Generic Milk Advertising: Optimal Allocation Among Types of Media

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Abstract: *$200 million is spent annually on generic dairy promotion. Consequently, allocation of expenditures by media type (print, radio, television and outdoor) is important. This analysis frames the allocation of expenditures in an optimal control framework. Results suggest benefits occur by redistributing funds.*

Introduction

Each year more than $200 million is spent promoting milk and dairy products. Promotion strategies take many forms, including the use of television, outdoor, radio and print advertisements. Spending too little on one media type or too much in another constitutes a missed opportunity to garner high returns. Little attention has been focused on this aspect of generic milk advertising. Indeed, it will be shown that reallocation of expenditures strengthens retail milk demand and improves profitability. Research pertaining to the effectiveness of milk advertising includes Thompson and Eller (1977), Thompson (1978), Forker and Liu (1986), Kinnucan and Forker (1986), Ward and McDonald (1986), Kinnucan (1987), Goddard and Tielu (1988), Liu and Forker (1988), Wohlegenant and Clary (1992), Kaiser et al (1994) and Kaiser and Liu (1996). These studies have shown that dairy advertising has a significant impact on fluid milk consumption. For instance, Thompson and Eller regress per capita fluid milk sales on monthly advertising expenditures and other important variables and find a significant advertising coefficient. Kinnucan finds similar results using an advertising goodwill variable and six month lag period in his simulation. Liu and Forker step beyond simulation and examine generic fluid milk advertising within an optimal control framework, allocating advertising expenditures among various cities in New York state. Their treatment is particularly relevant to our study. The work of Wohlegenant and Clary and Kaiser et al. examines the linkages between farm and retail prices in order to evaluate dairy advertising. Along a similar vein, Goddard and McCutcheon study the optimal investment of producers in generic milk advertising in Ontario and Quebec. The authors find that increasing

producer investment may be beneficial. Kaiser and Liu contrast the effectiveness of brand advertising versus generic advertising on fluid milk consumption.

None of the aforementioned have considered the impact of advertising expenditures according to media type. Kinnucan and Thomas (1996) determine the impact of the media allocation decision on catfish producer welfare. Capps and Schmitz (1991) use simulation to disentangle the impact of print versus television advertising for a Texas milk market order. Clearly, there is an opportunity to explore the media allocation decision in a thorough manner. Our focus considers this decision as an optimal control problem. The methodology is most similar to Liu and Forker (1990). However, in their study, the authors treat expenditures in a particular geographical market as the decision variable and fail to distinguish between media type. Our study distinguishes between media type and thus extends the literature in this area. It also quantifies benefits of reallocating expenditures at a national level.

Conceptual Framework

Theoretic models place advertising within an optimal control framework. Nerlove and Arrow's capital theoretic approach considers advertising as an investment in firm goodwill. Vidae and Wolfe view advertising as a method by which to capture market potential. Gould allows captured and uncaptured market interaction in a diffusion approach. Liu and Forker (1989) review advertising in an optimal control framework.

These theoretical approaches are the basis of empirical study (Liu and Forker). However, these approaches assume the firm controls either the price or quantity of its production. The assumption is not valid for generic dairy promotion. Rather, an endogenously determined farm milk price and the subsequent supply response more

accurately reflect dairy market structure. More specifically, our fluid advertising model is comprised of three parts: a retail fluid sales equation, farm milk supply equation and the equation for the blend price. Dairy farmers receive a blend price based on federal order class prices and utilization percentages. This price is a function of fluid sales and fluid milk supply, given the exogenous Class 1 differential and the Class 2 price. The objective of the promotion agency is to maximize the discounted net revenue stream from farm milk sales where control variables are advertising expenditures for each media type.

Retail Fluid Sales Equation

Retail fluid milk demand is a function of advertising expenditures, prices, income and other factors. The demand relationship may be represented as:

(1) $A_{t+1} = \Phi\ (U_{i,t+1}, A_t) + Z_{t+1}$

where A_t is the retail sales of milk in time period t. $U_{i,t+1}$ is the advertising expenditure in time t+1 of media type $i \in$ {outdoor, print, radio, television}.

