

# Strategic Pricing Behavior under Asset Value Maximization

An Empirical Assessment of the U.S. Retail Margarine and Butter Markets

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May 2005

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## Abstract

This paper investigates a comprehensive assessment of firm strategic behavior under financial market uncertainty. A general theoretical model of market value maximization (MVM) is constructed using a traditional capital asset pricing format. The model built on the nonlinear Almost Ideal Demand Systems (AIDS) and structural first-order conditions is developed. By full information maximum likelihood (FIML) estimation, the model evaluates pricing strategies in the U.S. margarine and butter retail markets using 4-week interval scanner data from 1998 to 2002. The model of profit maximization is rejected in favor of the MVM structure, and it indicates that financial market uncertainty plays an important role in the pricing behavior in this industry. We estimate the price elasticities of demand for leading brands and investigate the degree of market power in this industry.

**Keywords:** Market Value Maximization, AIDS, FIML, Model Selection

*Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27, 2005*

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# 1 Introduction

The purpose of this paper is to develop a comprehensive theoretical and empirical assessment of firm strategic behavior under financial market uncertainty. The firms choose pricing strategies in a differentiated retail product market. A general theoretical model of market value maximization (MVM) is constructed using a traditional capital asset pricing format.

We develop and implement a model built on the nonlinear Almost Ideal Demand Systems (AIDS) and structural first-order conditions. By full information maximum likelihood (FIML) estimation, the AIDS model evaluates pricing strategies in the U.S. margarine and butter retail markets using 4-week interval scanner data from 1998 to 2002. We estimate the price elasticities of demand for leading brands and investigate the degree of market power in this industry.

The MVM model suggests Lerner indexes derived from profit maximization will be estimated above their true values. This is a simple misspecification bias that ignores the returns required to compensate firms for nondiversifiable risk. This is a crucial finding in light of the current state of industrial organization work and antitrust law.

Testable hypotheses generated from the theoretical structure are also evaluated. By the Wald and likelihood ratio tests, the model of profit maximization is rejected in favor of the MVM structure, and we conclude that financial market uncertainty plays an important role in the pricing behavior of firms in this industry. The result suggests that models of pure profit maximization may be largely misspecified. The Vuong and Wald tests rule out a stable benchmark equilibrium outcome (i.e. Bertrand, Stackelberg, etc) suggesting that market power varies and is derived from a combination of structural factors in the market. Finally, the results of our model are compared to that of a commonly presumed market structure: Bertrand pricing. The results indi-

cate fairly large differences in measured outcomes of elasticities and Lerner indexes of market power. This underscores the importance of getting the market structure correct before proceeding with subsequent empirical analysis.

The research in this paper provides several important additions and extensions to the literature. First, we are not aware of any previous attempt to estimate a flexible demand system while introducing financial market risk into the market structure. Second, this is a very large system comprised of three brands, an aggregation of all other brands and an aggregation of private labels. Most previous brand level studies have either worked with multiple brands in the pricing system alone, or worked with a few brands, and used linear ad hoc demand systems to estimate the full demand system. This study, therefore represents a full extension of the AIDS model to address pricing and financial risk in a disaggregated system. Third, there has been no previous attempt to evaluate pricing strategies in the U.S. margarine and butter retail markets.

The remainder of this section contains discussions of the demand system, roles of risk, capital asset pricing model, and new empirical industrial organization approach.

## 1.1 Almost Ideal Demand System

The analysis of strategic behavior of firms using a structural model is widely used in the New Empirical Industrial Organization (NEIO) literature. In many cases, researchers simplify the structural model by specifying ad-hoc or approximated demand specifications, and reduced form conditions because of the complexity of flexible demand and cost functions. However, ad-hoc demand specifications do not satisfy all the requirements of consumer theory.

Pioneered by Deaton and Muellbauer (1980a, b), the AIDS approach has been extensively used in the economics, marketing and agricultural economics literature.<sup>1</sup>

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<sup>1</sup>For example, Duffy (1995), Richards et al (1997), Verbeke and Ward (2001), Cotterill et al

Recently, Dhar, Chavas, and Gould (2003) [DCG] estimated a pricing system for the U.S. carbonated soft drink industry and rejected the commonly applied assumption of expenditure exogeneity. The research in this study uses DCG as a key point of departure. In particular, we begin with the AIDS structure, which provides a fully flexible functional form for the purpose of demand estimations. A common alternative is the random coefficients discrete choice model of demand. Although this model can reduce the number of parameters to be estimated, it often imposes restrictions that may not be implied by the general utility theory (see Bajari and Benkard (2003) for a discussion of this point). We then incorporate risk concerns and consider demand as operating through an almost ideal demand system. We also estimate expenditures as endogenous to the system.

## 1.2 Market Value Maximization

In traditional industrial organization models, firms are assumed to maximize profits. However, the profit maximization assumption implicitly ignores potentially other important considerations of the firm. In particular, firms may seek to maximize the returns to its capital as it perceives the functioning of capital asset pricing in publicly traded stock markets. In that sense, the firm sees a trade-off between raw short-term profit maximizing decisions and trying to endogenously control or minimize nondiversifiable risk. Firms can seldom announce list prices, contract for advertising, set quality, and select output levels after observing demand. Instead, at least some of these operating decisions typically must be completed *ex ante*, and stochastic demand then necessitates decision-making under risk.

One of the goals in this study is to investigate firm pricing decisions building from a model of asset value maximization under imperfect competition and uncertainty (2000), Eakins and Gallagher (2003), and Jones et al (2003).

tainty. The vast majority of industrial organizational theory is constructed on the premise that firms maximize profits. In practice however, firm managers driven by incentive packages may focus on equity valuation, which is only partially derived by profitability. Stability of profits and demonstrating growth in profits also represent major goals of firms seeking higher equity values. In its simplest form, we might think about a manager that is aware of financial market factors in setting prices. When profit objectives are being exceeded, perhaps the manager opts for a more competitive posture to drive up the market share. Perhaps the manager chooses to increase promotion activities, which may drive down profits but assure greater brand identity and a perception of product sales stability. The decision trade-off arrives through joint financial market objectives of profitability and financial market risk. We pay attention to risk factors when firms can choose pricing strategies and market structures. The MVM model developed in this paper is a general model with a special case of simple profit maximization. As a result, the empirical test of the single minded profit maximization objective is straightforward.

### **1.3 Capital Asset Pricing Model**

The capital asset pricing model (CAPM) was independently developed by Sharpe (1964), Lintner (1965), and Mossin (1966). This model assumes that the investor's objective is to maximize the expected return of portfolios, subject to an acceptable level of risk (or minimize risk, subject to an acceptable expected return). The assumption of a single period, coupled with assumptions about the investor's attitude toward risk, allows risk to be measured by the variance (or standard deviation) of the portfolio's return. The CAPM states that the expected return of any risky asset is a linear function of its tendency to co-vary with the market portfolio.

Although the single-period CAPM framework adopted in this study came under

considerable debate during the 1990s,<sup>2</sup> as pointed out in Frankfurter (1995), the CAPM is still an acceptable approach for evaluating and pricing financial assets compared with all other methodologies. Obviously, if risk can be fully arbitrated, then firms would not worry about risk and proceed toward profit objectives. No anecdotal or empirical evidence suggest risk transfer markets can or ever will fully achieve such a theoretical objective. In this paper, the CAPM structure is used primarily as tool to describe and structure the financial market objective. The role of financial market risk is then allowed to enter into product market decisions to measure their outcome. Therefore, even if CAPM is but a rough gauge of financial market activity, the theoretical effects would not generally be overturned with a more precise measure of financial market behavior. Empirically, the effects of financial market risk enter very simply into the demand system and follow the CAPM prescription for risk management, which allows for a direct test of financial market influence on product markets.

## 1.4 New Empirical Industrial Organization

The approach of full structural estimation of all relevant firm-specific parameters is a key feature of the “new empirical industrial organization (NEIO)” (Bresnahan 1989). A primary goal of research in this area is the understanding of firms’ competitive interactions in a particular industry.

The NEIO estimates “conduct parameters” that reveal the nature of a firm’s interaction with each of the other firms. Given a set of firms, the size and magnitudes of these parameters characterize the pair-wise interaction between any two of them. Such an approach has been referred to the conjectural variations (CV) approach in the

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<sup>2</sup>See Fama and French (1992), Black (1993a, 1993b), and Kothari, Shanken and Sloan (1995) for details.

economics literature, for example, Iwata (1974), and Roberts and Samuelson (1988).

An alternative to the conduct parameter framework is the “menu-approach,” which consists of estimating various alternative games represented by the demand and respective first-order conditions, and identifying the best-fitting game.<sup>3</sup> The conduct parameter approach offers the advantage that it is empirically more tractable when the number of firms and/or the number of competitive instruments exceeds two. However, this argument is true only when the competing games are nested in one another. If non-nested models are present, it turns out that the menu-approach is more desirable. Because the collusive games are non-nested and the Bertrand, Stackelberg leader, Stackelberg follower, and consistent conjectures are nested in the CV games, both the menu-approach and conduct parameters are used in the current study.

Essentially, the market structure is chosen as the model that best measures the gap between the demand curve and the marginal cost curve. The structural first-order conditions are obtained like those in the much of NEIO literature. However, the current model differs in an important aspect that the objective functions of maximizing both market values and profits are considered. The strategic behaviors on the choice variable, price, with different combinations of Nash, Stackelberg, and collusion are tested. Note that only pure strategies are considered to reduce the complications of analysis.

The rest of this paper is organized as follows: Section 2 presents the demand system and all the equations used in the estimation. In section 3 we discuss the data issues. The details that describe estimation procedures, along with structured hypothesis tests, and criteria for selecting the market structure are contained in section 4. All empirical results and discussions are collected in section 5. Finally, concluding

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<sup>3</sup>See, for example, Gasmı, Laffont, and Vuong (1992) [GLV], Kadiyali (1996), and Vilcassim, Kadiyali, and Chintagunta (1999) [VKC].

remarks are provided in section 6.

## 2 Conceptual Model

Because the fully flexible AIDS model is highly nonlinear, some assumptions on the supply/cost side are important to reduce the complexity of analysis and make the empirical implementation more tractable. Therefore, for the structure used in this study, the following assumptions are maintained:

- (1) Exogenous demand shifters.
- (2) Constant marginal cost.
- (3) Firms have full information about own/rival's pricing strategies and cost.
- (4) Firms only play pure strategies.
- (5) Pricing strategies of each brand are made simultaneously.
- (6) Firms use the same pricing strategies in the study period.

