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Estimating Threshold Effects of Generic Fluid Milk and Cheese
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by

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Estimating Threshold Effects of Generic Fluid Milk and Cheese Advertising

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Abstract

The purpose of this paper is to investigate the threshold effect of the U.S. generic fluid milk and cheese advertising programs. A threshold delineates the level of advertising intensity that has to be met to generate a specific level of sales effect. Given that promotional organizations face budget constraints, it is of particular interest to ascertain if there exists a minimum threshold that an advertising campaign has to overcome to yield a non-trivial sales effect. To the best of our knowledge, there is no study focusing on the threshold effects of generic advertising of agricultural products.

The estimation results confirm that, for both fluid milk and cheese advertisings, there exist three thresholds which partition the quarterly observations between 1975 and 2004 into four possible regimes depending on the level of advertising intensity in each period. The generic fluid milk advertising goodwill coefficient is found to be relatively small for the regime with the lowest advertising intensity, building up to a higher level as the regime progresses, but eventually drops to lower levels as the intensity continues to grow, reflecting the eventual arrival of the diminishing returns of advertising. The pattern of initial build up, however, is not detected in the cheese equation in which the estimated goodwill parameter starts at a rather large magnitude in the first regime, but declines monotonically and drastically in the second and third regimes, only to become statistically not different from zero in the fourth regime.

To evaluate the performance of the National Dairy Board (NDB) programs over time, the estimated demand equations are used to simulate the effect on sales of a change in the fluid milk and cheese advertising expenditure paths, focusing on the first ten years and the second ten years of the NDB's operation since 1984. While an increase in advertising expenditures has the effect of increasing sales (holding regime configuration constant), it is found that this scale effect of additional advertising may be outweighed by the negative effect of a downward shift in the goodwill coefficient arising from regime change. In other words, sales can be made lower as the result of increased advertising, a feature not supported by the conventional model of no threshold. Indeed, in the cheese case advertising elasticity is found to be negative when evaluated at some levels larger than the historical pattern. Compared to the result pertaining to the first ten years, the benefit-cost ratio of the fluid milk program suggests that the NDB has moved its fluid milk operation scale closer to optimal during the second ten years. The optimal fluid milk advertising expenditure level for the second ten years is found to be between 105 and 110 percent of the historical level.

This paper will contribute to the discussion among researchers, program managers, and industry participants on the importance of entertaining the threshold effect of advertising when examining program effectiveness and the optimal allocation of program dollars. Researchers need to be aware of the potential pitfalls of their conventional econometric estimates (and, hence, the limitations of their policy suggestions) when the true model is of threshold type. Program managers have argued that advertising effectiveness may vary, depending on the intensity of their campaigns and have long sought this information in their spending allocation decisions. The insights provided in this paper will enhance our understanding of the threshold effect of advertising.

Estimating Threshold Effects of Generic Fluid Milk and Cheese Advertising

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With the proliferation of commodity checkoff programs and the resulting intensification of generic advertising and promotion activities, a significant amount of resources and effort have been devoted to measuring the economic impacts of these programs. For example, many studies have aimed at isolating the causal relationship between advertising expenditures and sales of the commodity in question. The estimated advertising-sales relationship is then used for program evaluation and management purposes. To ensure that the estimation is unbiased and possesses as many other desirable statistical properties as possible, great effort has been exerted to: 1) include all other important explanatory variables, 2) evaluate alternative functional relationships between advertising and sales, and 3) experiment with different ways of accounting for advertising delay and carryover effects over time.

In addition to the econometric issues listed above, recent authors have attempted to refine the estimate by questioning the appropriateness of treating advertising parameters as constant over time. For example, Ward and Dixon (1989) in their fluid milk study argue that the effect of advertising on sales can be affected by changes in the underlying structure of the industry such as the inception of the National Dairy Board (NDB) and specify advertising parameters as a function of some exogenously determined structural dummy variables. Chung and Kaiser (2000), and Schmit and Kaiser (2004) treat advertising parameters as a function of changes in such variables as advertising theme, competing product advertising, and prices, arguing that a time-varying parameter model may provide a more accurate estimate of advertising effectiveness because consumers' response to advertising varies as tastes and demographics evolve along the

time continuum. In a similar vein, Kinnucan and Venkateswaran (1993) specify advertising parameters as a function of a time trend.

A second area of pursuit in parameter non-constancy has to do with the asymmetry in advertising effectiveness. Arguing that consumers do not necessarily respond at the same pace to an increase in advertising relative to a decrease in advertising, Vande Kamp and Kaiser (1999) segment an advertising goodwill variable into increasing and decreasing parts and include them as explanatory variables in their fluid milk sales equation. While the method of segmenting the advertising variable, *ex post*, may not be satisfactory econometrically, the notion that the sales effect of advertising depends, in part, on whether the advertising campaign is in an expansion or contraction phase is intuitive.¹

Allowing for threshold effects, this study focuses on a third area of non-constancy in advertising parameter. A threshold delineates the level of advertising intensity (as measured, for example, by expenditure level) that has to be met to generate a specific level of sales effect. Given that promotional organizations face budget constraints, it is of particular interest to ascertain if there exists a minimum threshold that an advertising campaign has to overcome to yield a non-trivial sales effect. While rarely investigated within an appropriate estimation framework, the notion of advertising threshold is not new in the literature. For example, behavioral psychologists have argued that sales response to advertising may exhibit a threshold effect because repetitions are often needed to ingrain a stimulus in the consumer's mind before a purchase decision is made (Greenberg and Suttoni, 1973). Corkindale and Newall (1978) find in their survey of 22 corporations that a majority of the respondents believe that advertising thresholds exist in their market environments for the reason just cited. In a study of 97 consumer

¹ Vande Kamp and Kaiser owe their notion of advertising asymmetry to Farrell (1952) who estimated demand irreversibility for various consumer products.

goods, Lambin (1976) notices that smaller brands tend to have significantly higher advertising shares than their market shares when compared with larger brands, suggesting that there may be a threshold in reaching a certain level of communication effectiveness. Using a switching-regime model, Vakratsas et al. (2004) address the issue of advertising threshold for two product categories: liquid laundry detergent, a frequently purchased product in a relatively stable, mature market; and the Sports Utility Vehicles (SUV) and passenger minivans, which are referred to as products in newly developed, competitive markets. The authors find advertising threshold effects in the SUV and minivans markets, but do not detect the same effect in the liquid laundry detergent market. For other frequently purchased products such as frozen entrées, however, Dubé, Hitsch, and Manchanda (2005) find evidence of advertising thresholds using a logit-type demand specification.

To the best of our knowledge, no study has examined the threshold nature of generic advertising of agricultural products. Using a bona-fide threshold estimation procedure, this article investigates the effect of U.S. generic fluid milk and cheese advertising programs employing quarterly data spanning over a period of 30 years. The hypothesis is that advertising-sales relationship may vary across regimes, depending on the intensity of advertising efforts. For example, one might postulate that advertising has no effect on sales in the low expenditure regime in which a minimum threshold is yet to be reached, has only a modest effect in the medium expenditure regime, and has a large effect in the high expenditure regime, with the possibility of a fourth regime reflecting the eventual diminishing returns of advertising. Hansen's (1996, 1999, 2000) threshold estimation procedure is used to estimate the threshold parameters and test for the existence of the threshold effect.

The organization of the article is as follows. Section 2 presents a conceptual model that allows for threshold effects in the advertising-sales relationship. Section 3 discusses the empirical specification and the data, followed by the estimation results in Section 4. Based on the estimated models, simulations are conducted in Section 5 to investigate the effectiveness of generic fluid milk and cheese advertising programs during the first and second ten years of the NDB which was charged to oversee the operation of the U.S. milk promotion programs since its inception in 1984. A summary and conclusions can be found in Section 6.