The time lag for consumers to absorb and act on an advertising message is an empirical issue. In our model, $\Phi\ (U_{i,t+1}, \bullet)$ captures the positive impact on sales of current expenditures. Lag effects of advertising and sales decay are captured by the lagged dependent variable $\Phi\ (\bullet, A_t)$. Z_{t+1} captures contemporaneous impact on demand of all other variables.

Farm Milk Supply Equation

The supply of raw milk depends on the expected farm milk price, capacity, variable costs and other factors. Assume farmers have a naive price expectation so that the perceived price in time t+1 is the same as the current price. Represent the farm supply equation as:

(2.1) $S_{t+1} = f(p^f_t, S_t) + W_t$

S_{t+1} is the farm supply of milk in period t+1, a function of milk blend price in the previous period (p^f_t). $f(p^f_t, \bullet)$ captures the role p^f_t has on S_{t+1}, and $(\bullet, S_t)$ accounts for the negative impact of depreciation in farm production capacity. W_t represents the lag impacts of the other variables in time t on S_{t+1}.

The blend price (p^f_t) is endogenous. The national model assumes a single marketing order exists for producers. Under the order, processors buy raw milk paying the Class 2 price (P_t) for all milk sold plus the Class 1 milk differential (δ_t) while an additional premium (Pr_t) may be added. The average blend price is:

(2.2) $p^f_t = (\delta_t) * A_t/S_t + P_t + Pr_t.$

Given (2.2) we may rewrite the supply transition equation (2.1) as:

(2) $S_{t+1} = \Psi(A_t, S_t|\delta_t, P_t, Pr_t) + W_t$

where A_t, S_t are state variables conditional on exogenous variables δ_t, P_t and Pr_t.

Inequality Constraints

Inequality constraints reflect the realities of the dairy promotion. Clearly, retail milk sales cannot exceed supply:

(3.1) $A_t \leq S_t.$

Advertising may not exceed budgetary constraints. We restrict spending of all media types ($\sum_i U_{i,t} = U_t$) in period t to be no greater than historical expenditures, $\bar{U}_t$[1]. That is,

(3.2) $U_t \leq \bar{U}_t$.

Finally, the following nonegativity conditions are imposed.

(3.3) $A_t \geq 0, U_{i,t} \geq 0, S_t \geq 0.$

Objective Function

For given initial conditions (A_o,S_o) the promotion agency's objective is to maximize the discounted net revenue stream subject to constraints by choosing advertising expenditures for each media type { $U_{i,t}$: t = 0,1,… T } so as to drive the level of retail milk sales { A_t: t = 1,2, … T } and farm supply {S_t: t = 1,2,…T} to the optimal path[2]. We represent this mathematically as:

$$Z = \sum_{t=0}^{T-1} \rho^t \{p^f_t * S_t - U_t\} + \rho^T * V(A_T, S_T),$$

where $\rho^T \equiv (1 + r)^{-1}$ and r is the interest rate; and $V(A_T, S_T)$ is a salvage term including terminal cash flow and the terminal value of the states A_T and S_T. Using (2.2) the objective can be expressed in terms of prices {δ_t}, {P_t} and {Pr_t}:

$$(4) \qquad Z = \sum_{t=0}^{T-1} \rho^t \{\delta_t * A_t + (P_t + Pr_t) * S_t - U_t\} + \rho^T * V(A_t, S_t)$$

The Econometric Model

The econometric model consists of a demand equation and a supply equation for the United States. The estimation is based on quarterly data from the first quarter of 1984 to the final quarter of 1993.