Assumption 1 does not apply to the endogeneity of expenditures. Assumption 2 simplifies the supply of raw material and promotion expenditure used to determine marginal costs and subsequently the output-market's structural characteristics. This assumption is common and performs reasonably well in structural market analysis, for example, VKC and GLV. Assumptions 3 through 6 are to facilitate the analysis of firm's strategies. With full information on own/rival's pricing strategies and cost, we do not have to deal with games with incomplete information. Assumption 4 eliminates formal tests of mixed strategies. Assumption 5 means that pricing strategies are made simultaneously and/or these strategies are not contingent on each other. Assumption 6 implies neither mergers nor acquisitions are considered. For example, the well-known case that Dairy Farmers of America (DFA) proposed to purchase Sodiaal North America brands in the Philadelphia and New York metropolitan market area



in Year 2000 is not considered in the study. With these assumptions at hand, we are ready to present the conceptual model. Let us begin with the demand specification.

## 2.1 Demand Specification: AIDS

In this section we first derive the ordinary presentation of Barten-Gorman AIDS model.<sup>4</sup> The modified AIDS model incorporating demographics will follow.

Let  $V(p, M)$  and  $E(p, u)$  denote indirect utility and expenditure functions defined by

$$\begin{aligned} V(p, M) &= \max_x \{U(x) : p'x \leq M\}, \\ E(p, u) &= \min_x \{p'x : u(x) \geq u\}, \end{aligned}$$

where  $U(x)$  is the direct utility function,  $x$  is the consumption bundle of a representative consumer and  $x = (x_1, \dots, x_n)$ ,  $p$  is a corresponding  $n \times 1$  price vector,  $M$  is income, and  $u$  is a reference utility level. By duality,

$$E(p, V(p, M)) = M, \quad x_i(p, M) = h_i(p, V(p, M)), \quad i = 1, \dots, n. \quad (1)$$

where  $x_i(p, M)$  is Marshallian demand and compensated (Hicksian) demand  $h_i(p, u) = \partial E(p, u) / \partial p_i$  obtained via Shephard's lemma.

In the demand analysis, it is generally desirable that a demographic modification of a demand system acts both through scaling, as originally proposed by Barten (1964), and through translating, as suggested by Gorman (1976). The modifications that scale and translate demand systems are referred as Barten-Gorman modifications. An example of general Barten-Gorman forms of budget shares is

$$w_i(M, p, d) = t_i(d) + s(d)w_i(M^*(p, d), p, d), \quad (2)$$

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<sup>4</sup>More discussions on the Barten-Gorman AIDS model can be found in Perali (2003).

where  $t_i(d)$  is a translating function,  $s(d)$  is a budget share scaling function,  $d$  is a vector of demographic variables, and  $M^*(p, d)$  is modified income.

Demand with budget shares affine in the logarithm of income is the logarithmic subclass of the *Price Independent Generalized Linear* (PIGL) class, which Muellbauer (1975, 1976) terms *PIGLOG*. The demographically modified Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980a, b) are considered below. It takes Barten-Gorman form specified as equation (2). The expenditure function associated with this preference structure is

$$E(p, u, d) = \left[ a(p, d) (\Psi(u))^{b(p, d)} \right] p^T(p, d). \quad (3)$$

Taking the logarithm on equation (3) yields

$$\ln E(p, u, d) = [\ln a(p, d) + b(p, d) \ln (\Psi(u))] + \ln p^T(p, d), \quad (4)$$

where the household-specific price index  $\ln a(p, d)$  is specified as a translog,

$$\ln a(p, d) = \delta + \sum_{i=1}^n \alpha_i \ln(p_i^*) + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij}^* \ln(p_i^*) \ln(p_j^*), \quad (5)$$

and the index  $b(p, d)$  is a Cobb-Douglas price aggregator,

$$b(p, d) = \exp \left[ \sum_{i=1}^n \beta_i \ln(p_i^*) \right]. \quad (6)$$

Moreover, the logarithm of overhead function is given by

$$\ln p^T(p, d) = \sum_{i=1}^n t_i(d) \ln p_i^*. \quad (7)$$

The corresponding Barten-Gorman AIDS indirect utility function linear in  $\ln M$  can be obtained from equation (4) by duality,

$$\begin{aligned} \ln V &= \ln (\Psi(u)) = \frac{\ln M^* - \ln a(p, d)}{b(p, d)} \\ &= \frac{\ln M^* - \left[ \delta + \sum_{i=1}^n \alpha_i \ln(p_i^*) + \frac{1}{2} \sum_{i=1}^n \sum_{j=1}^n \gamma_{ij}^* \ln(p_i^*) \ln(p_j^*) \right]}{\exp \left[ \sum_{i=1}^n \beta_i \ln(p_i^*) \right]}, \end{aligned}$$

where  $\gamma_{ij} = (\gamma_{ij}^* + \gamma_{ji}^*)/2$ ,  $\ln M^* = \ln M - \sum_{i=1}^n t_i(d) \ln p_i^*$ , and  $p_i^* = p_i m_i(d)$ . Note that  $m_i(d)$  is a scaling demographic function. Therefore, the Barten-Gorman AIDS ordinary budget share obtained via Roy's identity is

$$w_i = \alpha_i + t_i(d) + \sum_{j=1}^n \gamma_{ij} \ln(p_j^*) + \beta_i [\ln M^* - \ln a(p, d)]. \quad (8)$$

For empirical convenience, the translating demographic function  $t_i(d)$  and the scaling demographic function  $m_i(d)$  are generally specified as

$$t_i(d) = \sum_{r=1}^R \tau_{ir} \ln(d_r), \quad m_i(d) = \exp \left[ \sum_{r=1}^R \kappa_{ir} \ln(d_{ir}) \right], \quad \forall r = 1, \dots, R. \quad (9)$$

However, the choice of the functional form of the demographic function is not restricted to any particular one.

With the Barten-Gorman AIDS ordinary budget share equation (8), we may incorporate demographic variables into the demand system. In particular, we specify

$$m_i(d_{ilt}) = \left[ \sum_{l=1}^L \sum_{t=1}^T d_{ilt} \right]^{-1}, \quad t_i(d) = \sum_{k=1}^K \lambda_{ik} Z_{klt},$$

where  $Z_{klt} = \ln [d_{klt} m_k(d_{klt})]$ .

Therefore, the modified AIDS model is as follows:

$$w_{ilt} = \alpha_{0i} + \sum_{k=1}^K \lambda_{ik} Z_{klt} + \sum_{j=1}^N \gamma_{ij} \ln(p_{jlt}) + [\beta_i \ln(M_{lt}) - \beta_i \ln(P_{lt})], \quad (10)$$

$$i = 1, \dots, N; l = 1, \dots, L; t = 1, \dots, T;$$

where  $w_{ilt} = p_{ilt} X_{ilt} / M_{lt}$  is the market share for the product of brand  $i$  consumed in city  $i$  at time  $t$ ,  $X$  is consumer goods,  $p$  is goods price for  $X$ , and  $M$  is total expenditure on  $N$  goods.<sup>5</sup>  $Z_{klt}$  is the  $k^{\text{th}}$  socio-demographic variable, and  $\gamma_{ij}$  is a cross-effect of brand  $j$ 's price on the market share of brand  $i$ .  $\beta_i$  can be interpreted

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<sup>5</sup>We drop subscripts for notational simplicity wherever no confusion is caused.

as the slope of demand function while  $P$  is a price index defined by

$$\begin{aligned} \ln(P_{lt}) &= \delta + \sum_{m=1}^N \alpha_m \ln(p_{m lt}) + \sum_{m=1}^N \sum_{k=1}^K \lambda_{mk} Z_{k lt} \ln(p_{m lt}) \\ &+ \frac{1}{2} \sum_{m=1}^N \sum_{j=1}^N \gamma_{mj} \ln(p_{m lt}) \ln(p_{j lt}). \end{aligned} \quad (11)$$

The theoretical structure implies symmetry restrictions (Equation (12a)) and homogeneity restrictions (Equation (12b)):

$$\gamma_{ij} = \gamma_{ji}, \forall i \neq j. \quad (12a)$$

$$\sum_{i=1}^N \alpha_{0i} = 1; \quad \sum_{i=1}^N \lambda_{ik} = 0, \forall k; \quad \sum_{i=1}^N \gamma_{ij} = 0; \quad \sum_{i=1}^N \beta_i = 0. \quad (12b)$$

To maintain theoretical consistency with the AIDS model, additional restrictions are applied to the demographic translating parameters

$$\alpha_{0i} = \sum_{r=1}^9 \nu_{ir} D_r, \quad \sum_{r=1}^9 d_{ir} = 1, \quad i = 1, \dots, N. \quad (12c)$$

where  $\nu_{ir}$  is the parameter for brand  $i$  associated with the regional dummy variable  $D_r$  for region  $r$ . As a result, the demand equations do not have intercept terms. The parameter  $\delta$  may be difficult to estimate and is often set to some predetermined value. We follow the approach suggested by Moschini, Moro, and Green (1994) and set  $\delta = 0$ .

## 2.2 The Model of Market Value Maximization

One of goals of this study is to develop hypotheses tests about the two possible objectives of the firm: profit maximization and market value maximization. The next subsection that follows presents the market value maximization model and highlights the differences of the two objective functions.

Before we introduce the model of MVM, the uncertainty term has to be incorporated to the analysis. The uncertainty term is assumed on the demand side only.

### 2.2.1 Demand Uncertainty

There are two common settings used to convey demand uncertainty:  $\tilde{X} = X + \tilde{e}$  or  $\tilde{X} = X(1 + \tilde{e})$ , where  $X$  is quantity demanded. Of course, the implications of these two settings are very different. We assume the managers of each brand know the pricing strategies of other brands (i.e., market structure is known) and the prices of raw materials, so the uncertainty comes from quantity demanded only. To facilitate the analysis, below we assume the uncertainty is additively linear, i.e.,  $\tilde{X} = X + \tilde{e}$ . and  $\tilde{e}$  is assumed to be normally distributed with mean zero. It turns out that the demand system incorporating the uncertainty is given by

$$\tilde{w}_{ilt} = w_{ilt} + \varepsilon_{ilt}, i = 1, \dots, N; l = 1, \dots, L; t = 1, \dots, T. \quad (13)$$

where  $w_{ilt}$  is defined in Equation (10) and  $\tilde{\varepsilon}_{ilt} = p_{ilt}\tilde{e}_{ilt}/M_{lt}$ , capturing the uncertainty of the market share facing the firms.

