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M. E. Smith, E. O. van Ravenswaay, S. R. Thompson — Sales Loss Determination In Food Contamination Incidents: An Application To Milk Bans In Hawaii

This article presents a procedure for estimating sales loss following a food contamination incident with application to the case of heptachlor contamination of fresh fluid milk in Oahu, Hawaii in 1982. A major finding is that media coverage following the incident had a significant impact on milk purchases and that negative coverage had a larger effect than positive coverage. This conclusion implies that public statements by producers or government to assure the public of safe food supplies may be ineffective in restoring consumer confidence following the discovery of a food safety problem. American Journal of Agricultural Economics, August, 1988.

Key Words: food contamination, food safety policy, milk demand

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SALES LOSS DETERMINATION IN FOOD CONTAMINATION INCIDENTS: AN APPLICATION TO MILK BANS IN HAWAII

Incidents of chemical and bacterial contamination of food have become increasingly frequent, raising questions about their human health and economic consequences. This article concentrates on the economic consequences of such incidents for food producers. It reports a model that can be used to estimate the effects of a contamination incident on food sales. The model is applied to the incident of heptachlor contamination of milk on Oahu, Hawaii which occurred in 1982. The article also reports tests of hypotheses about the effect of positive and negative media coverage on product sales. These hypotheses have significant implications for government and industry strategies for responding to contamination incidents.

CONCEPTUAL FRAMEWORK

In order to estimate sales loss, a model of how consumers respond to a contamination incident must be specified. The theoretical basis of the model presented here was developed by Swartz and Strand to analyze the effect on purchases of a ban on sales of oysters harvested from the kepone-contaminated James River. Their model is pertinent because the situation we wish to analyze involves both bans and recalls of milk contaminated with heptachlor. However, two refinements to their model are introduced.

Swartz and Strand argue that a consumer's perception of the quality (Z_i) of a good (X_i) affects that consumer's level of utility. Further, a consumer's perception of product quality will depend on information (N) that a consumer obtains or receives about product quality. Thus, a consumer's utility function may be expressed as $U(X_i(Z_i(N)))$.

The problem following a contamination incident is to understand how a consumer allocates income (I) among goods when information about the quality of one of those goods has changed. Let X_1 denote the quantity obtained of the good for which quality information is changing, X_2 denote the quantity of all other goods obtained, P_1 and P_2 denote the respective prices of those goods, and C denote the cost of obtaining information. Then the consumer's problem is to solve

(1) $\text{Max } L = U(X_1(Z_1(N)),X_2) + \lambda\,(I-P_1X_1-P_2X_2-CN)$.

If information about the quality of X_1 is exogenous, as might be expected when there is media coverage of a contamination incident, the personal cost of obtaining information is zero. Then, the first order conditions yield the hypothesis that the demand for X_1 is a function of prices, income, and information:

(2) $X_1 = X_1(P_1,P_2,I,N)$.

As Swartz and Strand note, the effect of receiving information that the quality of a good has declined has the opposite effect of positive advertising; the demand curve for that good shifts downward.

To apply this model, it is important to distinguish incidents where public health warnings have been issued about a food, but no recall or ban has taken place, from those where food has been recalled or banned. In the former case, consumers are provided information about a potential risk, but the consumption decision is left to consumers. Thus, the demand curve for the product would likely shift downward after the incident, with the extent of the shift depending on the information available to consumers about the risk, how likely they are to receive that information, and their subsequent evaluation of the trade off between the risks and (net) benefits of consumption. Empirical studies have attempted to capture this effect by incorporating dummy and/or trend variables to represent the health warning in models of consumer purchases (Brown; Hamilton; Mowen; Mowen and Pollman; Shulstad and Stoevener; Schuker, et al.).

For a product ban or recall, it is less clear why the demand for the product would fall because, presumably, all of the contaminated food is condemned or recalled. Thus consumers would face no immediate risk of exposure, although purchases would fall if supplies are constrained. However, reports in the popular press indicate that after such incidents sales decline despite adequate (uncontaminated) supplies. Moreover, these declines affect sales of both producers whose products were contaminated and producers of the same product whose product was not contaminated.