Retail Fluid Sales Equation

The dependent variable for the retail fluid sales equation is A_{t+1}. The independent variables include advertising expenditures of the following types: Print, Radio, TV and Outdoor. Additionally, the National Dairy Board began advertising milk on television in 1984. To account for the interaction of program with other generic television advertising, we generate a dummy variable (NDB) which is multiplied by TV. Advertising variables

are deflated by the Media Cost Index and are specified as second-order polynomial distributed lag functions of the current and previous four quarter's expenditures with both end point restrictions imposed. This restriction is common in econometric modeling of dairy advertising (Kaiser et al., Wohlgenant and Clary). Other variables include lagged retail demand (A_t), seasonal dummy variables (SEAS(1), SEAS(2), SEAS(3)), a price index for non-alcoholic beverages (PBEV), a price index for meat products (PMEAT), income (INCOME), and a trend (TREND). These price and income variables are deflated by the Consumer Price Index. The equation is specified in double logarithmic form and estimated using OLS. Results of estimation are shown in Table 1. As expected, INCOME is significant and positively correlated with fluid milk demand. PBEV quantifies the change in milk demand for a change in the price of beverage substitutes and is positive and significant. Conversely, PMEAT, which suggests a complementary (negative) relationship with milk demand, is not significant. TREND reflects shifts in consumer preferences to low fat products and is significant and negative. Importantly, each of the media type elasticities (PRINT, TV, RADIO, OUTDOOR) is positively correlated with fluid milk demand and significant. The exception is the OUTDOOR elasticity which, though signed as expected, is not significantly different from zero.

Farm Milk Supply Equation

Farm milk supply (S_{t+1}) is regressed on lagged farm supply for three periods (S_t, S_{t-1}, S_{t-2}), an output/input price ratio (i.e. the lag blend price (p^f_t) divided by the lag feed cost index ($PFEED_t$)), the deflated lag slaughter cow price ($PKCOW_t$), two dummy variables set to 1 for January 1984 through June 1985 and April 1986 through September 1987,respectively, a trend variable and seasonal dummies. Estimation results are shown in Table 1. The

output-input ratio captures the effect of output price on supply and is significant and positive. The lag dependent variables capture farm capacity constraints. The slaughter cow price accounts for the opportunity costs of maintaining a dairy herd. The two dummy variables capture the supply effect of the 1984-85 Milk Diversion Program (MDP) and the 1986-87 Dairy Termination Program (DTP) respectively. Each is significant and signed negative. Finally, TREND captures the impact of technology on dairy production and has a positive, significant relationship with dairy supply.

Table 1. Estimation Results

Retail Fluid Sales Equation		Adj. R^2 = .9603 DW = 2.05		
Variable		Coefficient		t-statistic
C		1.017		4.606
SEAS(1)		-0.032		-4.784
SEAS(2)		-0.074		-13.303
SEAS(3)		-0.051		-15.097
A_t		0.33		3.007
$PMEAT_t$		-0.048		-0.702
$INCOME_t$		0.236		3.749
$PBEV_t$		0.035		1.88
TREND		-0.043		-2.996
PRINT		0.004		1.911
RADIO		0.0022		2.466
TV		0.0003		2.616
OUTDOOR		0.0006		0.9526
NDB		0.0004		1.893

Farm Milk Supply Equation		Adj. R^2 = .9644 DW = 2.03		
Variable		Coefficient		t-statistic
C		1.409		3.147
SEAS(1)		0.007		0.54
SEAS(2)		0.058		4.238
SEAS(3)		-0.013		-0.945
S_t		0.669		5.127
S_{t-1}		-0.454		-3.489
S_{t-2}		0.387		3.442
$p^f_t/PFEED_t$		0.068		1.994
$PKCOW_t$		-0.058		-2.663
TREND		0.037		2.299
MDP		-0.022		-2.445
DTP		-0.027		-3.139