### 2.2.2 First-Order Conditions for Prices under MVM

We adopt a model of MVM where the decision maker pursues the interests of risk-averse owners of diversified-portfolio by maximizing the firm's equilibrium value in the capital market. To reflect the financial incentives, we employ the capital asset pricing model (CAPM). Based on CAPM, MVM firm  $h$  maximizes

$$V_h = \frac{1}{1+r} [E(\tilde{\pi}_h) - \lambda \text{COV}(\tilde{\pi}_h, \tilde{r}_m)], \quad (14)$$

where  $r$  is the risk-free interest rate,  $\tilde{\pi}_h$  is the stochastic perpetual flow of net earnings,  $\lambda$  is the equilibrium shadow price of market risk reduction, defined by  $\lambda = [E(\tilde{r}_m) - r]/\sigma_m^2$  and  $\tilde{r}_m$  is the stochastic rate of return of market portfolio.

Firm  $h$ 's profits are given by

$$\tilde{\pi}_h = \sum_{t=0}^{\infty} D^t \left\{ \sum_{i=1}^{n_h} [(p_{it} - c_{it})(X_{it} + \tilde{e}_{it}) - U_i] \right\}, \quad (15)$$

where  $n_h$  is the number of brands produced by firm  $h$ ,  $D$  is the discount factor, and  $U_i$  is the fixed cost (see section 2.3 for details). Location subscript  $l$  is suppressed for notational simplicity. Brand  $i$  of firm  $h$  faces demand function  $X_{it} = X_{it}(p_{it}, p_{-it})$ , where  $X_{it}(\cdot)$  can be derived from (10);  $p_{-it}$  is pricing strategy of rival brands other than brand  $i$ .

We then derive first-order conditions on price. The first-order conditions in price of MVM are given by

$$X_i - \lambda \text{COV}(\tilde{e}_i, \tilde{r}_m) = - \sum_{k=1}^{n_h} \left[ (p_k - c_k) \sum_{j=1}^N \frac{\partial X_k}{\partial p_j} \frac{\partial p_j}{\partial p_i} \right], \quad \forall i, h. \quad (16)$$

The pricing conjectural variation  $\eta_{ji} = \partial p_j / \partial p_i$  is given by the brand  $i$ 's conjecture of brand  $j$ 's price response. Note that  $\eta_{ji} = 0$ ,  $\forall j \neq i$  under the Bertrand competition in price. Note that under the setup of additively linear uncertainty  $\tilde{X} = X + \tilde{e}$  the difference between MVM and profit maximization is the second term on the left side of the equation. This also allows us to test the significance of the financial component.

We may introduce an additional parameter  $\theta$  to construct a general MVM presentation of first-order conditions. As a result, general first-order conditions are given by

$$X_i - \theta \lambda \text{COV}(\tilde{e}_i, \tilde{r}_m) = - \sum_{k=1}^{n_h} \left[ (p_k - c_k) \sum_{j=1}^N \frac{\partial X_k}{\partial p_j} \frac{\partial p_j}{\partial p_i} \right], \quad \forall i, h. \quad (17)$$

where  $\theta$  measures how the financial component impacts on the product market. A positive  $\theta$  implies that the decision maker considers financial market risk when making product market decisions. Equation (17) turns out to nest two special objectives that firms pursue: pure MVM if  $\theta = 1$  and profit maximization if  $\theta = 0$ . Note that although all of above arguments are based on the additively linear uncertainty, they can be easily applied to a more general case.

### 2.3 Constant Marginal Cost

We assume constant linear marginal cost specification which is common and performs reasonably well in structural market analysis (see for example, VKC and GLV). The total cost function is

$$TC_{ilt} = U_i + c_{ilt}X_{ilt}, \quad (18)$$

where  $U_i$  is the brand specific unobservable cost component and is assumed fixed (i.e., does not vary at the mean of the data).  $c_{ilt}$  is the observable marginal cost component and specified as

$$c_{ilt} = \mu_0 + \mu_1 UPV_{ilt} + \sum_{j=1}^2 \mu_{2j} MCH_{iltj}, \quad (19)$$

where  $UPV_{ilt}$  is the unit per volume and represents the average size of the purchase and  $MCH_{iltj}$  is the in-store marketing, including price reduction and all other merchandising (display and feature).

This setting is different from that in the model without any cost information, for example, Nevo (2001). Nevo (2001) uses the information on the demand side to recover the constant cost by assuming the Bertrand competition while the current study uses in-store marketing as a proxy to estimate the marginal cost. The latter provides flexibility in modeling the market structure and admits the empirical tests among the competing models.

### 2.4 Expenditure Endogeneity

Following Blundell and Robin (2000) and DCG, to control expenditure endogeneity, the reduced form expenditure equation is specified as

$$\begin{aligned} M_{it} &= f(\text{time trend, income}) \\ &= \xi Trend_t + \sum_{r=1}^9 \zeta_r D_r + \psi_1 INC_{it} + \psi_2 INC_{it}^2, \quad t = 1, \dots, T, \end{aligned} \quad (20)$$

where  $Trend_t$  is a linear time trend, capturing any time specific unobservable effect on consumer's butter and margarine expenditures. The variable  $INC_{it}$  is median household income in city  $l$  at time  $t$  which is used to capture the effect of income differences on butter and butter substitutes purchases.

### 3 Discussion of the Data

The data sets for this study are from Information Resources, Inc. (IRI), CMR, COMPUSTAT, Center for Research in Security Prices (CRSP), and Current Population Survey (CPS).

#### 3.1 IRI

The main data set from IRI consists of different measures of sales and prices, and in-store marketing activities. The information contains all UPC-coded products in the margarine and butter category from retail store scanners for 32 cities/markets<sup>6</sup> across the United States and 58 periods based on 4-week interval from January 25, 1998<sup>7</sup> to June 9, 2002. As a result, there are 13 periods in 1998-2001 and 6 periods in 2002.

In IRI's main dataset, there are 744 brands from 134 parent companies,<sup>8</sup> in which the butter category contains 351 brands while the category of butter substitutes has 385 brands, including margarine, spreads, and butter blends. There exist no explicit data on individual private labels; instead, IRI provides the aggregations of

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<sup>6</sup>They are Atlanta, Baltimore/Washington, Boise, Boston, Buffalo/Rochester, Chicago, Columbus, Dallas/Ft Worth, Denver, Des Moines, Detroit, Indianapolis, Jacksonville, Kansas City, Little Rock, Memphis, Milwaukee, Minneapolis/St Paul, New Orleans/Mobile, New York City, Oklahoma City, Philadelphia, Phoenix/Tucson, Pittsburgh, Portland (OR), Raleigh/Greensboro, Richmond/Norfolk, Salt Lake City, San Diego, San Francisco/Oakland, Seattle/Tacoma, and Tampa/St Petersburg.

<sup>7</sup>The dates covered in the first period are from December 29, 1997 to January 25, 1998.

<sup>8</sup>However, we only analyze 736 brands from 130 firms after dropping some unreasonable data points.



all branded products and private labels. Subject to the data availability and obvious computational limitation, the estimation involved the top 3 brands, an aggregate “all other” group and private labels. Both private labels and all others are treated as two individual brands. That is, firms of private labels and all others are assumed to behave coordinately, and then they have same pricing and marketing strategies within their own categories.

[Table 1 is about here.]

As shown in Table 1, the market share of private labels is 23.95%.<sup>9</sup> Top 3 brands have 62.76% of market share. Figure 1 depicts the market shares by each brand. Except the holiday seasons, the market share of each brand is stable which may imply that this is a mature market. The volume sales of each brand are shown in Figure 2. In Figure 2, the volume sales have four peaks which occur during the holiday seasons from 1998 to 2001. If we closely examine Figures 1 and 2, the total volume sales increased during the holiday seasons. However, the market share of brand 1 dropped while those of the rest increased in these periods. To adjust the seasonality, we add 12 dummy variables (*Season*).<sup>10</sup>

The brand prices are presented in Figure 3. Brand 3 charges relatively high prices because its major product is butter. We add a dummy variable (*Butter*) to measure the impacts caused by this fact.

[Figures 1, 2 and 3 are about here.]

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<sup>9</sup>According to previous studies, the private labels in the butter market have about 50% of market share. However, we explore margarine and butter together here.

<sup>10</sup>Note that our main dataset is based on a 4-week interval. There are 13 periods in each year from 1998 to 2001.

Though there are 32 cities in the dataset, to keep panel data balanced, the final number of cities investigated is 28.<sup>11</sup> Because there are 58 observations in each city, each brand has 1624 (=58\*28) complete data observations.

The variables used in the analysis consist of price, volume sales, dollar sales, unit sales, volume per unit, in-store marketing variables: price reduction and all other merchandising (feature and display).<sup>12</sup>

### 3.2 Financial Component and Simulation

Under the CAPM framework the financial components we need are the annual rate of return of market portfolio ( $\tilde{r}_m$ ) and the annual risk-free rate ( $r$ ), which can be obtained from the database of Center for Research in Security Prices (CRSP). The annual rate of return of market portfolio is computed from CRSP Indices on S&P 500. The annual risk-free rate is based on the 90 Day Bill Returns of U.S. Treasury. In the study period the mean of  $\tilde{r}_m$  is 7.35% and its standard deviation is 18.8% whereas those of annual risk-free rate are 5.23% and 0.78% respectively.

An additional variable is the uncertainty term,  $\tilde{e}_i$ . It is simulated using a Monte Carlo method. Therefore,  $\tilde{e}_i$  is a random drawing from a standard normal distribution  $N(0, 1)$  and the moment matching technique is used to adjust the samples. To match the first and second moments we calculate the mean of samples,  $E(\tilde{e}_i)$ , and the standard deviation of the samples,  $\sigma_i$ . The adjusted samples is given by  $[\tilde{e}_i - E(\tilde{e}_i)]/\sigma_i$ ,  $i = 1, 2, \dots n$ . These adjusted samples have the correct mean of zero and the correct standard deviation of 1. The adjusted samples are used for all calculations. We estimate each model 30 times with different draws of  $\tilde{e}_i$  and assume it is sufficient to eliminate any noticeable error.

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<sup>11</sup>Those with missing values are excluded.

<sup>12</sup>The in-store marketing is measured in dollars per pound.

### 3.3 Demographic Data

The demographic data consist of two parts: (1) 9 division binaries are from Census Bureau Geography<sup>13</sup> and (2) 7 other demographic variables are from Current Population Survey – Annual Demographic Survey (March CPS Supplement)<sup>14</sup> and IRI for 1998-2002. The data of CPS can be obtained by using DataFerrett<sup>15</sup> provided by the US Census Bureau.