Threshold Sales Response Equation

For illustration purposes, consider the following demand equation depicting a conventional advertising-sales relationship for the product in question (fluid milk or cheese):

$$(1) \quad y_t = \mathbf{x}'_t \boldsymbol{\beta} + \varepsilon_t,$$

where y_t and \mathbf{x}_t , respectively, are the retail demand quantity and a vector of demand determinants (or their nonlinear transformations) at time t , $\boldsymbol{\beta}$ is the associated vector of regression parameters and ε_t is the error term. The vector of demand determinants includes the traditional economic variables such as prices and income, as well as generic and branded advertising goodwill variables which are to account for the effect on sales of advertising while recognizing that there is usually carryover effect associated with a given campaign (Vande Kamp and Kaiser, Chung and Kaiser, Schmit and Kaiser). Specifically, each of the advertising goodwill stocks is assumed to evolve in the following manner:

$$(2) \quad GW_t = \sum_{k=0}^m w_k AD_{t-k},$$

where GW_t is the advertising goodwill stock (generic or branded) which depends on advertising expenditures at $t-k$, AD_{t-k} , with $k = 0, 1, \dots, m$, where m is the number of quarters of advertising carryover.² The coefficient w_k is the weight assigned to AD_{t-k} and different structures for w_k will be entertained in the empirical section.

To allow for threshold effect, consider the case in which the effect on sales of generic goodwill depends on the advertising intensity of the program. Further, for concreteness, consider the case in which there are three regimes for advertising intensity: low, medium, and high regimes. The advertising-sales relationship in equation (1) can be modified as:

$$(3) \quad \begin{array}{ll} \mathbf{x}'_t \boldsymbol{\beta} + \theta^H GGW_t + \varepsilon_t & \gamma_U < I_t \\ y_t = \mathbf{x}'_t \boldsymbol{\beta} + \theta^M GGW_t + \varepsilon_t & \text{if } \gamma_L < I_t \leq \gamma_U \\ \mathbf{x}'_t \boldsymbol{\beta} + \theta^L GGW_t + \varepsilon_t & I_t \leq \gamma_L \end{array}$$

where GGW_t is the generic goodwill stock (for fluid milk or cheese), \mathbf{x}_t contains other demand determinants, I_t is the intensity of generic advertising in question, and γ_L and γ_U are the lower and upper thresholds partitioning the observations into the three regimes. Equation (3) dictates that if the threshold variable, I_t , lies between the lower and upper thresholds, the medium intensity regime prevails and the generic goodwill parameter takes the value of θ^M . On the other hand, if I_t lies below (above) the lower (upper) threshold, the generic goodwill parameter takes the value of θ^L (θ^H). The parameter vector $\boldsymbol{\beta}$ for other demand determinants is treated as regime independent to focus attention on the threshold effects of generic advertising while conserving the degree of freedom.

² Given that the current study employs quarterly data, the construction of the goodwill variable in (2) does not consider the delay effect of advertising. Had a delay of d periods been required, the index for the summation sign in (2) would have been from $k = d$ to m .

If the thresholds, γ_L and γ_U , were known, the estimation of equation (3) would be straightforward as the observations could then be partitioned into three groups and the usual regression procedure would apply. This insight motivates Hansen's (1999) one-dimensional grid search of identifying threshold estimates in a multiple-stage estimation framework. In the first stage, one considers only a single threshold and obtains its estimate by minimizing the corresponding single-threshold sum of squared errors function. In the second stage, one introduces an additional threshold and obtains (again via a one-dimensional grid search) the estimate of this second threshold by minimizing the corresponding double-threshold sum of squared errors function, holding constant the first threshold estimate. To improve the asymptotic efficiency of the first estimate, Hansen (1999) proposes a third-stage estimation in which the first threshold is re-estimated via a minimization of the double-threshold sum of squared errors function, holding constant the second threshold estimate. While equation (3) entertains only two thresholds, Hansen's (1999) procedure is readily extendable to higher-order threshold models.

Using the above-mentioned grid-search procedure, the two thresholds in equation (3) can be estimated in conjunction with other model parameters. The distribution theory for threshold estimates is provided by Hansen for the case of independent and identically distributed errors (1999) and for the case of conditionally heteroscedastic errors (2000). To ascertain the statistical relevance of the two-threshold model, vis-à-vis the alternative of a single threshold model and that of no threshold, likelihood ratio statistics can be computed in the usual way. However, there are complications in testing for thresholds, arising from the fact that a threshold is not identified under the null hypothesis that it does not exist. While this dilemma, commonly referred to as the unidentified nuisance parameter problem (Andrews and Ploberger, 1994), renders invalid the conventional distribution of the test statistic, Hansen (1996) was able to arrive at an asymptotic

distribution free of the nuisance parameter via a conditional transformation of the conventional distribution. The author (1996) proposes a bootstrap simulation procedure to approximate the requisite conditional transformation.

Empirical Specification

The variables included in the empirical estimation of the retail fluid milk and cheese demand equations are similar to those in Kaiser (2000) and Schmit and Kaiser. The estimations involve U.S. data from the first quarter of 1975 (1975.1) through the fourth quarter of 2004 (2004.4). Within the threshold regression framework, per capita retail demands are specified as functions of own price, substitute prices, income, consumer demographics, consumption trend, consumers' attitudes toward bovine somatotropin (bST), generic and branded advertising goodwill stocks, and seasonality. Specifically, in the fluid milk equation the own price is the consumer price index for whole milk and the substitute price is the consumer price index for nonalcoholic beverages, while in the cheese equation they are the consumer price index for cheese and the consumer price index for meats, respectively. The income figures are the per capita disposable personal income and the demographic variable is the percentage of the U.S. population under age six. A trend variable with 1975.1 being one is used to capture the general consumption trend in fluid milk, and a structural dummy variable of 1994.1 – 2004.4 equaling 1 and 0 otherwise is used to account for consumer's health concern toward the adoption of bST in milk production. Table 1 reports the descriptive statistics and sources of the data used in the study.

Equation (2) specifies goodwill as a function of current and lagged advertising expenditures which are measured in million dollars and deflated by an appropriate media cost

index (with 2004.1 ~ 2004.4 as the base periods).³ Within the conventional regression framework, previous authors (e.g., Cox 1992, Vande Kamp & Kaiser) have specified different functional forms (e.g., geometric polynomial and exponential functions) for the lag weights w_k in (2) and estimated them simultaneously with the regression parameters in (1). Estimating equation (2) simultaneously with the threshold equation (3), however, would complicate the estimation procedure in Hansen (1999) and may invalidate the asymptotic theory therein. Instead, the lag weights for advertising expenditures are specified exogenously and, upon entertaining ten different weighing schemes, are chosen as 1.0 for the current quarter expenditures and 0.55, 0.3 and 0.15 for the lagged expenditures of the immediate past three quarters.⁴

Turn to the threshold equation in (3) and note the following empirical details. First, the equation has generic advertising intensity, I_t , as the threshold variable which is to compare against the threshold parameters, γ 's, for separating the sample into different regimes. Generic fluid milk and cheese advertising expenditures (deflated by their respective media cost indices) are used as proxies for advertising intensity in the fluid milk and cheese equations, respectively.⁵

³ Different media cost indices are used to deflate fluid milk and cheese advertising expenditures. This is because the two advertising programs have historically used different mixes of medium which have different rates of inflation.