Swartz and Strand hypothesize that perceived quality of remaining food supplies may decline after a ban or recall because consumers have imperfect information about the suspect portion of product supplies. Their primary source of information, media coverage of the incident, may not be sufficiently detailed to make this determination. Thus, demand declines with the extent of negative media coverage of the ban or recall because this coverage lowers consumers' perceptions of product quality.

Swartz and Strand demonstrated this response by including in their model of demand for oysters in Baltimore a measure of negative media coverage of the closure of the James River oyster beds due to kepone contamination. They quantified negative media coverage of the ban on oyster harvest by assigning a score of 0, .25, .75, or 1 to articles in major newspapers depending on their judgement of the probability that the article would negatively affect consumer judgements of oyster safety. This score was weighted by a probability of the article being read which was proxied by newspapers' market share and prices for advertising space. They found that this measure of negative media coverage of the ban was statistically significant in explaining declines of purchases of (safe) oysters.

The model we have developed to estimate sales losses is similar to that of Swartz and Strand. However, we allow for the possibility that the news media may also report positive information following a recall or ban on food and that this type of information may also affect purchases. After a ban or recall, government and private firms likely will develop strategies for responding to the contamination problem. For example, they might issue public statements that the problem has been eliminated, remaining food supplies are safe, or new safety measures have been undertaken. Given the previous theoretical discussion, this positive information likely would have a positive effect on sales.

The veracity of this positive effect has implications for government and food producers in responding to a ban or recall of food following a contamination incident. If positive information can counteract the negative effect of a ban or recall on sales, then unneccessary consumer and producer losses which result from imperfect information might be avoided. Swartz and Strand argued that losses would have been avoided in the Baltimore oyster market if government had provided consumers better information about the safety of remaining food supplies, and that government provision of this information would have been justified if its costs did not exceed their estimate of welfare losses. However, the empirical impact of positive information can not be determined from their results because only negative media coverage was included in their model.

The model reported below differs from Swartz and Strand's in another respect as well. We hypothesize that news media reports are not the only source of information about a contamination incident. Product quality is communicated to consumers from numerous other sources such as in-store information, information sent from sellers directly to buyers, and word of mouth. These sources of information are particularly important where products have been recalled, as in the case examined below.

CASE STUDY

In March, 1982, over 80% of the milk produced on Hawaii's most populous island of Oahu was contaminated with the pesticide heptachlor. In March and April of 1982, eight recalls of milk and dairy products on Oahu were announced, each followed by government and industry assurances that milk was safe. In the next 15 months, 36.2 million pounds of contaminated milk were dumped. Consumers became reluctant to buy locally produced milk. Since dairymen were reimbursed \$8.6 million for the contaminated milk by the federal Dairy Indemnification Program, uncompensated losses of Class I (fluid) milk sales over and above the dumping loss were a major portion of producer losses. This article concentrates on estimating the uncompensated losses of Class I sales.

Although a considerable amount of milk was recalled or dumped due to excessive heptachlor residues, press reports and interviews with knowledgeable individuals in Hawaii indicated that remaining milk supplies were sufficient to meet milk demands following the incident. Milk demand fell considerably after announcements of milk recalls and bans. Shortfalls in Oahu supplies were supplanted by imports from neighboring islands and the use of imitation milk products by schools. Consequently, declines in fresh fluid milk sales after the incident were not likely due to supply constraints.

To estimate sales losses, the difference between projected sales without the incident and an estimate of actual sales after the incident was obtained.[1] Projected and estimated monthly sales were obtained from an econometric model of fluid milk demand. The model is specified to include the retail price of milk, the price of a substitute in consumption, income, population, seasonality, demographic and other changes over time, and negative and positive information on the contamination incident. Since the farm level pricing structure is set by the milk commissioner, the price of fluid milk was assumed to be exogenous for estimation purposes; hence, OLS estimation was used. Moreover, because the income variable was highly collinear with a trend variable used to represent demographic and other changes over time, the regression equation was estimated conditional upon an income elasticity of 0.27 (Renaud).[2] The lagged effect of information was approximated by a second-degree Almon lag structure.