The second part includes PERLT10K (percentage of household earning less than \$10,000), PERGT50K (percentage of household earning more than \$50,000), HUN-  
DER15 (average number of people under age 15), H\_NUMBER (average household size), A\_AGE (median household age), FSPANISH (percentage of Hispanics), and POPU (population).<sup>16</sup>

We merge CPS data with IRI data by using the variable of GMMSA (Geography - MSA or PMSA FIPS Code) in the CPS database. The areas covered by CPS and IRI are approximately the same. Furthermore, because the March CPS Supplement database is annual, the linear projection is used to obtain the 4-week interval data.

The descriptive statistics presented in Table 1 summarize the discussions in this section. In the next section we will discuss the procedures used in the estimation.

## 4 Estimation Procedures

The full demand system could be estimated with a full information maximum likelihood that measures the wedge between price and marginal costs while simultaneously accounting for revenue uncertainty through the CAPM structure. To explore the ef-

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<sup>13</sup>See Reference Resources for Understanding Census Bureau Geography. The website is <http://www.census.gov/geo/www/reference.html>.

<sup>14</sup>See [http://www.nber.org/data/cps\\_basic.html](http://www.nber.org/data/cps_basic.html).

<sup>15</sup>See <http://dataferrett.census.gov/>.

<sup>16</sup>Population data come from IRI.

fects of risk, we estimate the demand system [Equations (10), (17), (19), and (20)]. The remainder of this section is devoted to describe the detail model selection procedures used in this study.

#### 4.1 Model Selection 1: MVM vs. Profit Maximization

The general MVM presentation in equation (17) nests pure MVM ( $\theta = 1$ ) and profit maximization ( $\theta = 0$ ). One can test these two hypotheses by conducting the likelihood ratio test or Wald test. The likelihood ratio statistic for model selection is given by

$$LR = -2 [\ln L(\mathbf{b}^*) - \ln L(\mathbf{b})],$$

where  $\mathbf{b}^*$  is the vector of parameter estimates of either model of MVM or profit maximization;  $\mathbf{b}$  is the vector of parameter estimates of the general model; and  $\ln L(\cdot)$  is the log value of the likelihood function.  $LR$  has an asymptotic  $\chi^2(q)$  distribution, where  $q$  is the number of restrictions imposed. That is, the degrees of freedom equal to the difference between the number of parameters in the general model and the restricted model (MVM or profit maximization). For the current work,  $q = 1$ .

The alternative Wald test can also evaluate nested models. We briefly review below and then turn to the second set of model selection: market structure.

Let  $\hat{\mathbf{b}}$  be the vector of parameter estimates obtained without restrictions. Suppose the null hypothesis contains a set of restrictions

$$H_0 : c(\mathbf{b}) = \mathbf{q}. \tag{21}$$

If the restrictions are valid, then at least approximately  $\hat{\mathbf{b}}$  should satisfy them. If the hypothesis is erroneous, however,  $c(\hat{\mathbf{b}}) - \mathbf{q}$  should be farther from  $\mathbf{0}$  than would be explained by sampling variability alone. The Wald test is intended to formalize this

notion. The Wald statistic is given by

$$W = [c(\widehat{\mathbf{b}}) - \mathbf{q}]' (\text{Var}[c(\widehat{\mathbf{b}}) - \mathbf{q}])^{-1} [c(\widehat{\mathbf{b}}) - \mathbf{q}]. \quad (22)$$

Under  $H_0$ , in large samples,  $W$  has a chi-squared distribution with degrees of freedom equal to the number of restrictions; i.e., the number of equations of  $c(\widehat{\mathbf{b}}) - \mathbf{q} = \mathbf{0}$ . A large value of  $W$  leads to rejection of the hypothesis.

The advantage of the Wald test is that it only requires computation of the unrestricted model. However, we still need to compute the covariance matrix in Equation (22). Since the restrictions to be investigated are linear, that is,  $c(\mathbf{b}) = \mathbf{Rb}$ , the Wald statistic can be simplified as

$$W = [\mathbf{Rb} - \mathbf{q}]' (\mathbf{RVar}[\widehat{\mathbf{b}}]\mathbf{R}')^{-1} [\mathbf{Rb} - \mathbf{q}]. \quad (23)$$

The degree of freedom is the number of rows in  $\mathbf{R}$ .

## 4.2 Model Selection 2: Market Structure

In this section we discuss the model selection procedures. Since we only analyze pure strategies, managers of each brand have four strategies available: Stackelberg Leadership, Stackelberg followership, non-cooperative Nash-Bertrand, and collusion. It turns out that there are  $4^5$  possible combinations in pricing strategies to be investigated.

Given the computational requirements of the FIML estimation, it would be very costly to actually estimate all of the possible structures in this manner. In his seminar work, Dixit (1986) shows that most pure strategy games can be nested in a conjectural variation (CV) model. The CV can be interpreted as fixed points that establish consistency between the conjecture and the reaction function associated with a particular game. As investigated in GLV the collusive game is not nested in the model of CV. In addition to the collusive model, therefore, we can determine the strategies

that managers of each brand use by testing the statistical significance of the restrictions imposed by the games on the estimated CV parameters. The procedure of the model selection consists of two steps:

**Step I:** Use the Vuong test to determine the best fitted among non-nested models.

**Step II:** From the best fitted model, estimate the CV parameters and use the Wald test to test different combinations of non-cooperative strategies, including Bertrand, Stackelberg leader, Stackelberg follower, and consistent conjectures.

#### 4.2.1 Step I

With regard to model selection, 5 possible combinations of collusions in pricing strategies were considered, including C0 (each brand operates non-collusively), C1 (brand 1+brand 2), C2 (brand 1+brand 3), and C3 (brand 2+brand 3), C4 (brand 1+brand 2+brand 3). Table 4 depicts the arrangements and corresponding numbers of conjectural variations of 5 models.

We do not incorporate All Others or Private Labels in the collusion analysis since each of them consists of hundreds of individual brands. It seems reasonable to assume that behaving independently is easier than behaving cooperatively for these two aggregate brands. This assumption dramatically reduces the analysis complications. There are 5 candidates (C0, C1, C2, C3, and C4) in pricing spaces. Thus, we need to determine the best fitted model from 5 non-nested competing ones.

It is worth mentioning that we assume that those brands outside the collusions play CV strategies since the CV model is unrestricted and convenient for most pure strategy games to be nested in. Another remark needs to be addressed here. To simplify the analysis we assume that only one collusion can exist. That is, we do not deal with the cases of more than two coalitions in the market.

The cases of C0, C1, C2, C3, and C4 in pricing space are estimated in the FIML

estimation mentioned above and then the Vuong test is used to determine the best fitted model because these 5 models are non-nested. The Vuong test is briefly discussed in the next section.

#### 4.2.2 Vuong Test

Vuong (1989) proposes a test statistic for non-nested models that is well suited for our model selection purposes. Let  $f_k(y_t|\mathbf{x}_t)$  denote the predicted probability that the random variable  $\mathbf{Y}$  equals  $y_t$  under the assumption that the distribution is  $f_k(y_t|\mathbf{x}_t)$ , for  $k = i, j$ , and let

$$LR_t(\hat{\mathbf{b}}_i, \hat{\mathbf{b}}_j) = \ln \left( \frac{f_i(y_t|\mathbf{x}_t)}{f_j(y_t|\mathbf{x}_t)} \right).$$

Vuong's statistic for testing the non-nested hypothesis of model  $F_i$  against model  $F_j$  is given by

$$V = \frac{\sqrt{n} \left[ \frac{1}{n} \sum_{t=1}^n LR_t \right]}{\sqrt{\frac{1}{n} \sum_{t=1}^n (LR_t - \overline{LR_t})^2}}. \quad (24)$$

Vuong shows that  $V$  is asymptotically distributed as standard normal. The statistic is bidirectional. If  $|V|$  is less than the critical value, the test does not favor one model or the other; otherwise, large values favor model  $F_i$  whereas small (negative) values favor model  $F_j$ . This implies that the test statistic not only tells us whether the models are significantly different from each other but also the sign of the test statistic indicates which model is appropriate.

The previous tests are based on the *unadjusted* likelihood ratio (LR) statistic. There are, however, many parallel statistics that can be used to form a model selection test. We consider the following *adjusted* LR statistic:

$$\widetilde{LR}_n(\hat{\mathbf{b}}_i, \hat{\mathbf{b}}_j) \equiv LR_n(\hat{\mathbf{b}}_i, \hat{\mathbf{b}}_j) - K_n(F_i, F_j), \quad (25)$$

where  $K_n(F_i, F_j)$  is a correction factor depending on the characteristics of the competing models  $F_i$  and  $F_j$  such as their number of parameters. We use two ex-

amples to illustrate the possible corrections, which are  $K_n(F_i, F_j) = d_i - d_j$  and  $K_n(F_i, F_j) = (d_i/2) \ln(n) - (d_j/2) \ln(n)$ , corresponding to Akaike (1973) and Schwarz (1978) information criteria, where  $d_k$  is the parameter number of model  $F_k$ , for  $k = i, j$ . The adjustment is important for the competing models with different numbers of parameters (like the current models) because more parameters usually imply higher likelihoods, which needs to be corrected. At the stage of the Vuong test, as a result, we run the unadjusted as well as two adjusted LR tests. Based on these tests, we will select the most fitted model.

### 4.2.3 Step II

Once obtaining the best fitted model, we further explore the CV model. Since we analyze 5 brands in this study, if every brand can be a Stackelberg leader, there are 7 probable games for the CV models, including the Bertrand competition and consistent conjectures, in pricing strategies. The notations below are B (Bertrand),  $S_i$  (brand  $i$  is a Stackelberg leader),  $i=1, 2, \dots, 5$ , and CS (consistent conjectures).

In the CV model,  $CV_{ij} = 0, \forall i \neq j$  for the Bertrand game. For the Stackelberg game, Dixit (1986) has demonstrated that at equilibrium the CV parameter of a Stackelberg leader should be equal to the slope of the reaction function of the follower while follower's CV parameter should be equal to zero.

Based on the CV estimates, we compute the slopes of the reaction function of followers under the hypothetical Stackelberg leadership for each brand. The fixed points are identified by setting 10,000 iterations.<sup>17</sup> Because B,  $S_1$ - $S_5$ , CS are nested in the CV model, we may test different combinations of Bertrand, Stackelberg leader, Stackelberg follower, and consistent conjectures by the Wald test.

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<sup>17</sup>In general each converges in less than 100 iterations if the fixed points do exist.