⁴ The ten weighing schemes used in the construction of the goodwill variables can be categorized into two groups: 1) monotonically declining weighing schemes with a lag length of three or five quarters, and 2) hump-shaped (peaking at various lags) weighing schemes with a lag length of three or five quarters. Within each of the two groups, the choice of the weights does not affect in any significant way the magnitudes of the regression and threshold coefficients. The monotonically declining weighing scheme is chosen over the hump-shaped alternative because the former gives rise to tighter confidence intervals for the coefficients. Holding other aspects of the weighing specification constant, the estimation results from a three-lag model are essentially identical to those from a five-lag model. The three-lag model is chosen for parsimonious reasons.

⁵ An alternative candidate for the threshold variable is the generic goodwill stock which is constructed as a linear function of current and lagged advertising expenditures. This specification is dismissed because it yields wrong signs of some of the regression coefficients.

Second, the income and own price variables in the fluid milk equation are deflated by the consumer price index for nonalcoholic beverages, an approach in line with the specification in Kaiser who argues that there exist strong correlations between substitute price and own price for dairy products.⁶ Third, the income and own price variables in the cheese equation are deflated by the consumer price index for meats, treating as the substitute price.⁷ Fourth, the equations are estimated in Gauss, based on a code taken from Hansen's website:

<http://www.ssc.wisc.edu/~bhansen>.

Estimation Results

The estimation results are reported in this section, with the first subsection focusing on the threshold parameter estimates and the second subsection on the regression coefficients as well as the elasticity measures.

Test for Threshold Effects and Threshold Parameter Estimates

The existence of advertising threshold is investigated by a sequence of likelihood ratio tests of comparing alternative models. One starts with the null hypothesis of no threshold vs. the alternative hypothesis of one threshold, and progresses sequentially to the null hypothesis of T

⁶ Alternative specifications of including own price, income and substitute prices as separate explanatory variables, while deflating each of them by the consumer price index for all items, resulted in much wider confidence intervals for the estimated threshold parameters and for some of the regression coefficients.

⁷ Similar estimation results are obtained under the alternative specification of including consumer price index for fats and oils as the substitute price. This is consistent with Schmit and Kaiser's finding that the choice between meats price and fats and oils price is inconsequential to the estimation results. In the current model of threshold regression, however, it is found that the confidence intervals for the threshold estimates are not as tight when using fats and oils price as the deflator.

thresholds vs. the alternative hypothesis of $T+1$ thresholds as warranted by the test result. Table 2 reports the likelihood ratio statistics, along with Hansen's 1996 bootstrapped critical values for the sequential tests.

In the case of fluid milk demand equation, the null hypothesis of the conventional model of no advertising threshold is soundly rejected at one percent significant level in favor of the alternative of one threshold. A same level of rejection is achieved when comparing the null hypothesis of one threshold with the alternative of two thresholds. However, the test result of entertaining the possibility of a third threshold is not as unambiguous; one can reject the two-threshold null in favor of the three-threshold alternative only at a significant level slightly above five percent (p-value is six percent). Finally, the result of testing for the existence of a fourth threshold leads one to conclude that there are at most three advertising thresholds in the fluid milk equation.

That there exist three thresholds for generic advertising is similarly confirmed in the cheese equation. The null hypothesis of no threshold (vs. the alternative of one threshold) can be rejected at one percent significant level. The null hypothesis of one threshold (vs. the alternative of two thresholds) can be rejected at ten percent significant level (p-value is eight percent), and the null hypothesis of two thresholds (vs. the alternative of three thresholds) can be rejected at five percent significant level (p-value is two percent). The final test of entertaining a fourth threshold fails to reject the null of only three thresholds at conventional significant levels.

The estimates of the three thresholds and their 95% asymptotic confidence intervals are reported in table 3. For the fluid milk case, the threshold estimates are 14.39, 18.98, and 39.50, with the associated confidence intervals non-overlapping, suggesting that the estimates are distinct statistically. The threshold estimates indicate that if the generic fluid milk advertising

expenditures (measured in 2004 media dollars) should fall below \$14 million the first regime would prevail, between \$14 and \$19 million the second regime would prevail, between \$19 and \$40 million the third regime would prevail, and above \$40 million the fourth regime would prevail. To place the above threshold estimates within a historical context of the observed data, note that the first and second thresholds lie below the median of the deflated generic fluid milk advertising expenditures (\$20 million) and the third threshold is above the 75 percentile of the data range (\$30 million). Notice also that, out of a total of 120 observations, 22 quarters fall into the first regime, 29 quarters the second regime, 54 quarters the third regime and 15 quarters the fourth regime. Figure 1 illustrates the above mentioned sample separation into various regimes of the historical data. The observations before the inception of the NDB fall mainly in the first (R1) and second (R2) regimes, whereas observations during the first ten years of the NDB fall mainly in the second (R2) and third (R3) regimes and those during the second ten years of the NDB mainly in the third (R3) and fourth (R4) regimes. The findings in table 3 and figure 1 unequivocally demonstrate the importance of allowing for regime separations in the estimation of the sales response of generic fluid milk advertising.

As to the generic cheese advertising in table 3, the threshold estimates are \$0.82 million, \$2.46 million, and \$23.07 million (measured in 2004 media dollars), with the confidence intervals non-overlapping. In comparing with the data, the first and second thresholds lie below the 25 percentile (\$6 million) of the observations while the third threshold is above the 75 percentile (\$17 million), suggesting the third regime is the dominating regime which accounts for 50 percent of the data range. Out of a total of 120 observations, 13 quarters fall into the first regime, 11 quarters the second regime, 87 quarters the third regime and 9 quarters the fourth regime. Figure 2 shows that, with the exception of the period from 1984 to 1987 which belongs

to the fourth regime of unusually high expenditures (over \$23 million), the third regime (\$3 ~ \$23 million) has predominated since the beginning of the 1980s, prior to which the observations mainly fall into the low expenditure category of the first (below \$0.8 million) and second (\$0.8 ~ \$3 million) regimes. Again, the estimation results confirm the importance of allowing for regime separations in assessing the sales effectiveness of generic cheese advertising.

Regression Parameter Estimates and Elasticities

The estimation results pertaining to the empirical counterpart of equation (3) are reported in table 4. Unless noted otherwise, all the coefficients are significant at, at least, 95 percent confidence level. Focus first on the regime dependent parameter: generic goodwill. The estimation results reveal how the generic goodwill stock affects demand under alternative regimes. In the fluid milk equation, the largest coefficient is the one pertaining to the second regime (0.089), with those for the first (0.068) and third (0.065) regime being about equal in magnitude and the one for the fourth regime (0.048) the smallest. This result is interesting because it suggests a requirement of an initial build up of the generic goodwill via boosting advertising intensity to reach a certain level of sales effect, but the effect diminishes as the goodwill stock continues to grow. The pattern of initial build up, however, is not detected in the cheese equation in which the estimated goodwill parameter starts at a rather large magnitude of 2.589 in the first regime, but declines monotonically and drastically in the second (1.247) and third (0.057) regimes, and eventually becomes statistically not different from zero in the fourth regime. Lacking of a build up phase notwithstanding, the cheese result still supports the notion of diminishing returns of advertising and, indeed, it has zero effect when the intensity is so high that the fourth regime prevails.

