Evaluating Generic Milk Promotion Effectiveness with an Imperfect Competition Model

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A framework is proposed for incorporating the degree of market competition in evaluating milk promotion effectiveness. The imperfect competition model allows simultaneity in price and quantity with an endogenous fluid milk premium. The model's usefulness is demonstrated with Japanese generic milk promotion data. Results show a conventional exogenous-price or exogenous-premium model will underestimate returns to milk promotion.

Key words: fluid milk premium, generic milk promotion, imperfect competition.

Although raw milk is essentially a homogeneous input in the production of fluid milk and manufactured dairy products, in many countries the price received for fluid milk usage is higher than the price received for manufactured product usage. Such differences indicate that prices are not competitively determined. This certainly is the case in the United States, where federal and state milk marketing order programs establish minimum Class I price differentials (premiums) for most milk marketed. There are also over-order fluid premium payments resulting from negotiations between cooperatives and fluid processors.

Changes in milk advertising expenditures should produce changes in milk prices as well as in milk demand. Thus, an advertising program's effectiveness should account for changes in both price and quantity; each should be treated as endogenous. Most studies of U.S. dairy markets either assume an exogenous fluid milk price (Thompson, Eiler, and Forker; Liu and Forker 1988, 1990; Ward and Dixon; Blisard, Sun, and Blaylock; Forker and Ward) or an exogenous fluid (Class I) price differential (Kaiser, Streeter, and Liu; Kaiser et al.; Liu et al.). No studies known to the authors have used a degree-of-competition measure, nor an endogenously determined fluid price differential in U.S. dairy models.

In the Japanese market, the assumption of an exogenous fluid price or premium is even less appropriate because milk prices are determined in individual negotiations between prefectural milk marketing boards (designated dairy cooperatives) and the processors they supply. Prefectural board and processors' market power is crucial in milk price determination. In addition, because generic promotion expenditures are defrayed by assessments on milk marketings, assessment increases affect fluid milk marketings, which in turn increases assessments. Promotion expenditures should therefore be treated as endogenous.

Using Japanese generic milk promotion data, we develop a framework for measuring the effectiveness of generic milk advertising, incorporating the degree of market competition. Results assuming endogenously determined fluid premiums are then compared with a conventional model assuming an exogenous fluid premium.

Our imperfect competition model employs a type of conjectural variations similar to that used by Suzuki, Lenz, and Forker (SLF) to examine market impacts of decreasing Japanese milk support prices. However, the present conceptual model differs from SLF in its
consideration of both manufacturers' (buyer) and producer marketing boards' (seller) market power.

**Japanese Milk Promotion System**

The National Milk Promotion Association of Japan (NMPAJ) has been the sole agency responsible for Japanese generic milk promotion since 1978. Each prefectural milk marketing board contributes to the NMPAJ in addition to promoting its prefectural brand. In the present analysis, we only consider the NMPAJ's nationwide generic program.\(^1\)

For fiscal year 1990 (April-March), the total budget of NMPAJ was 8 billion yen (equivalent to $61.5 million). This revenue came from three sources: voluntary assessments (2.8 billion yen), government subsidies (4 billion yen), and carryover from FY 1989 (1.2 billion yen). Unlike the U.S., where only dairy farmers pay mandatory promotion assessments, the Japanese program is voluntary, and retailers and wholesalers are included in addition to farmers. Assessments on farmers and wholesalers are 0.24 yen per kilogram (kg) (8.4¢/cwt) of fluid milk and 0.10 yen per kg (3.4¢/cwt) of manufacturing milk marketed. Retailers are assessed 0.24 yen per kg (8.4¢/cwt) of fluid milk purchased from wholesale processors.

The 8 billion yen from NMPAJ's 1990 budget was divided among three primary expenditure categories: promotion (6.4 billion yen), administration (0.4 billion yen), and carryover to 1991 (1.2 billion yen).\(^2\) NMPAJ's promotion activities encompass media advertising, and a wide variety of non-advertising activities.\(^3\) With the exception of a cheese fair, NMPAJ's promotional activities are primarily focused on expanding fluid milk consumption.