## 5 Empirical Results

This section contains all the results and discussions from the estimation and testing procedures described in the previous section. We begin with the FIML estimation.

### 5.1 FIML Estimation

The estimation of the AIDS model, applied to the U.S. retail margarine and butter market, is implemented using a full information maximum likelihood (FIML) approach. The demand equations and the MVM first-order conditions as well as marginal costs and expenditure endogeneity are jointly estimated. The estimation is run for 3 firm-level brands, an aggregate category for all other brands, and a final category for private label brands, in which Brand 1 and 2 produce margarine and Brand 3 produces butter only while All Others and Private Labels produce both butter and margarine. Starting values are determined from a linearized version of the demand equations and the convergence criterion for the gradients is set at 0.0001.

Note that, by definition,  $\sum_{i=1}^5 w_i = 1$ , where  $w_i$  is the expenditure share of good  $i$ . Thus, the dependent variables are linearly dependent, implying the singularity of the variance of the error terms. Practically this singularity problem can be handled by dropping one equation, thus estimating the remaining 4 demand equations. The parameters from the equation dropped can be recovered from the homogeneity restrictions. As a result, the FIML estimation in this study consists of 10 equations in the system, including 4 demand equations, 5 first-order conditions, and 1 equation for expenditure endogeneity.

With regard to numbers of parameters in the estimation, there are 91 demand-related parameters from equation (10), 12 expenditure endogeneity parameters from equation (20), 20 marginal cost parameters from equation (19). For equation (17)

the parameters include 1 finance component and the price conjectural variation (CV) whose number depends on the market structure specified in each competing model detailed in column (4) in Table 4.<sup>18</sup> See Table 2 for more details.

[Table 2 is about here.]

Using standard model selection criterion, we select firm's objective and the market structure that best fit the data and impose that structure on all other analyses. Section 5.2 and 5.3 contains the results of the model selection procedures. Section 5.2 examines the assessment of the market value maximization principal. In particular, a restricted (profit maximization) system is estimated and tested versus an unrestricted system (general market value maximization). The Lerner index, price, and expenditure elasticities are computed based on the best fitted model determined in section 5.3. While price and expenditure elasticities are presented and discussed in section 5.4, serving as a benchmark, the Lerner indexes under the profit maximization and Bertrand assumption in pricing are also reported in section 5.5. Note that all tables of empirical results are collected in the end of the paper.

## 5.2 Model Selection 1: MVM vs. Profit Maximization

One of our major research objectives is to explore whether firm level financial components can effect product market strategies. As indicated in equation (17), profit maximization is shown as simply a special case of the more general MVM model. In the first order condition, the general form contains the term  $\lambda\text{COV}(\tilde{e}_i, \tilde{r}_m)$ . Therefore, testing the significance of this term requires one additional parameter to be estimated. The purpose of conducting this test is to highlight the importance of market

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<sup>18</sup>The full parameter set is available upon request.

risk components, which are widely ignored in the traditional industrial organization literature.

The Wald test and likelihood ratio test are used to test if ignoring financial components is acceptable. The Monte Carlo method is employed to simulate the risk components. The MVM model is estimated 30 times with different draws of the uncertainty term and is assumed sufficient to eliminate any noticeable errors. The results are reported in Table 3.<sup>19</sup> The range of estimated  $\theta$  is from 0.3252 to 0.3751 while the mean is 0.3456. The Wald statistics are more than 1000 and the LR statistics are more than 250 in all draws, which demonstrate the statistical significance of the financial component. Thus, a significant finding is that financial market risk has an important role that shapes the strategic interaction among firms in the margarine and butter market.

Because the traditional industrial organization approach concerns more profit than market value objectives, much of our attention is paid to the general MVM against profit maximization. That is, we care more about whether  $\theta > 0$  than whether  $\theta = 1$ . The mean of estimated  $\theta$ , 0.3456, which is different from the theoretical prediction, 1 might be due to the assumption of the additively linear uncertainty, the restrictions of CAPM, and not incorporating the financial structure of firms, for example, debts and equities in the study. Though the null hypothesis  $\theta = 1$  is also rejected in the test (not reported here), the decision maker always has financial concerns as long as  $\theta > 0$ . The results reported in Table 3 provide sufficient evidence to support this concern.

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<sup>19</sup>Table 3 is based on model C0 mentioned in section 4.2. We also conduct the same tests for model C1-C4. The general results are held; i.e.,  $\theta = 0$  is rejected across models C0-C4 though we do not report the statistics here.

## 5.3 Model Selection 2: Market Structure

In the second set of model selection, 5 possible combinations of collusions in pricing strategies were considered, including C0 (each brand operates non-collusively), C1 (brand 1+brand 2), C2 (brand 1+brand 3), and C3 (brand 2+brand 3), C4 (brand 1+brand 2+brand 3). Table 4 depicts the arrangements and corresponding numbers of conjectural variations of 5 models.

To identify the best fitted market structures in pricing, we perform the model selection procedure specified in section 4.1. The results are reported in Table 4: Column 1-Vuong Test (VT); column 2-Akaike Information Criterion (AIC); column 3-Schwarz Information Criterion (SIC). The numbers in each row indicate how the best model (model C0) performs relative to the others. Because the statistics are all greater than 1.96, the Vuong test and its adjustments (AIC and SIC) indicate that model C0 is the best fitted model, in which each brand operates non-collusively in price.

### 5.3.1 CV Parameters

Table 5 shows the CV estimates of price. All 20 pricing CVs are significant. Moreover, there are 13 negative pricing CV estimates; that is, not all brands raise prices when its competitors do so.

Clearly, the market pricing we observe does not fit the classic case of price games under product differentiation. Part of the reason may come in the inability of wholesalers to quickly respond to competitor price changes. Given that supermarkets control retail prices, the time delays related to a reaction may be a limiting factor for our model. This can be noted in the last column of Table 5 where all of the branded products react to price decreases (increases) with price increases (decreases). The results also seem to suggest that butter and margarine are not overly competitive

groups in the spreadable fats food category.

This result is also probably best explained by lack of resale price maintenance on the part of brand wholesalers. Supermarkets have control over final prices and the nonresponsiveness may indeed be the exercise of retailer market power, or the interaction of private label pricing, which the supermarket may have an incentive to promote, and branded products.

### 5.3.2 Wald Test

In this section we further examine what identifying market structures fit data better. Based on the results obtained in Step I of the model selection procedures, the CV model of C0 is investigated in more detail. The Wald test is used to complete Step II of model selection in this section. To test the Stackelberg games, the slopes of reaction functions of followers have to be estimated first. They are computed at the means of relevant variables. These results are presented in Table 6. The computations of fixed points indicate that all of S1-S5 and CS can be candidates of Stackelberg leaders. Table 6 indicates that the slopes of reaction functions for all hypothetical cases must be negative to sustain the models of Stackelberg or consistent conjectures in price.

Once the slopes of reaction functions are calculated, the Wald test is ready to be implemented. The results are presented in Table 7. As shown in the table, all different combinations of Bertrand, Stackelberg leadership, and consistent conjectures for the pricing strategies are rejected. The result implies that the CV model for pricing strategies in model C0, where each brand operates non-collusively in price, is the final winner.

After the best fitted model is determined, we then work on the price and expenditure elasticities derived from this model in Tables 8 and 9.

## 5.4 Elasticities

The results for determining the best fitted market structure was discussed in section 5.3. We now report the price elasticity matrix derived from this market structure in Table 8 while the expenditure elasticities are reported in Table 9.<sup>20</sup>

In Table 8, own price elasticities are all significantly negative. The elasticities of all highly differentiated products maintain inelastic demand. As mentioned before, since All Others and Private Labels are aggregated from hundreds of differentiated niche-type products, it is not surprising that this group of products is relatively inelastic in price. Brand 1 is more inelastic than brands 2 and 3, which supports the notion that this dominant firm may have strong customer loyalty and strategies to differentiate these lines have been successful. Brands 2 and 3 are relatively more price sensitive than the other brands in the study. Perhaps this signals relatively less brand loyalty, poor differentiation strategies, and other factors that limit these brands from improving their market position relative to brand 1 or private labels.

Moving to cross elasticities, brand 1 and 2 are found to be substitutes, which was not surprising given that both are margarine lines, while there are not clear relationships between brands 1 and 3 and brands 2 and 3. The negative cross elasticities of the rest of products imply they are roughly complements. The result is consistent with Gould, Cox, and Perali (1991), where different food fats and oils, including butter, margarine, short, cooking, and lard are generally complements. Alternatively, the negative cross elasticities might be due to that retail firms control final prices than any true complementary relationship. For example, when branded products are offered at lower prices, supermarkets can instantaneously react by lowering the price of its own private labels.

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<sup>20</sup>The elasticity estimates can be derived from the AIDS model. They are all computed at the means of relevant variables and the associated standard errors are obtained by the delta method.

The expenditure elasticities are reported in Table 9. All are positive and statistically significant. Recall that brand 3, All Others and Private Labels all have significant butter components aggregated within while brands 1 and 2 are lower priced, margarine brands. Private Labels, All Others, and brand 3 are above unity, consistent with the finding that these items contain butter products and generally charge relatively higher prices.

## 5.5 Lerner Indexes

The Lerner indexes of the best fitted model are shown in column (2) of Table 10. The range of Lerner indexes are from 0.0092 (All Others) to 0.2821 (brand 3). The lowest Lerner index of All Others is consistent with the smaller market shares. From brands 1, 2, and 3, it indicates that branded butter producers may have higher market power than branded margarine ones in the current analysis. Within the category of margarine, brand 1 has more market power than brand 2 because of brand 1's larger market share. Private Labels also have a higher Lerner index, which is consistent with growing market power of supermarkets in the spreadable fats category.

To examine how the specification of market structure influences the estimation of Lerner index, we use the Bertrand assumption as a benchmark because this is often an assumed market structure for many retail studies on differentiated products. Columns (1) in Table 10 reports the estimated Lerner indexes for the Bertrand model, which indicates that firms in the differentiated product market have significant market power. The Lerner indexes in the best fitted model [columns (2)] are quite different relative to those obtained from the assumption of Bertrand competition [columns (1)]. The result demonstrates the importance of selecting the correct market structure. From comparisons of Lerner indexes, it is easy to see that the Bertrand competition commonly seen in the study of the differentiated products might be misspecified and

the Lerner indexes are sensitive to the specification of market structure.

We further compare the Lerner indexes of MVM and profit maximization models. Column (3) shows that the model of profit maximization estimates higher Lerner indexes. The average Lerner index of profit maximization is greater than that of MVM by 5.08% with a range of 51.09% (All Others) to 1.10% (Brand 3). This result is consistent with the theoretical findings and supports the concept that Lerner indexes generated under profit maximization are overstated in the presence of financial risk.