Turn to other regression coefficients in table 4 which are specified as regime invariable. The own price coefficients have the expected negative sign in both equations, but the one in the cheese equation is significant only at the ten percent level. Both income coefficients are positive and highly significant. The branded cheese goodwill variable has a positive coefficient in the cheese equation, but the branded fluid milk goodwill variable is deleted from the fluid milk equation as its coefficient (positive aside) is not statistically different from zero at the usual confidence levels. The estimation results from the fluid milk equation also confirm previous findings of a positive correlation between fluid milk consumption and percentage of population under age six, and a negative correlation between fluid milk consumption and the adoption of bST (Kaiser, Schmit and Kaiser).⁸ The history patterns of a downward trend in fluid milk consumption and an upward movement in cheese consumption are reflected in the signs of the trend coefficients in the two equations. All the quarter dummy variables are highly significant, indicating a strong seasonal pattern in the consumption of dairy products. To address the problem of autocorrelation in the initial equations (not reported), a first-order autoregressive [AR(1)] term for the residuals is included in the fluid milk equation and both the first-and second-order [AR(2)] autoregressive error terms are included in the cheese equation.⁹ The Breusch-Godfrey statistic indicates that the residuals in both fluid milk and cheese equations are free from

⁸ Following Kaiser and Schmit and Kaiser, the age variable and the bST dummy variable are excluded from the cheese demand equation. The finding that there exist threshold effects in generic cheese advertising reported in the previous subsection remains valid when the age and bST variables are also included in the cheese equation, albeit only two thresholds were identified by the likelihood ratio tests. With the inclusion of those two variables, the coefficients for the own price and branded cheese goodwill variables became insignificant (and the bST coefficient was also insignificant).

⁹ The autoregressive parameters are estimated with other regression parameters, holding constant the threshold coefficients. The imposition of the autoregressive error terms does not change the estimated regression coefficients and their t-ratios in any significant manner.

autocorrelations. Finally, the adjusted R-squared is 0.96 for fluid milk and 0.99 for cheese, indicating good fit of the data.

To facilitate comparison between the estimated parameters in table 4 with those obtained by recent authors using national data, table 5 reports elasticities of key variables, evaluated at the sample means, along with their standard errors. The generic goodwill stock elasticities (henceforth goodwill elasticities) for fluid milk are regime dependent, ranging from 0.04 for the fourth regime to 0.08 for the second regime. Those elasticity measures fall within the range of previous estimates [e.g., 0.04 in Schmit and Kaiser, 0.05 in Kaiser, and 0.06 in Blisard et al. (1999)]. As to the cheese case, the estimated goodwill elasticities for the third and fourth regimes are within the range of previous results of 0.01 ~ 0.02 (Schmit and Kaiser; Kaiser; and Blisard et al.), while the elasticity for the first and second regimes are estimated to be much larger.

Regarding the own-price elasticity in table 5, the current estimate of -0.2 for fluid milk is in consonance with those found in Kaiser (-0.17) and Blisard et al. (-0.12), but is much larger in magnitude than the one reported in Schmit and Kaiser (-0.04). The estimated own-price elasticity of cheese is -0.15 which is smaller in absolute value than those reported in previous studies not recognizing the threshold effect of advertising (e.g., -0.32 in Kaiser, -0.35 in Schmit and Kaiser, and -0.62 in Blisard et al.). The comparison of the income elasticity of fluid milk demand is mixed, with the current estimate (0.45) being similar to the one reported in Schmit and Kaiser (0.42), but larger than those in Kaiser and Blisard et al. (0.18 and 0.21, respectively). The income elasticity for cheese is 0.2, which is similar to those reported in Blisard et al. (0.24) and Kaiser (0.31), but smaller than the 0.66 estimate reported in Schmit and Kaiser. As to the branded goodwill elasticity for cheese advertising, the current estimate of 0.03 is identical to that in Kaiser. Finally, the age elasticity for fluid milk indicates that as the percentage of population

under age six increases by one percent [e.g., from its mean figure of 7.3% to $(7.3 * 1.01) \%$], the per capita consumption of fluid milk would increase by 0.2%, a figure much smaller than those reported in Kaiser (0.6) and Schmit and Kaiser (0.8).

Simulation

The estimated fluid milk and cheese demand equations are used to simulate the effect on sales of changes in advertising expenditures, allowing for different regimes to manifest as the consequence of the expenditure change. The resulting advertising expenditure elasticity (henceforth advertising elasticity) differs from the goodwill elasticities in table 5 because the simulation here is with respect to a change in advertising expenditure flow, rather than in advertising goodwill stock. More importantly, the goodwill elasticities in table 5 pertain to individual regimes, while the simulated advertising elasticities in this section mimic the reality (of the model) by allowing regime to shift as the consequence of a change in advertising intensity. In the case of fluid milk, the simulation results are also used to obtain insights toward the optimality of the advertising program as the benefit of additional fluid milk sales due to an increased advertising can be easily evaluated using information on Class I differential.

In addition to the baseline simulation of historical spending pattern, advertising expenditures are set at a five percent increment of the historical level, up to a total of 100 percent increment, to gain insights into what would have been the sales effect had the NDB set its advertising expenditures at a higher level. To focus the analysis on the performance over time of the programs, the simulations are conducted for two periods: the first ten years (1984.4 – 1994.4) and the second ten years (1995.1 – 2004.4) of the NDB's operation.

The simulation results for fluid milk sales are reported in figure 3 in which advertising elasticities for each of the two simulation periods are computed at various hypothetical expenditure levels.¹⁰ Focus on the first pair of the bars appearing in the far left of the figure. Comparing the sales associated with 105 percent of the historical advertising expenditure level with the sales from the historical level gives an estimate of the historical fluid milk advertising elasticity of 0.052 for the first ten years of the simulation and 0.072 for the second ten years.¹¹ The difference in the sales effects is, in part, due to the fact that the magnitude of a fixed percentage shock is different for the two periods, given that the deflated advertising expenditures are much higher in the second period (\$33 million per quarter) than in the first period (\$23 million per quarter). In addition to the above scale effect on sales of the shock, there is a regime-shift effect also contributing to the higher advertising elasticity for the second period. This can be better understood by inspecting figure 1 and noting that the five percent increment in the expenditures in the first period had resulted in more observations being shifted from the third regime to the fourth regime, with the latter having a smaller goodwill coefficient (and, hence, a smaller sales effect, *ceteris paribus*).¹² The downward shift in the goodwill coefficient arising from regime change also underlies the diminishing returns property of the model, vividly illustrated in figure 3. Specifically, for each of the two simulation periods, the computed

¹⁰ For conciseness, the simulation results are reported only up to 20 percent increment of the historical advertising expenditures.

¹¹ The elasticity is arc, computed as the ratio of the percentage change in sales (from the base quantity) and the percentage change in advertising expenditures (from the base expenditures).

¹² Given the magnitude of the shock, note that there are two factors which determine the number of observations being shifted from regime 3 to regime 4 in each simulation period: the number of observations residing in the lower regime before the shock (i.e., the number of the candidates), and how close those observations are to the threshold bordering the two regimes (i.e., the qualification of the candidates).

advertising elasticity declines gradually from 0.052 to 0.029 for the first ten year period and from 0.072 to 0.025 for the second ten year period as an additional five percent of the historical spending level is being added to the base expenditures.

