. Considering the effects of both the cost difference and the common cost factor on retail milk prices together, we can see that the estimation results show that the behavior of the retail milk markets under study is consistent with oligopoly competition.

The coefficient estimate of average household income is of the expected sign (positive) in all four models. The effect of income on the retail price of 1% milk is statistically significant. The effects of household size on retail milk prices are statistically insignificant in the markets under study. The estimates of seasonal dummies of summer months show that retail prices of skim, 2%, and whole milk were lower in one or more summer months.
6. Conclusions

Markets for horizontally differentiated products with differential costs are important and have unique features. This paper studies sellers’ pricing strategy and market equilibrium in these markets under various competition scenarios in the context of retail milk markets. The cost difference between differentiated products and consumers’ disutility rate of consuming an alternative type of product other than his ideal type are two important factors for market shares and prices of differentiated products in this type of market. An increase of the cost difference will cause sellers to induce more consumers to purchase low-cost varieties. A higher disutility rate indicates that consumers are more reluctant to switch from their preferred types of products to an alternative type and, consequently, are more evenly split between different types of products. An increase in the cost difference may reduce the low-cost product price in a monopoly scenario. Its effect is positive in an oligopoly scenario. The cost difference has no impact on the low-cost product price under perfect competition. Consumers’ disutility rate of consuming an alternative type may reduce product prices in the monopoly scenario. It can increase prices in the oligopoly scenario but it has no effect under perfect competition. Other cost and preference factors also have different effects on prices of differentiated products under various competition scenarios, as the conceptual analysis demonstrated.

We used the predictions from the conceptual model to conduct an empirical study of the effects of cost factors on retail milk prices and to characterize competition in retail milk markets in 23 U.S. cities during the period of 1997-1999. The econometric model explains retail prices of all four types of milk very well for the cities during the time period under study. The oligopoly scenario is strongly supported by the estimation results for the retail milk markets in the 23 U.S. cities.
Table 1. The Effects of Cost and Preference Factors on Prices in the Basic Model.

<table>
<thead>
<tr>
<th></th>
<th>Perfect competition</th>
<th>Oligopoly</th>
<th>Monopoly</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-cost Product</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost difference (c)</td>
<td>0</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Common cost (C₀)</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Consumer disutility rate (r)</td>
<td>0</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Utility of other attributes (u₀)</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
<tr>
<td><strong>High-cost Product</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost difference (c)</td>
<td>1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Common cost (C₀)</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Consumer disutility rate (r)</td>
<td>0</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Utility of other attributes (u₀)</td>
<td>0</td>
<td>0</td>
<td>+</td>
</tr>
</tbody>
</table>

Note: The symbols, +, –, and 0 denote positive and <1, negative, and no effect, respectively. The number, 1, indicates the magnitudes of the effects of an one-unit increase of the corresponding variable.
Table 2. The Effects of Cost and Preference Factors on Prices in the Extended Model.

<table>
<thead>
<tr>
<th></th>
<th>Perfect competition</th>
<th>Oligopoly</th>
<th>Monopoly</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low-cost Product</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost difference (c)</td>
<td>0</td>
<td>+</td>
<td>≈0</td>
</tr>
<tr>
<td>Common cost (C₀)</td>
<td>1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Utility of other attributes (u₀)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>High-cost Product</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost difference (c)</td>
<td>1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Common cost (C₀)</td>
<td>1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Utility of other attributes (u₀)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Note: The symbols, +, −, and 0 denote positive and <1, negative, and no effect, respectively. The number, 1, indicates the magnitudes of the effects of an one-unit increase of the corresponding variable.
Table 3. The Effects of Cost and Preference Factors on the Retail Prices of Four Types of Milk.

<table>
<thead>
<tr>
<th></th>
<th>Perfect competition</th>
<th>Oligopoly</th>
<th></th>
<th>Monopoly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Basic</td>
<td>Extended</td>
<td>Basic</td>
</tr>
<tr>
<td>Skim milk</td>
<td>cost difference</td>
<td>0</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>common cost</td>
<td>1</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>($C_o$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1% milk</td>
<td>cost difference</td>
<td>1/3.5 = 0.286</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>common cost</td>
<td>1</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>($C_o$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2% milk</td>
<td>cost difference</td>
<td>2/3.5 = 0.571</td>
<td>+</td>
<td>−</td>
</tr>
<tr>
<td></td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>common cost</td>
<td>1</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>($C_o$)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole milk</td>
<td>cost difference</td>
<td>1</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>(c)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>common cost</td>
<td>1</td>
<td>1</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>($C_o$)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The symbols, +, −, and 0 denote positive and <1, negative, and no effect, respectively. The numbers, 1, 0.286, 0.571 indicate the magnitudes of the effects of an one-unit increase of the corresponding variable.
Table 4. Summary Statistics of Deflated Retail Prices and Costs ($ per hundredweight).