**Model**

Because there are many processors in the Japanese fluid sector, none having a large share of the market, fluid processors do not have much influence on price negotiations with the prefectural marketing board. On the other hand, there are few non-fluid-manufacturing dairy firms in Japan, and the market share of some of these firms is larger than their fluid counterparts. As a result, some manufacturing product dairy firms may have some market power and could influence the determination of the manufacturing milk price. Since Japan operates a deficiency payment system with two-tiered pricing for manufacturing milk, manufacturing dairy firms are required to pay the standard purchase price to farmers for within-quota milk marketings.\(^4\) The degree of manufacturing firms' market power becomes important in negotiating the over-quota milk price with the prefectural marketing board. Dominance of the manufacturers' power would be reflected by a rapidly declining over-quota milk price as quantity increases, while dominance of the boards' power would be reflected by an over-quota milk price that is close to the standard purchase price even as quantity increases.

Mathematically, the ith board's maximization problem is comparable to the following constrained maximization problem:\(^5\)

\[
\max NR^i = P_{ij} q^i_j + GP QT^i
\]
\[
+ P_m (q^i - q^i_j - QT^i) - \alpha^i
\]
\[
\text{s.t.}
\]
\[
(1) \quad Q^i = f(P, M)
\]
\[
(2) \quad Q^i = q^i_j + \sum_{j \neq i} q^j
\]
\[
(3) \quad OQT^i = \sum_{j \neq i} q^j - Q^i - \sum_{j \neq i} QT^j
\]
\[
(4) \quad \sum_{j \neq i} q^j = g(q^i)
\]
\[
(5) \quad P_m = h(OQT)
\]
\[
(6) \quad M = A/c
\]
\[
(7) \quad A = \alpha^i + \left[ 0.24 \sum_{j \neq i} q^j + 0.10 \left( \sum_{j \neq i} q^j - \sum_{j \neq i} q^j_j \right) + 0.24 \cdot 2 Q^i_j \right] + 0.10 (Q - Q^i_j) L + S
\]

\(^1\) The government pays farmers a deficiency payment for all within-quota milk marketings equal to the difference between the standard purchase price and the guaranteed price.

\(^2\) If \(q^i_j < QT^i\), the objective function is replaced by \(\max NR^i = P_{ij} q^i_j + GP (q^i_j - Q^i_j) - \alpha^i\). This is not the case in our analyses.

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\(^4\) If \(q^i_j < QT^i\), the objective function is replaced by \(\max NR^i = P_{ij} q^i_j + GP (q^i_j - Q^i_j) - \alpha^i\). This is not the case in our analyses.

\(^5\) Constraints (1) to (7) are based on the assumption that the ith board is a price taker in the fluid milk market.
Equation (1) is the aggregate fluid milk demand function, while equation (2) requires that aggregate fluid milk demand equal the sum of all marketing boards' fluid milk supply. Total over-quota manufacturing milk marketings are measured by equation (3). Equation (4) is the ith board's conjecture of the other boards' aggregate reaction function. The relationship between the price for over-quota manufacturing milk and the quantity of over-quota marketings is captured by equation (5). (Note that the coefficient, ∂P_m/∂(OQT), is a measure of the degree of dominance by the farmers' boards and manufacturing companies.) Total promotion messages are defined by (6). Equation (7) measures total promotion expenditures, which is composed of the voluntary assessments paid by the ith board, all other boards, wholesale fluid processors, fluid milk retailers, and wholesale manufacturing milk processors, plus government subsidies. The ith board's contribution to total promotion expenditures is defined by (8).

With aggregate assessment collection losses ranging from 32% to 55% during 1981-90, the collection ratio L must be included in equations (7) and (8) to avoid overstating assessment income. Although L should be endogenous, it is treated as exogenous in this model because of the difficulty of incorporating the factors which affect collection loss.

Taking \( q', QT', GP, c, Q, L, \) and \( S \) as given, the first-order conditions for this maximization problem (the Lagrangian of the problem is given in the appendix) can be reduced to the following expression by solving for variables \( P_f, P_m, Q_i, OQT, q'_i, a', M, \sum q'_j, \) and \( A \):

\[
\begin{align*}
\text{Equation (9) can be expressed in elasticity terms as}
\end{align*}
\]

\[
\begin{align*}
\text{Equation (10) can be expressed in elasticity terms as}
\end{align*}
\]

*Because the interest of this paper is on the prefectural boards' decision making, it is assumed that total milk supply is given and that each board allocates its raw milk supply to fluid and manufacturing uses to maximize its total milk sales revenues net of promotion assessments.*
where $e = |(\partial Q/\partial P)| (P/Q)$, which is the absolute value of the fluid milk own-price elasticity, $\eta = (\partial Q/\partial M) (M/Q)$, which is the fluid milk promotion elasticity, and $\theta' = (\partial Q/\partial Qj) (Qj/Q)$, which is conjectural elasticity (Appelbaum) or Tsujimura's "market response elasticity." By definition of conjectural elasticity, $e = 1$ implies monopoly or collusion and $e = 0$ implies price-taking behavior.