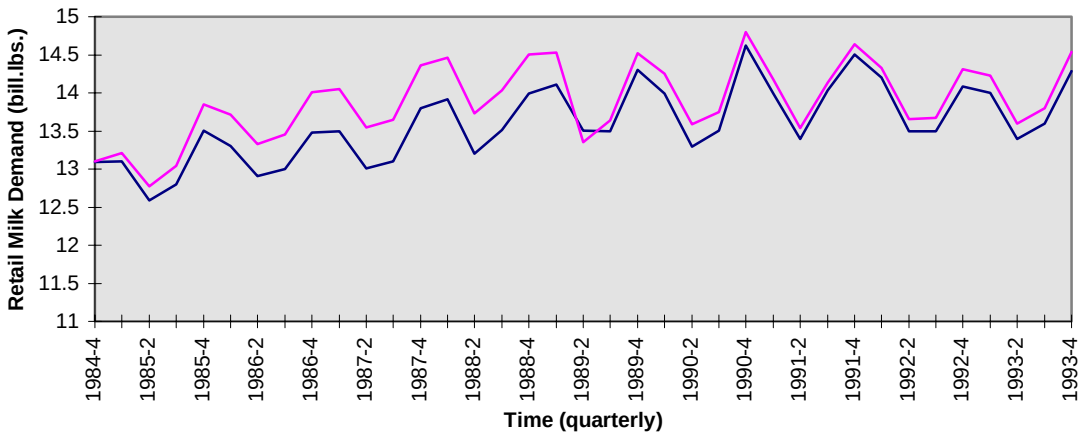
The Optimization

The estimated retail sales equation is adapted to the form of (1) by collapsing all terms into Z_{t+1} excluding lagged milk demand and advertising expenditures. Similarly, the farm milk supply equation is adapted by collapsing all but the blend price (p^f_t) and lag supply

(S_t) into W_t. It is then possible to maximize the objective function (4) subject to the state equations (2.1), the blend price formula (2.2) and nonnegativity constraints.

The interest rate (r) is one quarter the effective annual rate -- the rate on 6 month Treasury Bills between 1985-1995 (6.155%). Note that the terminal value function V(•) in (4) includes cash flow in the last period ($\delta_T A_T + (P_T + Pr_T)S_T$) and the values of the state variable, A_T and S_T, which represent the future income stream discounted by ρ and their respective decay (depreciation) rates[3]. The optimization problem is solved for the period beginning in the first quarter of 1984 through the final quarter of 1993, given prorated national fluid advertising expenditures.

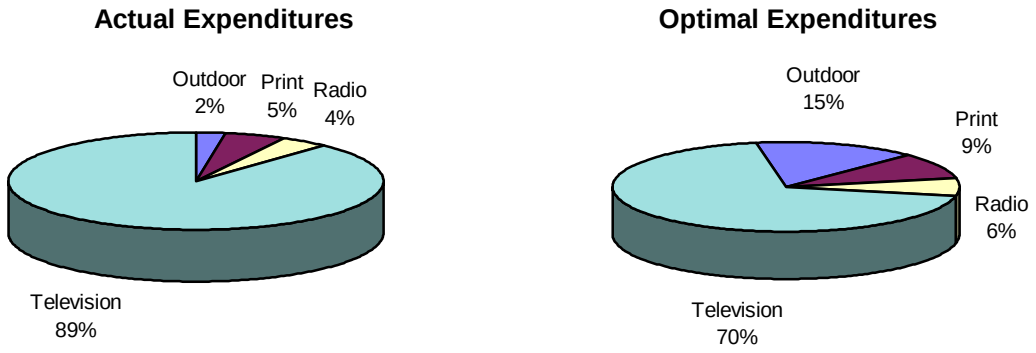
Figure I: Actual vs Optimal Demand (1984-1993)



Clearly, there are important benefits to redistributing advertising expenditures among media type. Figure I compares quarterly retail demand for fluid milk, both under observed (ACTUAL) and optimized expenditures (OPTIMAL). It is quite evident that OPTIMAL demand is greater than ACTUAL demand. The demand shift has a positive impact on profitability. The promotion agency's profit (sales minus advertising expenditures) increases by $29 million per annum.