The simulation results pertaining to cheese sales are reported in figure 4. Again focus on the first pair of the bars evaluating the sales effects in the two simulation periods of a five percent increase in cheese advertising expenditures from the historical level. As in the fluid milk case, the cheese advertising elasticity for the first ten years is found to be smaller than that for the second ten years (0.016 and 0.026, respectively), owing mainly to the fact that the increased cheese advertising expenditures has resulted in more observations in the first simulation period being shifted from the higher coefficient regime (R3) to the lower coefficient regime (R4) than in the second period.¹³ The effect on sales of a downward shift in the goodwill coefficient arising from regime change is most dramatically demonstrated in figure 4 when comparing advertising elasticities under different expenditure levels. Specifically, unlike the conventional model of no threshold, it is possible here for sales to be made lower as the consequence of an increase in advertising expenditures if the effect of the resulting downward shift in goodwill coefficient outweighs the scale effect of the increased advertising. Thus, figure 4 suggests that it was correct for the NDB not engaging in cheese advertising in the first simulation period beyond the level it had expended, as otherwise the marginal returns on sales would have been negative. As to the second simulation period in figure 4, the negative marginal returns of advertising would kick in only after the expenditures are increased to about 120 percent of the historical level. It is

¹³ As in the fluid milk case, the sales effect of a fixed percentage shock of the historical expenditures depends also on the magnitude of the historical expenditures. The deflated cheese advertising expenditures are in general higher in the first ten years than in the second ten years (\$18 and \$14 million per quarter, respectively), suggesting a larger sales impact for the first period (holding regime configuration constant). However, this scale effect was dominated by the regime shift effect just discussed.

interesting to note that the historical cheese expenditures for the second period were about 20 percent lower than that for the first period (see footnote 13).

Note that the discussion in the preceding paragraph does not involve the issue of optimality as it refers only to the sales effect of cheese advertising without making reference to the monetary costs and benefits of the advertising program. The optimality issue is difficult to tackle because the benefit to dairy farmers of additional cheese sales depends on a number of factors. If the government support price for cheese is binding, the additional cheese sales due to advertising would have the effect of reducing government purchase of the surplus cheese without affecting the price dairy farmers receive. On the other hand, if the market equilibrium prevails and the support price is not binding, the Class II price that dairy farmers receive would be endogenous, affected by the advertising-induced cheese sales.¹⁴ Thus, a complete analysis would entail a dairy industry model in the line of Liu et al. (1991) which allows for the market to switch between a market equilibrium regime and a government supported regime, depending on supply and demand conditions. Given the aim of the current study which focuses on the threshold effect of advertising, the development of a switching industry model with an embedded feature of advertising threshold is best left for future research.

In the case of fluid milk advertising, however, the optimality analysis is much more straightforward. An advertising-induced fluid milk sales reallocates milk from Class II to Class I usage and thus the benefits to dairy farmers can be evaluated at Class I differential (i.e., the difference between Class I and Class II prices). Compared to the case of no generic fluid milk advertising, the benefits and costs of the program are computed for the two simulation periods.

¹⁴ Under the stipulation of the Federal Milk Marketing Order, milk used in fluid products is placed in Class I, the highest priced class, while milk used to produce cheese, ice cream, yogurt, butter, nonfat dry milk, and other manufactured products is placed in Class II, or other lower-priced classes (U.S. Department of Agriculture, Agricultural Marketing Service, 2006).

The benefit-cost ratios are also computed for various increments of advertising expenditures from the historical level to gain insights toward the effectiveness of the NDB's fluid milk operation.

Focus on the benefit-cost ratios for the first simulation period in figure 5. Compared to the case of no advertising, the benefit-cost ratio of the fluid milk advertising program for the first period is 1.8, suggesting that the benefit of the program outweighs its costs and the net benefit to dairy farmers could have been made higher had the expenditures been set at a higher level. Had the advertising expenditures been increased to 120 percent (and beyond) for the first simulation period, the computed benefit-cost ratio would have dropped, approaching 1.2. As to the second simulation period, the benefit-cost ratio is 1.2 for the historical spending level, suggesting that the NDB has moved its fluid milk operation scale closer to optimal after being in existence for ten years. Indeed, the simulation results suggest that the optimal fluid milk advertising expenditure level for the second ten years is between 105 and 110 percent of the historical level, as beyond which point the benefit-cost ratio would fall below one.

Summary and Conclusions

While the threshold modeling approach is merely a way of introducing nonlinearity between sales and advertising, it allows researchers to capture the fact that repetitions in messages are often needed before a purchase decision is made – as Simon and Arndt (1980, p.13) aptly put it, “you’ve got to keep dripping the water onto the rock until it cracks.” From a practical viewpoint of program managers, the threshold approach is also useful as it provides unique insights toward the various ranges of advertising operation scale within each of which the marginal effect on sales of advertising remains more or less constant. Using a bona-fide threshold estimation

procedure, this study represents the first attempt to investigate if thresholds exist in the sales effect of U.S. generic fluid milk and cheese advertising programs.

The estimation results of the sales response equations confirm that, for both fluid milk and cheese advertisings, there exist three thresholds which partition the 30-year quarterly observations in the data into four possible regimes depending on the level of advertising intensity in each period. The generic fluid milk advertising goodwill coefficient is found to be relatively small for the regime with the lowest advertising intensity, building up to a higher level as the regime progresses, but eventually drops to lower levels as the intensity continues to grow, reflecting the eventual arrival of the diminishing returns of advertising. The pattern of initial build up, however, is not detected in the cheese equation in which the estimated goodwill parameter starts at a rather large magnitude in the first regime, but declines monotonically and drastically in the second and third regimes, only to become statistically not different from zero in the fourth regime.

To evaluate the performance of the national programs over time, the estimated equations are used to simulate the effect on sales of a change in the advertising expenditure path, focusing on the first ten years and the second ten years of the NDB's operation since 1984. While an increase in advertising expenditures has the effect of increasing sales (holding regime configuration constant), it is found that this scale effect of additional advertising may be outweighed by the negative effect of a downward shift in the goodwill coefficient arising from regime change. In other words, sales can be made lower as the result of increased advertising, a feature not characteristic of the conventional model of no threshold. Indeed, in the cheese case advertising elasticity is found to be negative when evaluated at some levels larger than the historical pattern. The results also show that there has been an increase in both fluid milk and

cheese advertising elasticities over the two simulation periods.

In the case of fluid milk advertising, the benefit of additional sales due to advertising is evaluated at Class I differential. The benefit-cost ratio of the fluid milk program during the first ten years of the NDB's operation is found to be 1.8, with the ratio approaching 1.2 as the historical expenditure level is being expanded. With the observed fluid milk advertising expenditures greatly increased during the second ten years, the benefit-cost ratio becomes 1.2 for the historical level, suggesting that the NDB has moved its fluid milk operation scale closer to optimal. Indeed, the simulation results suggest that the optimal fluid milk advertising expenditure level for the second ten years is between 105 and 110 percent of the historical level.

The optimality issue pertaining to cheese advertising is more difficult to tackle because of the complications of the market system, burdened by the classified milk pricing scheme and the dairy price support program. While it is not straightforward to cast the advertising threshold models of this study onto a switching dairy industry model which allows for the realization of either a market equilibrium regime or a government supported regime, this line of future research may prove to be fruitful in helping researchers gain a deeper understanding of the threshold effect of generic dairy product advertising and its impacts on the various components of the industry.