Since $P_j$ and $e$ are common to all boards, equation (11) requires that $e$ be the same for all boards (Holloway). We consider $e' = e$ with the assumption that the boards approximately realize the condition expressed by (11).

The market power parameter, $e$, is difficult to estimate directly as a function of explanatory variables because it is not derived from demand or costs, but rather depends on behavior (Helpman and Krugman). Another approach for obtaining a value of $e$ is to solve equation (11) for $e$ in each time period (we assume $e$ is constant for each time period) given actual observations for $P_j, SP, L, Q_j$, and $A$, as well as estimates of $e$ and $\eta$. Using the derived values for $e$, the full model is obtained for $Q_j, P_j, M, A, AS$, and $GR$ conditional on $L, c, \theta, S, Q, GP, QT$, and $SP$.

**Fluid Milk Demand Function**

The fluid milk demand function (12) is estimated in linear form using monthly data from April 1981 through December 1990. Two-stage least squares is used because the fluid milk price and quantity, as well as promotion expenditures, are endogenous. To overcome significant first-order autocorrelation in the disturbance term, the Cochrane-Orcutt procedure is employed. The fluid milk demand function is initially specified as a function of the following variables: fluid milk price, consumption expenditures, milk promotion expenditures, temperature, the ratio of persons under fourteen years old to the total population, price of soft drinks, and eleven monthly intercept dummy variables. Temperature is included because Japanese consumers drink more milk during warmer months. The monthly intercept dummy variables are included to capture monthly seasonality in milk consumption. Contrary to a priori expectations, neither the price of soft drinks nor the ratio of persons under fourteen years old to the total population are statistically significant explanatory variables. Consequently, these variables are dropped from the final model. The estimated fluid milk demand function used is

$$Q/N = 3.444 - 1.004 P_j/CPIF \quad (6.31) \quad (-5.18) + 4.524 FEXP/CPIF \quad + 0.015 TEMP \quad (2.56) \quad (3.45) + 0.224 [(A/N)/CPIF] \quad + 0.418 [(A/N)/CPIF]_1 \quad (1.91) \quad (1.91) + 0.583 [(A/N)/CPIF]_2 + 0.717 [(A/N)/CPIF]_3 \quad (1.91) \quad (1.91) + 0.822 [(A/N)/CPIF]_4 + 0.896 [(A/N)/CPIF]_5 \quad (1.91) \quad (1.91) + 0.941 [(A/N)/CPIF]_6 + 0.956 [(A/N)/CPIF]_7 \quad (1.91) \quad (1.91) + 0.941 [(A/N)/CPIF]_8 + 0.896 [(A/N)/CPIF]_9 \quad (1.91) \quad (1.91) + 0.822 [(A/N)/CPIF]_10 + 0.717 [(A/N)/CPIF]_11 \quad (1.91) \quad (1.91)$$

Fluid milk demand:

(12) $Q_j = f(P_j, M)$

Milk sales-maximizing allocation:

(13) $P_j - 0.24 L + [1 - 0.52 L (\partial Q_j/\partial M)/c] \eta Q_j/\partial Q_j = SP - 0.10 L$

Milk promotion messages:

(14) $M = A/c$

Total milk promotion expenditures:

(15) $A = AS + S$

Total assessments:

(16) $AS = [0.24 \cdot 3 Q_j + 0.10 \cdot 2 (Q - Q_j)] L$

Milk sales revenue:

(17) $GR = P_j Q_j + GP \cdot QT + SP (Q - Q_j - QT)$

where $AS$ is total assessments, $GR$ is milk sales revenue, $QT$ is total quota manufacturing milk, and all other variables are as previously defined. From this model, equilibrium values are

$\theta Q_j/\partial Q_j = SP - 0.10 L$
The Japanese marketing boards actually make promotion decisions on an annual rather than a monthly basis. Because the fluid demand function is estimated using monthly data, the equation is converted into an annual equation by summing all variables into annual values and assuming that the estimated parameters are valid for the annual relationship.\footnote{Because the fluid milk price variable cannot be summed into an annual value, its parameter is multiplied by 12.}

Although we would have preferred to use the wholesale price the boards receive from manufacturers, due to data availability, retail prices are used in estimating the demand equation. Consequently, it is assumed that the wholesale price parameter equals the retail price parameter. In the aggregated annual model, the distributed lag coefficients for promotion are summed into a single, long-run promotion-response coefficient. While other considerations, such as optimal timing of promotion expenditures, would dictate a more detailed analysis of carryover effects and discounted present values, of net returns to promotion, such considerations are beyond the scope of this analysis. Previous