However, the nominally high estimated Lerner indexes presented here should be interpreted carefully. The marginal costs may be under-estimated because in-store marketing has been used as a proxy because real wholesale cost information of branded butter and margarine were not available. This under-estimation of marginal costs applies to both models of MVM and profit maximization. It is believed that the over-estimated Lerner index under profit maximization setting still holds when more accurate cost information is incorporated.

## 6 Concluding Remarks

In this study we have presented and discussed results on the strategic pricing behavior in the U.S. margarine and butter markets. A general model of oligopoly strategic behavior is developed for firms choosing to maximize the market value of their assets. In section 2 we develop and implement a model built on the nonlinear Almost Ideal Demand Systems (AIDS) and structural first-order conditions for market value maximization. The underlying definition of the MVM is constructed using the capital asset pricing model, which focuses on profits and revenue stability.

Section 3 addresses the issues of data sets used in the study. The empirical procedures are detailed in section 4 where estimation of demand systems and the



model selection procedures are discussed step by step. Section 5 then presents the empirical findings in this study. Using retail scanner data on the U.S. margarine and butter industry from 1998 to 2002, full information maximum likelihood (FIML) estimations of the nonlinear AIDS model and structural first-order conditions in price are obtained.

From the FIML estimation, the test of different firm's objectives is a straightforward likelihood ratio or Wald test because strict profit maximization is shown to be nested within the MVM framework. The restricted model is soundly rejected and we conclude that financial market uncertainty plays an important role in determining the pricing behavior of firms in this industry. In particular, MVM firms are likely to spend more attention to product differentiation than the strict profit maximizers.

The MVM model also suggests traditional Lerner indexes will be estimated above their true values. This is a simple misspecification bias that ignores the returns required to compensate firms for nondiversifiable risk. When ignores, Lerner indexes conclude these required returns are rents extracted due to classic forms of market power. Thus when an industry is characterized by MVM, it produces a more valid and stronger test of market power. When market power is identified, the signal of noncompetitive prices is stronger because risk has been accounted for. This is a crucial finding in light of the current state of industrial organization work and antitrust law:

First and foremost, the results show that models built under the premise of static profit maximization are likely to overstate the case of high levels of economic profit. However, by setting the analytical bar higher and more accurately, the cases in which high Lerner indexes emerge, after accounting for an appropriate risk premium, should warrant more attention from antitrust authorities. Second, this study points out a very important part of why firms may merge and antitrust law needs to account for this. For example, it is often argued that vertical integration generates transaction

base efficiency gains. It is reasonable to assume that if these gains cut the variability of returns, then we should observe, *ceteris paribus*, an increase in the Lerner index. The evaluation of past mergers in this light would be a useful extension of this research. Merger approvals based on Chicago School efficiency arguments need to more formally consider the role of efficiency in reducing the variability of returns and subsequently demand greater downward pressure on expected Lerner indexes.

The Vuong test, the Akaike and Schwarz information criteria suggest the best fitted model is the one in which each brand operates non-collusively in prices. The Wald test supports the finding that all of Bertrand, Stackelberg leadership, and consistent conjectures in pricing should be rejected. Given the rather strong results from the model selection, we proceeded to estimate elasticities and Lerner index to explore market power in this market.

## **6.1 Contributions**

The research in this study provides several important additions and extensions to the literature. First, we are not aware of any previous attempt to estimate a flexible demand system while introducing financial market risk into the market structure. The results push the literature toward a richer model of firm behavior that endogenously considers financial market components in estimating traditional measures of market power, and pricing parameters from demand systems.

Second, this is a very large system comprised of three brands, an aggregation of all other brands and an aggregation of private labels. Most previous brand level studies have either worked with multiple brands in the pricing system alone, or worked with a few brands, and used linear ad hoc demand systems to estimate the demand system. This research, therefore represents an extension of the AIDS model to address pricing and financial risk in a disaggregated system.

Last, though not least, there has been no previous attempt to evaluate pricing strategies in the U.S. margarine and butter retail markets. The results presented in this study indicate that the empirical implementations are sensitive to model specifications. From comparisons of Lerner indexes in Table 10, for example, it is easy to see that the Bertrand competition commonly seen in the study of the differentiated products might be misspecified given that the best fitted market structure is other than the Bertrand competition. A misspecified mode of interactions may result in bad estimates and lead to wrong policy implications. It is believed that this study helps us better understand the U.S. margarine and butter markets and the analysis framework can be easily applied to any differentiated product markets.

## 6.2 Future Research

Finally we point out some possible avenues of research in the future. First, as mentioned above, issues of market power analyses arising from market structure changes, for example, vertical integration and merger should receive more attention in the context of risk concerns.

Second, we do not consider all possible games in the model selection stage. It may well be that some complex game not considered would appear consistent with the CV model. In addition, the estimations only involve firm's pure strategies in pricing and leaves out the possibility of mixed or dynamic strategies.<sup>21</sup> Though the pure strategy games considered in this study can be treated as degenerate cases of mixed strategy games, it is possible that actual behavior involves games with mixed strategies.

Third, the current study uses in-store marketing as a proxy to estimate the marginal costs. This provides the flexibility in modeling the market structure and

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<sup>21</sup>Examples of mixed strategy estimation can be found in Golan, Karp and Perloff (2000) and references therein.

admits empirical tests among the competing models compared with other studies lack of cost data. The results may be improved by estimating real costs of wholesale inputs and in-store marginal costs rather than using a proxy.

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**Table 1 Descriptive Statistics**

Brands	Price (\$/lb)		Market Share (%)		Expenditure share (%)		Total Revenue (\$M/city)	
BR1 (M)	1.18	(0.17)	37.50	(6.85)	29.81	(6.26)	40.75	(29.64)
BR2 (M)	1.05	(0.22)	15.66	(9.69)	13.66	(7.48)	15.06	(8.99)
BR3 (B)	3.40	(0.62)	9.60	(4.46)	16.43	(7.62)	29.69	(37.94)
AO (M&B)	2.19	(0.51)	13.29	(8.80)	14.59	(10.59)	26.87	(42.01)
PL (M&B)	1.85	(0.52)	23.95	(6.64)	25.51	(7.38)	41.11	(37.14)

Brands	Unit Per Volume		All Merchandising (%)		Price Reduction (%)		All Others (%) [Display & Feature]	
BR1 (M)	0.77	(0.07)	24.37	(9.03)	9.57	(6.90)	14.80	(8.32)
BR2 (M)	0.91	(0.06)	31.21	(13.75)	12.56	(8.74)	18.65	(12.66)
BR3 (B)	1.13	(0.06)	36.89	(23.42)	17.50	(16.04)	19.39	(20.49)
AO (M&B)	1.06	(0.08)	24.45	(15.42)	13.17	(9.84)	11.28	(12.60)
PL (M&B)	0.90	(0.09)	38.53	(21.41)	16.20	(13.97)	22.33	(17.73)

**Mean Values of Other Explanatory Variables**

Variables	Units	Mean		Variables	Units	Mean	
PERLT10K	%	8.64	(3.22)	Median Income	\$	44317.32	(6484.37)
PERGT50K	%	44.03	(6.63)	Per Capita Expenditure	\$	0.72	(0.19)
HUNDER15	#	0.58	(0.09)	$r_m$	%	7.35	(18.80)
H_NUMBER	#	2.57	(0.16)	$r_f$	%	5.23	(0.78)
A_AGE	Years	34.01	(2.42)				
FSPANISH	%	13.40	(10.74)				
POPU	#	3651213	(3361325)				

Note:

- (1) Product produced: M=margarine; B=butter.
- (2) Standard errors are in the parentheses.
- (3) BR1~BR3: Brand 1~Brand 3, AO: All Others, PL: Private Labels.



Figure 1 Market Shares by Brands

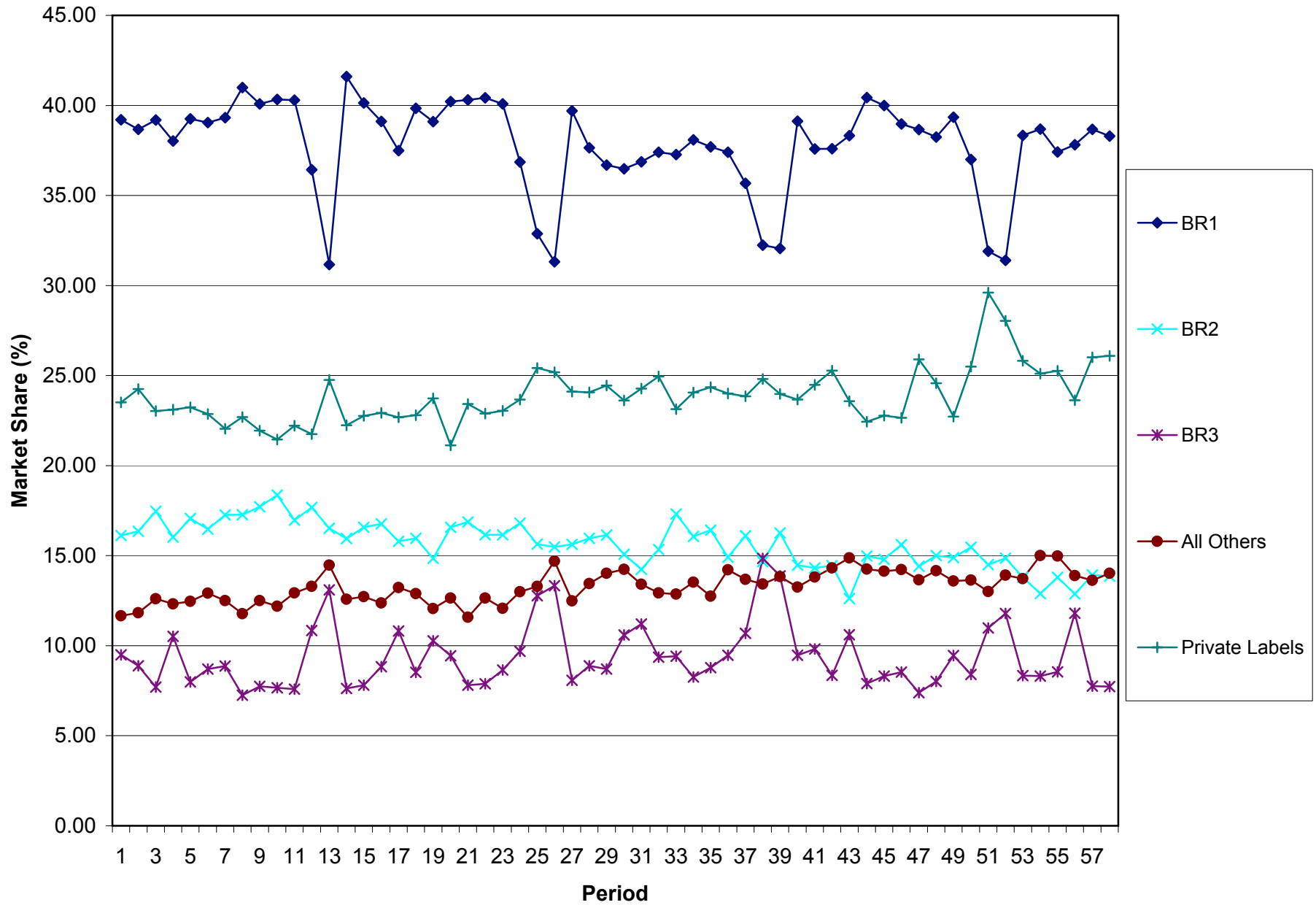


Figure 2 Volume Sales by Brands (Millions of lbs)