Careful examination suggests the origin of increased demand and profitability lies in the distribution of expenditures among print, tv, radio and outdoor advertising. The more effective a media type, the greater the share of total advertising expenditures it should receive relative to others. Figure II shows the allocation difference between actual and optimal expenditures. 89% of average quarterly expenditures were allocated to television in 1984 - 1993. Yet, under the optimal control framework, this figure is reduced to roughly 70%. Print, radio and outdoor expenditures are increased by 4%, 2% and 13% respectively in the optimal control framework. It follows that television advertising's marginal cost is greater than its marginal benefit. The reverse is true for print, outdoor and radio. Clearly, fluid milk sales and profits could be increased with a reallocation of media expenditures by type.

Figure 2. Percent of Total Media Expenditures by Type: Actual vs. Optimal



It is important to subject the previous results to a sensitivity analysis as a measure of robustness. To measure robustness, the control variables (media expenditures) should be altered separately and the optimization is repeated. Results are then reviewed for consistency. The results of the sensitivity analysis are shown in Table 2.

A standard deviation was added (subtracted) to each of the coefficient values for print, tv, radio and outdoor. Adding a standard deviation should make an advertising type

more effective relative to others, and it is expected the more effective a medium is the greater share of advertising expenditures it should receive. For instance, adding a standard deviation to the print coefficient improves its effectiveness relative to other variables. As is shown in the first line of Table 2, the improved print variable commands 14% of total expenditures where it once received 9% under the OPTIMAL framework (located at the bottom of the table). Interestingly, the relative share of TV expenditures decreases from 70% (OPTIMAL) to 65% whereas outdoor and radio advertising (15% and 6% respectively) are unchanged. Reducing the effectiveness of print by a standard deviation decreases its share of advertising expenditures to 5%. Such a reduction increases the relative share of Outdoor (16%), Radio (7%) and Television (72%).

In general, findings indicate that the measurement of the control variables is robust. Increasing the effectiveness of one media type increases its share of total media expenditures, while decreasing effectiveness reduces its share. Interestingly, at no time does television receive as large a share of total expenditures as were actually allocated.

Table 2. Percent of Expenditures by Media Type

	Media			
	Outdoor	Print	Radio	Television
Print (+)	15%	14%	6%	65%
Print (-)	16%	5%	7%	72%
TV (+)	13%	8%	5%	73%
TV (-)	20%	12%	8%	60%
Radio(+)	15%	9%	9%	67%
Radio(-)	16%	10%	4%	70%
Outdoor(+)	27%	8%	6%	59%
Outdoor(-)	0%	8%	11%	81%
ACTUAL	2%	5%	4%	89%
OPTIMAL	15%	9%	6%	70%

Conclusion

This analysis has examined how advertising resources are allocated among different media type – print, radio, television and outdoor. National expenditures for generic milk advertising have been studied within an optimal control framework. Within this framework, the retail demand system, farm supply system, supply response, and endogenous price system are considered. The model chooses to allocate funds to those media type which maximize promotion agency profit over time. Careful analysis has shown that allocating resources differently provide higher returns. Specifically, resources should be taken from television expenditures and redistributed to print, radio and outdoor advertising.

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[1] Advertising is not the sole promotion activity from which the agency must choose (e.g. product development and nutrition education). Modeling the advertising constraint in this manner assumes the agency optimally chooses among promotion activities. Analysis with increased funding is available upon request. Relaxing the constraint does not qualitatively change the results of this study.

[2] The objective function of this optimal control framework reflects the perspective of the promotion agency. A reasonable alternative is to maximize the net profit of producers, which accounts for costs of farm production. The two formulations, however, do not yield significantly different results because the supply response from advertising is minimal (Liu and Forker, 1988).

[3] To account for the terminal values (A_T,S_T), we allow the optimal control program to iterate an additional 40 periods (10 years) with appropriate restrictions on the control variables. Details are available in the authors' publication and available upon request.

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