Existing theory suggests that at some level of promotion expenditures, diminishing marginal returns occur. To incorporate this effect, the demand function is estimated using several forms with diminishing marginal promotion effects (linear expenditure system, double-log, semi-log, log-inverse, inverse). In terms of statistical

\[
\begin{align*}
\hat{Q}_f &= 0.583 (A/N/CPI)_{-12} + 0.418 (A/N/CPI)_{-13} \\
&\quad + 0.224 (A/N/CPI)_{-14} + 0.388 D1 \\
&\quad + 0.459 D2 + 0.394 D3 + 0.418 D4 \\
&\quad + 0.570 D5 + 0.606 D6 + 0.470 D7 \\
&\quad + 0.252 D8 + 0.609 D9 + 0.571 D10 \\
&\quad + 0.478 D11 + 0.825 (UQ^{\text{IN}})_{-1} \\
&\quad + 0.418 (1.91) (1.91) \\
&\quad + 0.388 (1.81) \\
&\quad + 0.418 (2.37) (2.32) \\
&\quad + 0.570 (3.46) (3.39) (3.06) \\
&\quad + 0.252 (1.67) (3.35) (3.36) \\
&\quad + 0.478 (2.66) (10.84)
\end{align*}
\]

\[R^2 = 0.970, \quad DW = 2.447\]

where

\[
\begin{align*}
Q_f &= \text{total fluid milk demand in 1,000 metric tons, (from \textit{Milk and Milk Products Statistics}, Ministry of Agriculture, Forestry and Fisheries),} \\
N &= \text{population in millions, (from \textit{Japan Statistical Monthly Report}, Prime Minister's Office),} \\
P_f &= \text{retail fluid milk price in yen per kg, (from \textit{Household Survey}, Prime Minister's Office),} \\
CPIF &= \text{consumer price index for food, 1985=100, (from \textit{Household Survey}, Prime Minister's Office),} \\
FEXP &= \text{average per capita food expenditures in 1,000 yen, (from \textit{Household Survey}, Prime Minister's Office),} \\
TEMP &= \text{average temperature in Tokyo in degrees Celsius, (from Meteorological Agency),} \\
A &= \text{generic fluid milk promotion expenditures in million yen, (from NMPAJ),} \\
CPI &= \text{consumer price index for all commodities, 1985=100, (from \textit{Household Survey}, Prime Minister's Office),} \\
D1-D11 &= \text{monthly intercept dummy variables, equal to one for respective months and zero otherwise,} \\
(UQ^{\text{IN}})_{-1} &= \text{lagged residual,} \\
R^2 &= \text{adjusted coefficient of determination,} \\
DW &= \text{Durbin-Watson statistic, and t-values are given in parentheses.}
\end{align*}
\]
studies also use the sum of advertising coefficients and do not consider discounted present values (Thompson, Eiler, and Forker; Thompson and Eiler). Moreover, Case and Shamblin show that the optimal advertising level remains surprisingly constant over a wide range of advertising carryover.

The derived annual market response elasticity ($\theta$) is shown in the last column of table 1. This elasticity declines monotonically from 0.16 in 1981 to 0.10 in 1989. Based on our estimates, the Japanese milk market is far from collusive, and is becoming more competitive over time. This result is consistent with the findings by Suzuki, Lenz, and Forker.

Marginal Rates of Return to Promotion

To estimate marginal rates of return to promotion, (12) through (17) are solved for annual equilibrium values of $Q_J$, $P_J$, and $A$, with the collection ratio ($L$) increased 1% above actual values. Because promotion expenditures are endogenous, an exogenous shock is applied to increase promotion expenditures using $L$. Marginal rates of return to promotion are calculated as the increase in wholesale fluid milk revenue divided by the increase in promotion expenditures. Since total milk supply is given, and only the allocation to fluid and manufacturing uses are in question, the only costs associated with the increased wholesale-level revenues are the increased promotion expenditures.

The second column of table 1 contains estimated marginal rates of return to promotion from 1981 through 1989 using the imperfect competition model. As the market becomes more competitive over time, the marginal rate of return to promotion declines, going from 6.04 in 1981 to 4.33 in 1989. Although the marginal rate of return to promotion does decrease overall, the results still imply substantial opportunities for revenue enhancement through increased promotion expenditures since rates of return are always larger than one.