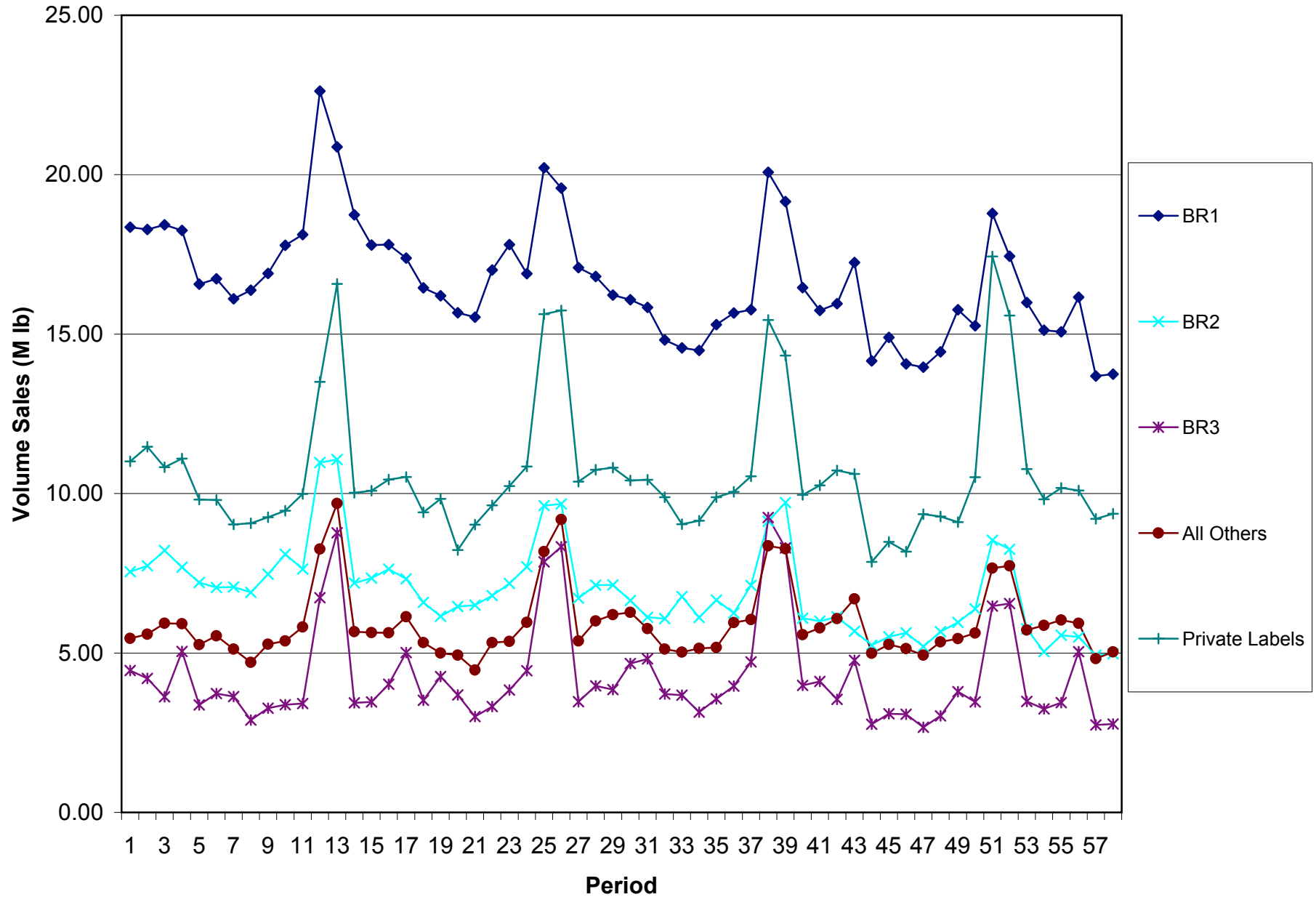
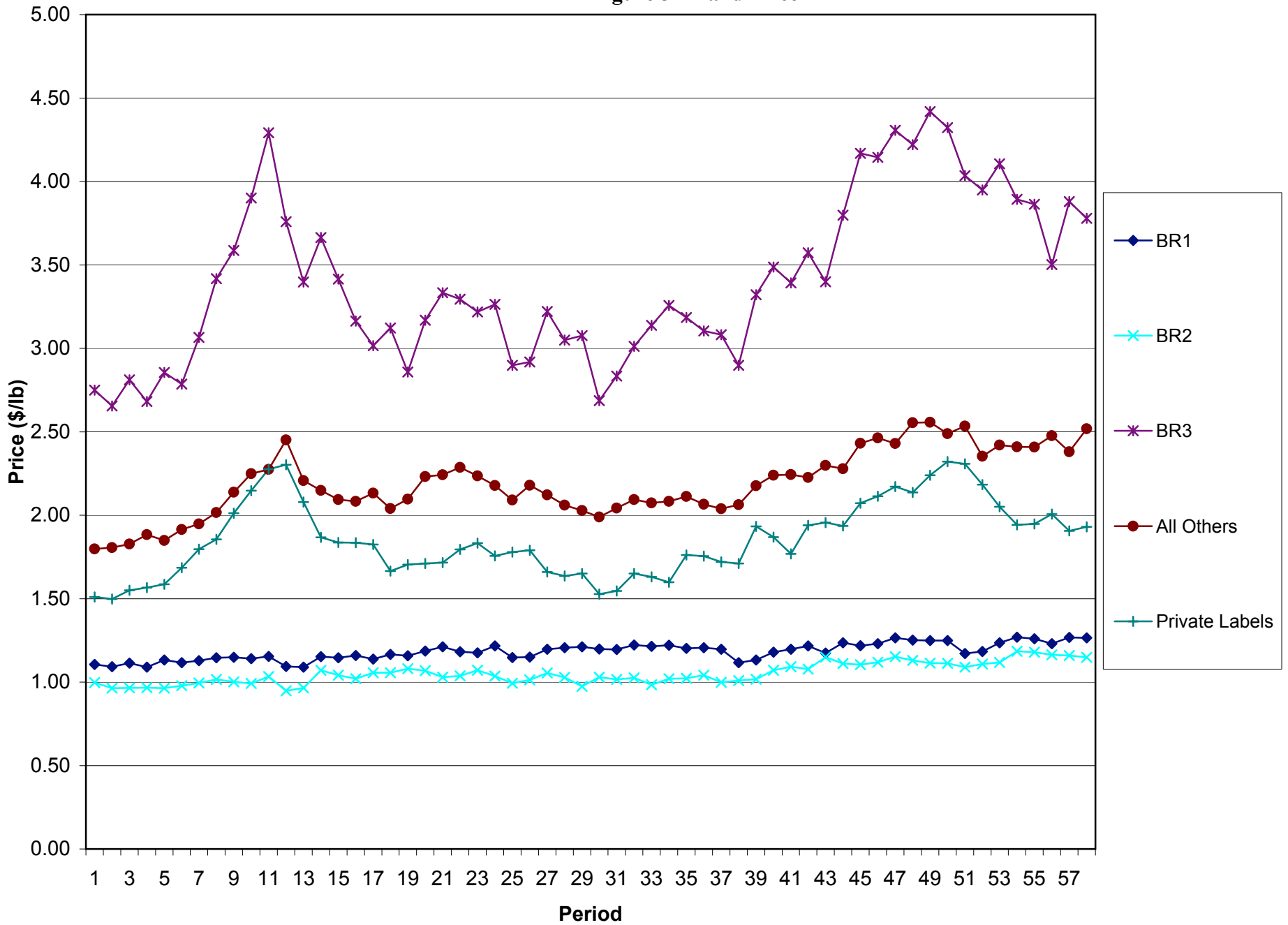


Figure 3 Brand Price



**Table 2 Numbers of Parameters in FIML Estimation**

<b>Equation</b>	<b>Parameter</b>	<b>Number</b>	<b>Note</b>
10	$\nu_r$	36	division binary, $r = 1 \dots 9$ .
	$\lambda_k$	28	socio-demographic variable, $k = 1 \dots 7$ .
	$\beta$	4	income term in AIDS
	$\gamma$	10	cross price effect in AIDS
	<i>Season</i>	12	seasonality dummy
	<i>Butter</i>	1	butter dummy
20	$\zeta_r$	9	regional dummy in income, $r = 1 \dots 9$ .
	$\xi, \psi_1, \psi_2$	3	time trend, median income and its square
19	$\mu_0$	5	intercept term
	$\mu_1$	5	unit per volume
	$\mu_{21}$	5	all other merchandising
	$\mu_{22}$	5	price reduction
17	$\eta$	*	CV in price
	$\theta$	1	Finance component

\* Numbers depend on the market structure. See column (4) in Table 4.