<table>
<thead>
<tr>
<th></th>
<th>Skim milk retail price</th>
<th>1% milk retail price</th>
<th>2% milk retail price</th>
<th>Whole milk retail price</th>
<th>Cost difference</th>
<th>Common cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>19.66</td>
<td>18.16</td>
<td>19.33</td>
<td>20.01</td>
<td>3.10</td>
<td>6.91</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>2.79</td>
<td>3.61</td>
<td>2.38</td>
<td>2.45</td>
<td>1.16</td>
<td>1.51</td>
</tr>
<tr>
<td>Coefficient of variation</td>
<td>0.14</td>
<td>0.20</td>
<td>0.12</td>
<td>0.12</td>
<td>0.37</td>
<td>0.22</td>
</tr>
</tbody>
</table>
Table 5. Estimation Results of Fixed Effect Panel Models for Retail Milk Prices.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Skim Milk</th>
<th>1% Milk</th>
<th>2% Milk</th>
<th>Whole Milk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost difference</td>
<td>0.23**</td>
<td>0.10**</td>
<td>0.24**</td>
<td>0.21**</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.028)</td>
<td>(0.028)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>Cost difference (1-week lag)</td>
<td>0.22**</td>
<td>0.29**</td>
<td>0.26**</td>
<td>0.24**</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(0.033)</td>
<td>(0.032)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>Cost difference (2-week lag)</td>
<td>0.005</td>
<td>0.11**</td>
<td>-0.018</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>(0.021)</td>
<td>(0.028)</td>
<td>(0.020)</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Common cost</td>
<td>0.15**</td>
<td>0.14**</td>
<td>0.16**</td>
<td>0.17**</td>
</tr>
<tr>
<td></td>
<td>(0.018)</td>
<td>(0.021)</td>
<td>(0.022)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Common cost (1-week lag)</td>
<td>0.23**</td>
<td>0.28**</td>
<td>0.28**</td>
<td>0.23**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.028)</td>
<td>(0.026)</td>
<td>(0.019)</td>
</tr>
<tr>
<td>Common cost (2-week lag)</td>
<td>0.04*</td>
<td>0.11**</td>
<td>0.026</td>
<td>0.078**</td>
</tr>
<tr>
<td></td>
<td>(0.015)</td>
<td>(0.022)</td>
<td>(0.016)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Income</td>
<td>0.015</td>
<td>0.038*</td>
<td>0.017</td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.021)</td>
<td>(0.015)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Household size</td>
<td>-0.05</td>
<td>-0.087</td>
<td>-0.10</td>
<td>0.17</td>
</tr>
<tr>
<td></td>
<td>(0.14)</td>
<td>(0.41)</td>
<td>(0.15)</td>
<td>(0.12)</td>
</tr>
<tr>
<td>June</td>
<td>-0.085*</td>
<td>0.0016</td>
<td>-0.085*</td>
<td>-0.092**</td>
</tr>
<tr>
<td></td>
<td>(0.033)</td>
<td>(0.040)</td>
<td>(0.037)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>July</td>
<td>-0.056</td>
<td>0.01</td>
<td>0.021</td>
<td>-0.071*</td>
</tr>
<tr>
<td></td>
<td>(0.04)</td>
<td>(0.052)</td>
<td>(0.046)</td>
<td>(0.039)</td>
</tr>
<tr>
<td>August</td>
<td>-0.069*</td>
<td>0.019</td>
<td>0.011</td>
<td>-0.063*</td>
</tr>
<tr>
<td></td>
<td>(0.037)</td>
<td>(0.043)</td>
<td>(0.041)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>Linear trend</td>
<td>0.032**</td>
<td>0.033**</td>
<td>0.007</td>
<td>0.027**</td>
</tr>
<tr>
<td></td>
<td>(0.0056)</td>
<td>(0.0065)</td>
<td>(0.0069)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Quadratic trend</td>
<td>-0.000089**</td>
<td>-0.00015**</td>
<td>0.000024</td>
<td>-0.000095**</td>
</tr>
<tr>
<td></td>
<td>(0.000032)</td>
<td>(0.00004)</td>
<td>(0.000038)</td>
<td>(0.000029)</td>
</tr>
</tbody>
</table>

Adjusted $R^2$ 0.94 0.84 0.91 0.89

Notes: The dependent variable in each column is the deflated retail price of the corresponding type of milk. There are 23 cities with 3588 observations. The estimates of fixed effect intercepts for the 23 cities are not reported here and are available upon request. Standard errors are in parentheses.

* Significantly different from zero at the 10% level.

** Significantly different from zero at the 1% level.
References