Table 1. Statistical Summary of Variables ^a

Variable	Units	Mean	Std. Dev.	Data Source
Retail fluid milk demand per capita	lbs. MFE	53.27	3.70	USDA/ERS
Retail cheese demand per capita	lbs. MFE	48.48	11.12	USDA/ERS
CPI for fresh milk and cream	1982-84=100	119.36	30.91	USDL/BLS
CPI for cheese	1982-84=100	121.04	34.73	USDL/BLS
CPI for nonalcoholic beverages	1982-84=100	109.70	25.57	USDL/BLS
CPI for meats	1982-84=100	121.38	32.02	USDL/BLS
Per capita disposable personal income	Thousand \$	16.34	7.14	Economagic, LLC
Percentage of the population under age six	%	7.26	0.28	Economagic, LLC
Generic fluid milk advertising expenditures	mil \$.	14.00	11.00	NICPRE
Generic cheese advertising expenditures	mil \$.	7.20	5.22	NICPRE
Branded fluid milk advertising expenditures	mil \$.	2.31	1.88	NICPRE
Branded cheese advertising expenditures	mil \$.	17.33	8.12	NICPRE
Media cost index for fluid milk	2004=100	2.38	1.24	NICPRE
Media cost index for cheese	2004=100	2.40	1.17	NICPRE

^a Retail fluid milk and cheese demands per capita are expressed in milkfat equivalent (MFE) basis, CPI denotes consumer price index, USDA/ERS stands for U.S. Department of Agriculture, Economic Research Service, and USDL/BLS stands for U.S. Department of Labor, Bureau of Labor Statistics. The data on advertising expenditures and media cost indices are provided by the National Institute for Commodity Promotion Research and Evaluation (NICPRE).

Table 2. Tests Results for Threshold Effects

Null Hypothesis	Alternative Hypothesis	Likelihood Ratio Statistic	Bootstrapped critical values ^a		
			1%	5%	10%
Fluid Milk:					
No Threshold	One Threshold	22.7	14.5	10.9	9.4
One Threshold	Two Thresholds	19.6	15.3	11.3	9.5
Two Thresholds	Three Thresholds	11.7	18.1	12.6	10.2
Three Thresholds	Four Thresholds	3.7	17.8	13.4	11.3
Cheese:					
No Threshold	One Threshold	17.5	15.5	11.4	10.1
One Threshold	Two Thresholds	9.7	14.0	10.8	9.4
Two Thresholds	Three Thresholds	13.4	14.3	10.6	9.1
Three Thresholds	Four Thresholds	5.2	14.6	10.2	8.9

^a 1,000 replications were conducted in each bootstrap run.

Table 3. Threshold Estimates

	Fluid milk		Cheese	
	Estimate	95% confidence interval	Estimate	95% confidence interval
First threshold	14.39	13.82 ~ 15.15	0.82	0.56 ~ 0.92
Second threshold	18.98	18.06 ~ 20.75	2.46	2.05 ~ 9.50
Third threshold	39.50	33.83 ~ 42.25	23.07	21.09 ~ 24.35

Table 4. Estimated Regression Parameters: Triple-Threshold Model

Variables	Fluid milk		Cheese	
	Coefficient	t-ratio	Coefficient	t-ratio
<u>Regime dependent parameter</u>				
Generic goodwill ^a				
Regime 1	0.068	4.4	2.589	5.1
Regime 2	0.089	8.2	1.217	4.0
Regime 3	0.065	8.2	0.056	2.9
Regime 4	0.048	8.6	0.016	1.0
<u>Regime independent parameters</u>				
Intercept	43.999	14.2	27.997	7.6
Normalized own price ^b	-9.998	-6.0	-7.218	-1.8
Normalized income ^b	1.685	8.0	0.792	2.7
Branded goodwill ^a	n.a. ^c	n.a.	0.022	3.1
Percentage under age six	1.429	3.7	n.a.	n.a.
bST dummy ^c	-0.920	-2.2	n.a.	n.a.
Time trend	-0.252	-11.2	0.272	13.5
Quarter dummy 1	-0.629	-3.2	-4.595	-14.2
Quarter dummy 2	-3.203	-16.2	-2.456	-7.8
Quarter dummy 3	-2.769	-13.9	-2.419	-7.7
AR(1)	0.542	5.7	0.329	3.5
AR(2)	n.a.	n.a.	0.293	3.0
Adjusted R-square	0.96		0.99	
First-order Breusch-Godfrey Test ^d	0.20 (3.84)		2.06 (3.84)	

^a Generic (branded) goodwill variables are specified as the weighted sum of current and previous three quarters' generic (branded) expenditures deflated by a media cost index.

^b Own prices and per capita disposable income in the fluid milk and cheese equations are normalized by a substitute price (CPI for nonalcoholic beverages in the fluid milk equation and CPI for meats in the cheese equation).

^c The bST dummy equals one from 1994.1 through 2004.4, and zero otherwise.

^d The Breusch-Godfrey statistic has a Chi-square distribution with n degree of freedom, where n is the order of autocorrelation under the alternative hypothesis. The critical value at five percent significance level is in parentheses.

^e n.a. = not applicable

Table 5. Selected Demand Elasticities at the Sample Mean

Variables	Fluid milk		Cheese	
	Estimate	Stand. Err.	Estimate	Stand. Err.
<u>Regime dependent parameter</u>				
Generic goodwill				
Regime 1	0.06	0.01	1.33	0.26
Regime 2	0.08	0.01	0.62	0.16
Regime 3	0.06	0.01	0.03	0.01
Regime 4	0.04	0.01	0.01	0.01
<u>Regime independent parameters</u>				
Normalized own price	-0.20	0.03	-0.15	0.08
Normalized income	0.45	0.06	0.20	0.08
Branded goodwill	n.a.	n.a.	0.03	0.01
Percentage under age six	0.20	0.05	n.a.	n.a.

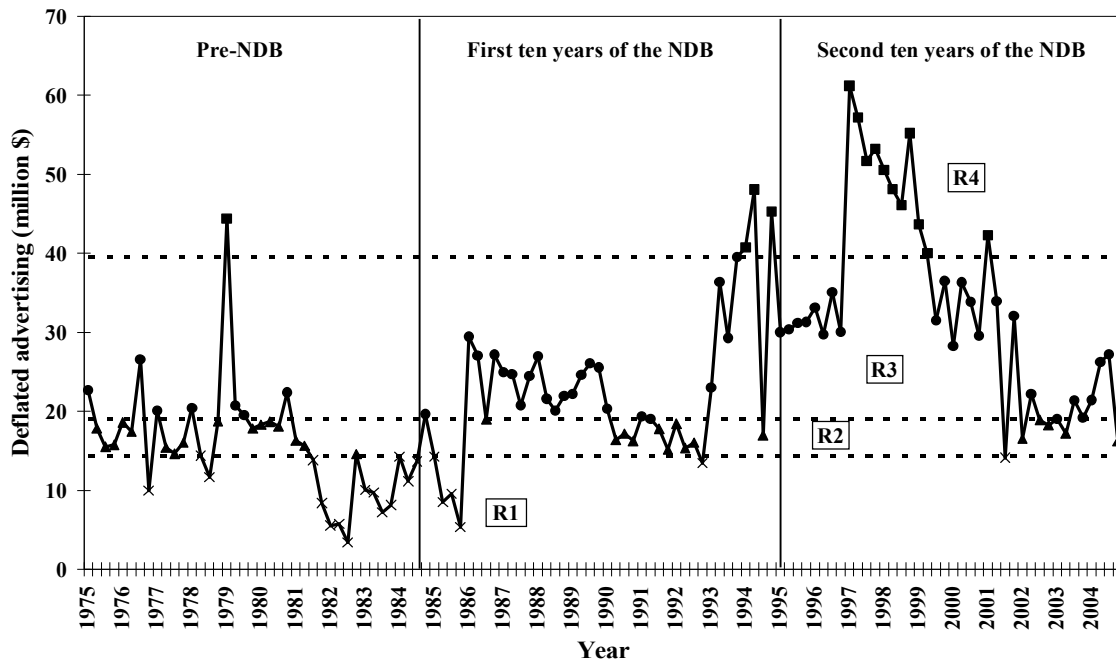


Figure 1. Regime classification of deflated generic fluid milk advertising expenditures (2004 media dollars)