**Table 3 Wald Test and Likelihood Ratio Test for Financial Component (MVM versus Profit Maximization in Pricing System)**

<b>Draw</b>	<b>Estimates</b>	<b>Standard Error</b>	<b>Wald statistic</b>	<b>LR statistic</b>
1	0.3569	0.0098	1338.04	354.49
2	0.3527	0.0087	1630.99	365.42
3	0.3458	0.0075	2142.03	355.11
4	0.3330	0.0082	1654.55	381.26
5	0.3783	0.0063	3633.31	252.00
6	0.3690	0.0079	2178.67	289.22
7	0.3669	0.0103	1258.21	442.44
8	0.3208	0.0078	1698.22	395.88
9	0.3451	0.0083	1712.88	355.79
10	0.3301	0.0082	1611.63	367.73
11	0.3676	0.0095	1503.89	462.89
12	0.3346	0.0078	1820.77	392.40
13	0.3442	0.0076	2054.92	366.42
14	0.3467	0.0090	1468.48	432.95
15	0.3517	0.0074	2230.45	327.26
16	0.3336	0.0070	2245.63	382.20
17	0.3510	0.0096	1344.35	365.03
18	0.3751	0.0101	1387.73	287.55
19	0.3573	0.0073	2365.81	356.31
20	0.3480	0.0091	1468.77	429.54
21	0.3255	0.0083	1536.45	391.12
22	0.3458	0.0080	1863.96	383.16
23	0.3372	0.0077	1922.31	384.77
24	0.3322	0.0071	2187.97	369.22
25	0.3408	0.0083	1681.56	403.32
26	0.3252	0.0076	1807.23	379.63
27	0.3472	0.0081	1854.66	445.08
28	0.3348	0.0073	2102.72	385.18
29	0.3385	0.0106	1028.39	387.52
30	0.3331	0.0091	1339.98	361.41

Note: The critical values at the 5% level of significance are 3.84 for both the Wald test and the LR test.

**Table 4 Vuong Test (Model C0 versus the Rest)**

<b>Model</b>	<b>(1) VT</b>	<b>(2) AIC</b>	<b>(3) SIC</b>	<b>(4) # of CV</b>
<b>C0</b>	0.0000	0.0000	0.0000	20
<b>C1</b>	6.7337	6.7256	6.7038	18
<b>C2</b>	8.0815	8.0730	8.0501	18
<b>C3</b>	7.5138	7.5052	7.4822	18
<b>C4</b>	13.7437	13.7193	13.6537	14

Note:

- (1) C0: each brand operates non-collusively  
C1: Brand 1+Brand 2  
C2: Brand 1+Brand 3  
C3: Brand 2+Brand 3  
C4: Brand 1+Brand 2+Brand 3
- (2) The numbers in column (1)-(3) indicate the Vuong statistics under the different criteria, which measure how model C0 is superior to the others. For example, the four entries of model C1 mean model C0 is better than model C1 by those amounts. The critical values for the 5% level of significance are -1.96 and 1.96.

**Table 5 CV Estimates of Price (Model C0)**

$\eta_{ji} = \frac{\partial p_j}{\partial p_i}$	<b>BR1</b>	<b>BR2</b>	<b>BR3</b>	<b>AO</b>	<b>PL</b>
<b>BR1</b>	NA	<b>1.7761</b> (0.0855)	<b>0.1759</b> (0.0073)	<b>-0.4575</b> (0.0142)	<b>-2.1567</b> (0.2290)
<b>BR2</b>	<b>-0.5041</b> (0.0254)	NA	<b>-0.1403</b> (0.0073)	<b>0.2519</b> (0.0074)	<b>-0.1600</b> (0.0077)
<b>BR3</b>	<b>-0.3915</b> (0.0225)	<b>-0.5533</b> (0.0281)	NA	<b>-0.3071</b> (0.0095)	<b>-0.5928</b> (0.0325)
<b>AO</b>	<b>0.3878</b> (0.0207)	<b>0.1295</b> (0.0058)	<b>-0.1466</b> (0.0067)	NA	<b>-0.2019</b> (0.0095)
<b>PL</b>	<b>-1.3391</b> (0.0780)	<b>0.7934</b> (0.0358)	<b>0.5110</b> (0.0258)	<b>-1.2194</b> (0.0373)	NA

Note:

- (1) Standard errors are in the parentheses.
- (2) Highlighted numbers are significant at the 5% level of significance.
- (3) BR1~BR3: Brand 1~Brand 3, AO: All Others, PL: Private Labels.

**Table 6(a) The Fixed Points If Brand 1 is a Stackelberg Leader in Price**

		$j$				
		BR1	BR2	BR3	AO	PL
$i$	BR1	1.0000	-0.9108	-1.0783	-1.1225	-1.3362
	BR2	0.0000	1.0000	0.0000	0.0000	0.0000
	BR3	0.0000	0.0000	1.0000	0.0000	0.0000
	AO	0.0000	0.0000	0.0000	1.0000	0.0000
	PL	0.0000	0.0000	0.0000	0.0000	1.0000

**Table 6(b) The Fixed Points If Brand 2 is a Stackelberg Leader in Price**

		$j$				
		BR1	BR2	BR3	AO	PL
$i$	BR1	1.0000	0.0000	0.0000	0.0000	0.0000
	BR2	-0.8698	1.0000	-0.9315	-0.9866	-0.9785
	BR3	0.0000	0.0000	1.0000	0.0000	0.0000
	AO	0.0000	0.0000	0.0000	1.0000	0.0000
	PL	0.0000	0.0000	0.0000	0.0000	1.0000

**Table 6(c) The Fixed Points If Brand 3 is a Stackelberg Leader in Price**

		$j$				
		BR1	BR2	BR3	AO	PL
$i$	BR1	1.0000	0.0000	0.0000	0.0000	0.0000
	BR2	0.0000	1.0000	0.0000	0.0000	0.0000
	BR3	-0.9904	-0.9211	1.0000	-0.9778	-0.9562
	AO	0.0000	0.0000	0.0000	1.0000	0.0000
	PL	0.0000	0.0000	0.0000	0.0000	1.0000

**Table 6(d) The Fixed Points If AO is a Stackelberg Leader in Price**

		$j$				
		BR1	BR2	BR3	AO	PL
$i$	BR1	1.0000	0.0000	0.0000	0.0000	0.0000
	BR2	0.0000	1.0000	0.0000	0.0000	0.0000
	BR3	0.0000	0.0000	1.0000	0.0000	0.0000
	AO	-1.1323	-1.0756	-1.0711	1.0000	-1.2924
	PL	0.0000	0.0000	0.0000	0.0000	1.0000

**Table 6(e) The Fixed Points If PL is a Stackelberg Leader in Price**

		$j$				
		BR1	BR2	BR3	AO	PL
$i$	BR1	1.0000	0.0000	0.0000	0.0000	0.0000
	BR2	0.0000	1.0000	0.0000	0.0000	0.0000
	BR3	0.0000	0.0000	1.0000	0.0000	0.0000
	AO	0.0000	0.0000	0.0000	1.0000	0.0000
	PL	-1.2668	-1.0424	-1.0452	-1.2803	1.0000

**Table 6(f) The Fixed Points If Consistent Conjectures in Price**

		$j$				
		BR1	BR2	BR3	AO	PL
$i$	BR1	1.0000	-0.8573	-1.0939	-1.3695	-1.8240
	BR2	-0.9346	1.0000	-1.0271	-1.3071	-1.5389
	BR3	-0.9989	-0.8607	1.0000	-1.1482	-1.3049
	AO	-0.9900	-0.8884	-0.9517	1.0000	-1.5670
	PL	-1.0943	-0.8478	-0.8680	-1.2049	1.0000

**Table 7 Wald Test Statistic (Model C0)**

Type of Game	Wald Statistic
<b>B</b>	19663.67
<b>S1</b>	45089.97
<b>S2</b>	59223.93
<b>S3</b>	15605.38
<b>SAO</b>	71549.50
<b>SPL</b>	23739.80
<b>CS</b>	151885.26

Note:

- (1) The degree of freedom for all tests is 20 and the critical value is 31.41 at the 5% level of significance.
- (2) **B** means Bertrand, **S $i$**  means that brand  $i$  is a Stackelberg leader, and **CS** means consistent conjectures.



**Table 8 Price Elasticity Matrix (MVM)**

Brands	BR1	BR2	BR3	AO	PL
<b>BR1</b>	<b>-0.5561</b> (0.0096)	<b>0.1327</b> (0.0033)	<b>0.0425</b> (0.0027)	<b>-0.0348</b> (0.0036)	<b>-0.2733</b> (0.0097)
<b>BR2</b>	<b>0.3329</b> (0.0081)	<b>-0.7873</b> (0.0055)	<b>0.1086</b> (0.0045)	<b>-0.1183</b> (0.0073)	<b>-0.0734</b> (0.0115)
<b>BR3</b>	<b>-0.0714</b> (0.0030)	-0.0013 (0.0023)	<b>-0.8383</b> (0.0064)	<b>-0.0524</b> (0.0025)	<b>-0.1868</b> (0.0075)
<b>AO</b>	<b>-0.2514</b> (0.0063)	<b>-0.2169</b> (0.0059)	<b>-0.0800</b> (0.0032)	<b>-0.0925</b> (0.0242)	<b>-0.6212</b> (0.0250)
<b>PL</b>	<b>-0.5071</b> (0.0119)	<b>-0.1441</b> (0.0059)	<b>-0.1662</b> (0.0057)	<b>-0.3811</b> (0.0144)	<b>-0.1659</b> (0.0188)

**Table 9 Expenditure Elasticity Matrix**

Brands	Estimates
<b>BR1</b>	<b>0.6872</b> (0.0105)
<b>BR2</b>	<b>0.6315</b> (0.0162)
<b>BR3</b>	<b>1.2220</b> (0.0057)
<b>AO</b>	<b>1.2711</b> (0.0170)
<b>PL</b>	<b>1.2648</b> (0.0160)

Note:

- (1) Standard errors are in the parentheses.
- (2) Highlighted numbers are significant at the 5% level of significance.
- (3) BR1~BR3: Brand 1~Brand 3, AO: All Others, PL: Private Labels.

**Table 10 Estimated Lerner Index in Pricing System**

<b>Brands</b>	<b>(1) MVM Bertrand</b>	<b>(2) MVM</b>	<b>(3) Profit Maximization</b>	<b>(4) [(3)-(2)]/(2)*100%</b>
<b>BR1</b>	0.3492 (0.0140)	0.2694 (0.0165)	0.2893 (0.0129)	7.39
<b>BR2</b>	0.3095 (0.0234)	0.2471 (0.0252)	0.2621 (0.0214)	6.07
<b>BR3</b>	0.4084 (0.0097)	0.2821 (0.0088)	0.2852 (0.0077)	1.10
<b>AO</b>	0.4001 (0.0382)	0.0092 (0.0983)	0.0139 (0.1232)	51.09
<b>PL</b>	0.3527 (0.0186)	0.2478 (0.0172)	0.2587 (0.0136)	4.40

Note:

(1) Standard errors are in the parentheses.

(3) BR1~BR3: Brand 1~Brand 3, AO: All Others, PL: Private Labels.