To compare these results with a conventional model, the present model is simulated assuming an exogenous fluid milk premium (or an exogenous fluid milk price because the manufacturing milk price is given). The third column of table 1 contains estimated marginal rates of return to promotion assuming an exogenous fluid milk premium. Since the fluid milk price declines over time, estimated rates of return to fluid milk promotion also decline throughout the simulation period. The estimated exogenous-price marginal rates of return range from 73% to 77% of the estimates in the imperfect competition model. The rate of return is higher in the imperfect competition model because increased promotion causes increases in both price and quantity, whereas only the quantity increases in the exogenous-premium model. As long as fluid demand is price-inelastic, revenue must increase more in the imperfect competition model than in the exogenous-price model.

Equations (12) through (16) can be manipulated to derive the following relationship:

\[
\frac{\partial P_J}{\partial L} = 0.14 - 0.2 \frac{\partial Q_J}{\partial M}c((\partial Q_J/\partial P_J) Q)/(1+\theta).
\]

Equation (18) gives the change in the fluid milk price associated with a marginal change in promotion expenditures (caused by a marginal change in the collection ratio). This equation shows how increases in the fluid milk price become larger as $\theta$ and $(\partial Q_J/\partial M)$ become larger and $(\partial Q_J/\partial P_J)$ becomes smaller. Because $\theta$ has declined over time, $\partial P_J/\partial L$ has also become smaller as shown in the fourth column of table 1.

### Table 1. Marginal Rate of Return to Promotion, $\partial P_J/\partial L$, and $\theta$

<table>
<thead>
<tr>
<th>Fiscal year</th>
<th>Marginal rate of return</th>
<th>Perfect competition model</th>
<th>Imperfect competition model</th>
<th>Exogenous-premium model</th>
<th>$\partial P_J/\partial L$</th>
<th>$\theta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>6.04</td>
<td>4.66</td>
<td>1.41</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>6.13</td>
<td>4.71</td>
<td>1.44</td>
<td>0.16</td>
<td></td>
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</tr>
<tr>
<td>1983</td>
<td>5.68</td>
<td>4.31</td>
<td>1.39</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>5.26</td>
<td>3.96</td>
<td>1.30</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>5.17</td>
<td>3.87</td>
<td>1.31</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>4.46</td>
<td>3.30</td>
<td>1.13</td>
<td>0.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>3.87</td>
<td>2.85</td>
<td>0.98</td>
<td>0.09</td>
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<td></td>
</tr>
<tr>
<td>1988</td>
<td>4.22</td>
<td>3.12</td>
<td>1.05</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>4.33</td>
<td>3.19</td>
<td>1.10</td>
<td>0.10</td>
<td></td>
<td></td>
</tr>
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</table>

Conclusion

We have developed a framework incorporating the degree of market competition in the evaluation of milk promotion effectiveness. The fluid milk premium is endogenously explained by the degree of market power. Using Japanese generic milk promotion data, we demonstrated how our framework improves estimates over a conventional exogenous-premium model. In Japan, estimated marginal rates of return with the exogenous-premium model were 23% to 27% smaller than those with our imperfect competition model. Such results indicate that analyses...
with an exogenous-premium model likely underestimate the rate of return to milk promotion when imperfect competition is present.

An equation was also derived to show how several parameters affect the magnitude of increase in the fluid milk price as promotion expenditures increase. The increase in milk price associated with an increase in promotion becomes larger as the market power parameter and promotion elasticity of fluid demand become larger and as the price elasticity of fluid demand becomes smaller.

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References


Appendix

Lagrangian Function for the Constrained Maximized Problem

The first-order condition for the constrained maximization problem is derived by solving the following Lagrangian:

\[ \Phi = \left( P_f q_j + G P Q T + P_n (q' - q_j - QT) - a' \right) \]

\[ + \delta_1 (Q_1 - f(P_n M)) \]

\[ + \delta_2 (Q_2 - (q_j + \sum q_j')) \]

\[ + \delta_3 (OQT - (\sum q_j - Q_1 - \sum QT)) \]

\[ + \mu (\sum q_j' - g(q_j')) \]

\[ + \omega (P_n - h(QOT)) \]

\[ + \gamma (M - A/c) \]

\[ + \mu [A - (a' + 0.24 \sum q_j) \]

\[ + 0.1 (\sum q_j' - \sum q_j') + 0.24 \cdot 2 Q_f \]

\[ + 0.10 \cdot (Q - Q_1) L + S_1] \]

\[ + \rho [a' - (0.24 q_j' + 0.10 (q_j' - q_j')] L]. \]