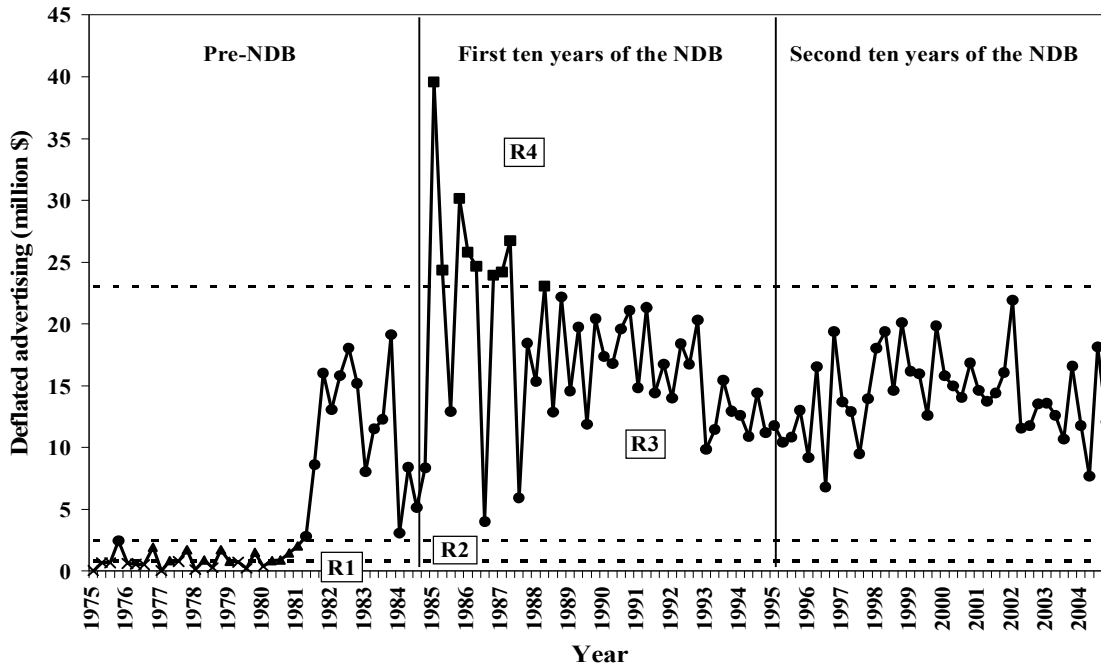


Figure 2. Regime classification of deflated generic cheese advertising expenditures (2004 media dollars)

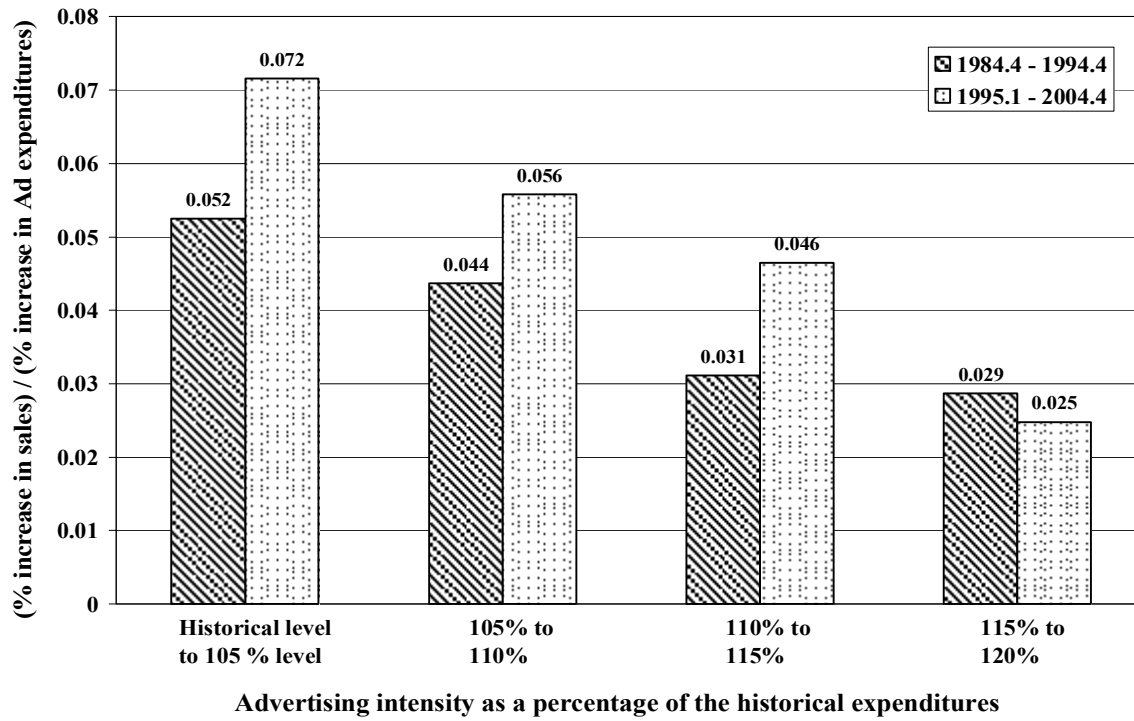


Figure 3. Generic fluid milk advertising elasticities at different levels of intensity

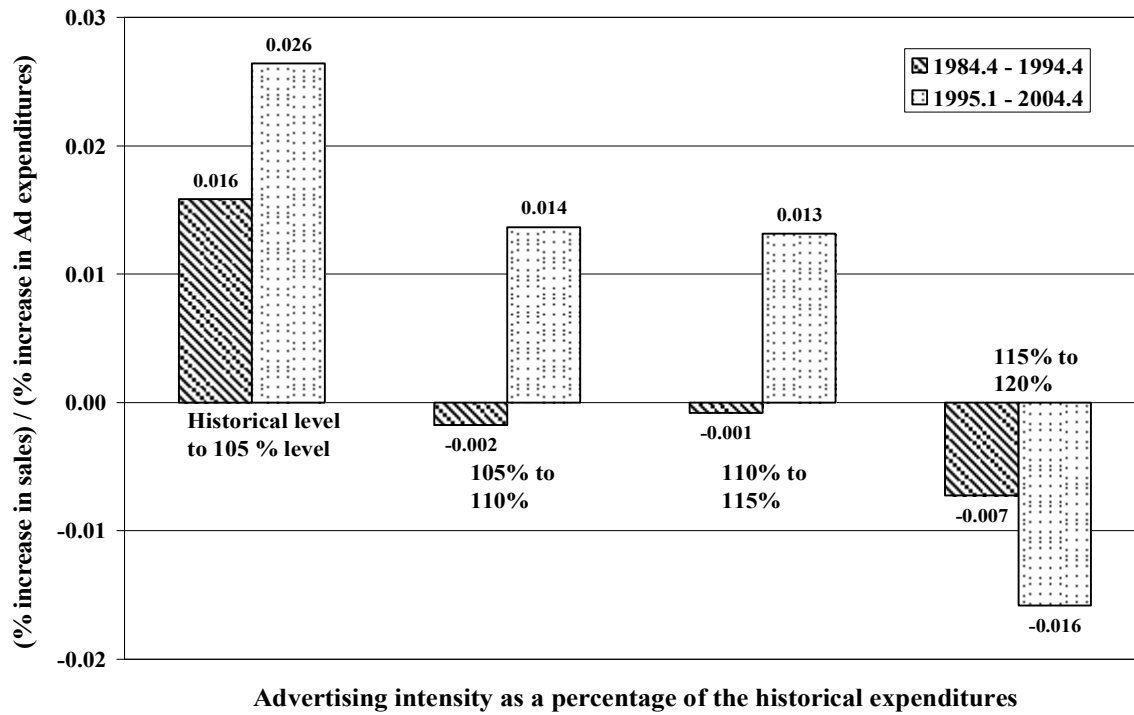


Figure 4. Generic cheese advertising elasticities at different levels of intensity

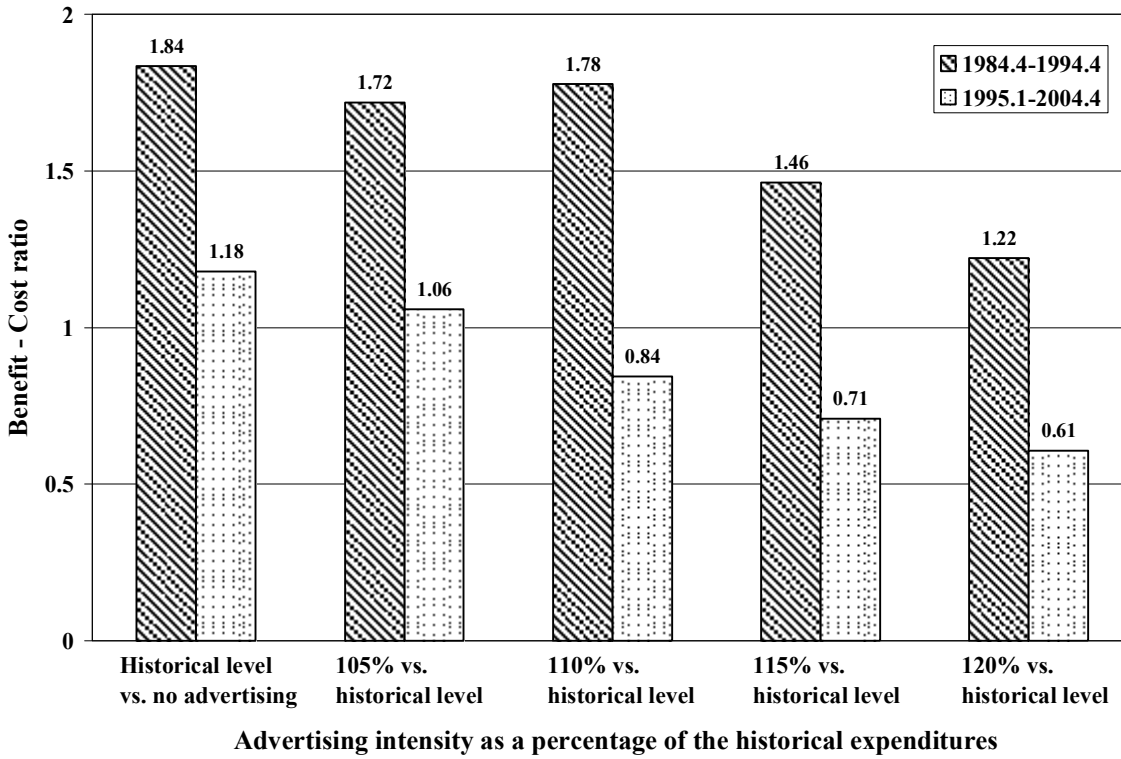


Figure 5. Benefit – cost ratio for generic fluid milk advertising

References

- Andrews, D.W.K., and W. Ploberger. 1994. "Optimal Tests when a Nuisance Parameter Is Present Only Under the Alternative." *Econometrica* 62:1383-414.
- Blisard, N., D. Blayney, R. Chandran, and J. Allshouse. 1999. *Analyses of Generic Dairy Advertising, 1984-97*. Washington DC: U.S. Department of Agriculture, ERS, Technical Bulletin 1873, February.
- Chung, C., and H.M. Kaiser. 2000. "Determinants of Temporal Variations in Generic Advertising Effectiveness." *Agribusiness* 16:197-214.
- Corkindale, D.J., and J. Newall. 1978. "Advertising Thresholds and Wearout." *European Journal of Marketing* 12:327-78.
- Cox, T.L. 1992. "A Rotterdam Model Incorporating Advertising Effects: The Case of Canadian Fats and Oils." In H.W. Kinnucan, S.R. Thompson, and H-S Chang, eds. *Commodity Advertising and Promotion*. Ames IA: Iowa State University Press, pp. 139-64.
- Dubé, J.-P., G.J. Hitsch, and P. Manchanda. 2005. "An Empirical Model of Advertising Dynamics." *Quantitative Marketing and Economics* 3:107-44.
- Economagic, LLC. 2005. "Economic Time Series Page." Online data source, Available at <http://www.economagic.com>.
- Farrell, M.J. 1952. "Irreversible Demand Functions." *Econometrica* 20:171-86.
- Greenberg, A., and C. Suttoni. 1973. "Television Commercial Wearout." *Journal of Advertising Research* 13(5):47-54.
- Hansen, B.E. 1996. "Inference When a Nuisance Parameter Is Not Identified Under the Null Hypothesis." *Econometrica* 64:413-30.
- . 2000. "Sample Splitting and Threshold Estimation." *Econometrica* 68:575-603.

- . 1999. "Threshold Effects in Non-dynamic Panels: Estimation, Testing, and Inference." *Journal of Econometrics* 93:345-68.
- Kaiser, H.M. 2000. "Impact of Generic Fluid Milk and Cheese Advertising on Dairy Markets 1984-99." Research Bulletin 2000-02, Department of Applied Economics and Management, Cornell University.
- Kinnucan, H. W., and M. Venkateswaran. 1994. "Generic Advertising; and the Structural Heterogeneity Hypothesis." *Canadian Journal of Agricultural Economics* 42:381-96.
- Lambin, J.J. 1976. "Advertising, Competition, and Market Conduct in Oligopoly Over Time." New York: American Elsevier Publishing Co.
- Liu, D.J., H.M. Kaiser, T.D. Mount, and O.D. Forker. 1991. "Modeling the U.S. Dairy Sector with Government Intervention." *Western Journal of Agricultural Economics* 16:360-73.
- Schmit, T.M., and H.M. Kaiser. 2004. "Decomposing the Variation in Generic Advertising Response over Time." *American Journal of Agricultural Economics* 86:139-153.
- Simon, J.L., and J. Arndt. 1980. "The Shape of the Advertising Response Function." *Journal of Advertising Research* 20(4):11-28.
- U.S. Department of Agriculture, Agricultural Marketing Service. *Dairy Federal Milk Marketing Orders*. Washington DC. Available at <http://www.ams.usda.gov/dairy/orders.htm#cpp>.
- U.S. Department of Agriculture, Economic Research Service. *Livestock, Dairy, and Poultry Outlook*. Various issues. Washington DC.
- U.S. Department of Labor, Bureau of Labor Statistics. 2005. *Consumer Price Index*. Washington DC. Available at <http://www.bls.gov/cpi>.

- Vakratsas, D., F.M. Feinberg, F.M. Bass, and G. Kalyanaram. 2004. "The Shape of Advertising Response Functions Revisited: A Model of Dynamic Probabilistic Thresholds." *Marketing Science* 23:109-19.
- Vande Kamp, P.R., and H.M. Kaiser. 1999. "Irreversibility in Advertising-Demand Response Functions: An Application to Milk." *American Journal of Agricultural Economics* 81:385-96.
- Ward, R.W., and B.L. Dixon. 1989. "Effectiveness of Fluid Milk Advertising since the Dairy and Tobacco Adjustment Act of 1983." *American Journal of Agricultural Economics* 71:730-40.