Monthly data from January 1977 to June 1983 were used in the analysis (Smith). This period included five years of data prior to the incident and 16 months afterward. The dependent variable was the monthy average number of ounces of fresh fluid milk consumption per capita per day, adjusted by a calendar composition factor (Schlenker and Christ) to account for the frequency of occurrence of each type of day during the month (i.e., number of Sundays, Mondays, etc.). Data on Class I milk utilization and the amount of milk dumped due to excessive heptachlor residues was obtained from the Hawaii Division of Milk Control. Class I utilization was assumed to approximate fluid milk demand prior to the contamination. However, after the contamination announcement, imported milk and school use of imitation milk was added to Class I utilization, and the amount of product returned from grocery stores and other outlets was subtracted from Class I utilization.

Per capita fluid consumption calculations were complicated by the fact that tourists comprise about 10% of total population, although this figure varies monthly. Hence, the monthly number of tourists on Oahu obtained from the Hawaii Visitors Bureau was added to the population estimates.

An unpublished survey provided by Foremost Dairies, Inc. indicated that the majority of consumers substituted fruit juice or drinks for milk following the incident. Further analysis showed that fruit drink was the most appropriate substitute in terms of sign and significance of its coefficients, its estimated elasticity, and its ability to explain variation in consumption.

Average retail food prices in eight Oahu supermarkets were obtained from one of the two major Honolulu newspapers which publishes a weekly food price guide. Monthly per capita personal income was obtained from Hawaii State personal income and population data. No generic milk promotions existed during the period of the analysis.

Information about the contamination incident, and, thus, about product quality, was approximated by two types of measures. Media coverage of the incident was approximated by coding articles in the two major Honolulu newspapers during the study period.[3] Each article was coded as either negative or positive depending on whether it presented positive or negative informaton about milk quality, the level of government protection, and milk processors' integrity in dealing with the contamination problem.[4] These codes were weighted on a scale of 0 to 5 by the prominence of each article using the "attention score" developed by Budd.[5] The weighted codes were summed for each month to obtain measures of both negative and positive media coverage. The absolute values of these two measures were used in actual estimation. Other sources of information on milk quality, such as recalls, in-store, and word of mouth information, were proxied by a dummy variable representing the contamination incident.

SPECIFICATION TESTS

In the initial model specification, positive and negative media were included in the regression model as separate regressors. It was originally anticipated that media coverage would be primarily negative in the early months of the study period when the majority of recalls and bans occurred, and that the intensities of negative reporting would decline over time. In contrast, positive coverage was anticipated to increase as dairy herds were cleared of heptachlor residues. However, the intensities of both types of coverage were correlated over time (see figure 1).

The resulting multicollinearity yielded little confidence in the coefficient estimates for the media variables. This created a problem of determining an appropriate specification for estimating lost sales and evaluating the effect of positive and negative media. To address this problem, we specified three nonnested alternative models and used the J test to determine which, if any, of the alternatives appeared misspecified when compared to the others (MacKinnon). The three models were:

(3) Model I $Y = W\beta + X\delta_0 + u_0$;

(4) Model II $Y = Z\gamma + X\delta_1 + u_1$, and;

(5) Model III $Y = N\theta + X\delta_2 + u_2$;

where W, Z, and N are matrices of (media) regressors unique to each model, X is a matrix of regressors common to all three models, and u_0, u_1, and u_2 are unknown stochastic residual terms. Model I imposes the restriction that negative media had a negative effect on sales and positive media had a quantitatively identical positive effect. Thus it included a variable, "net media", which is the difference between the two. Model II imposes the restriction that any news article on the contamination would have a negative

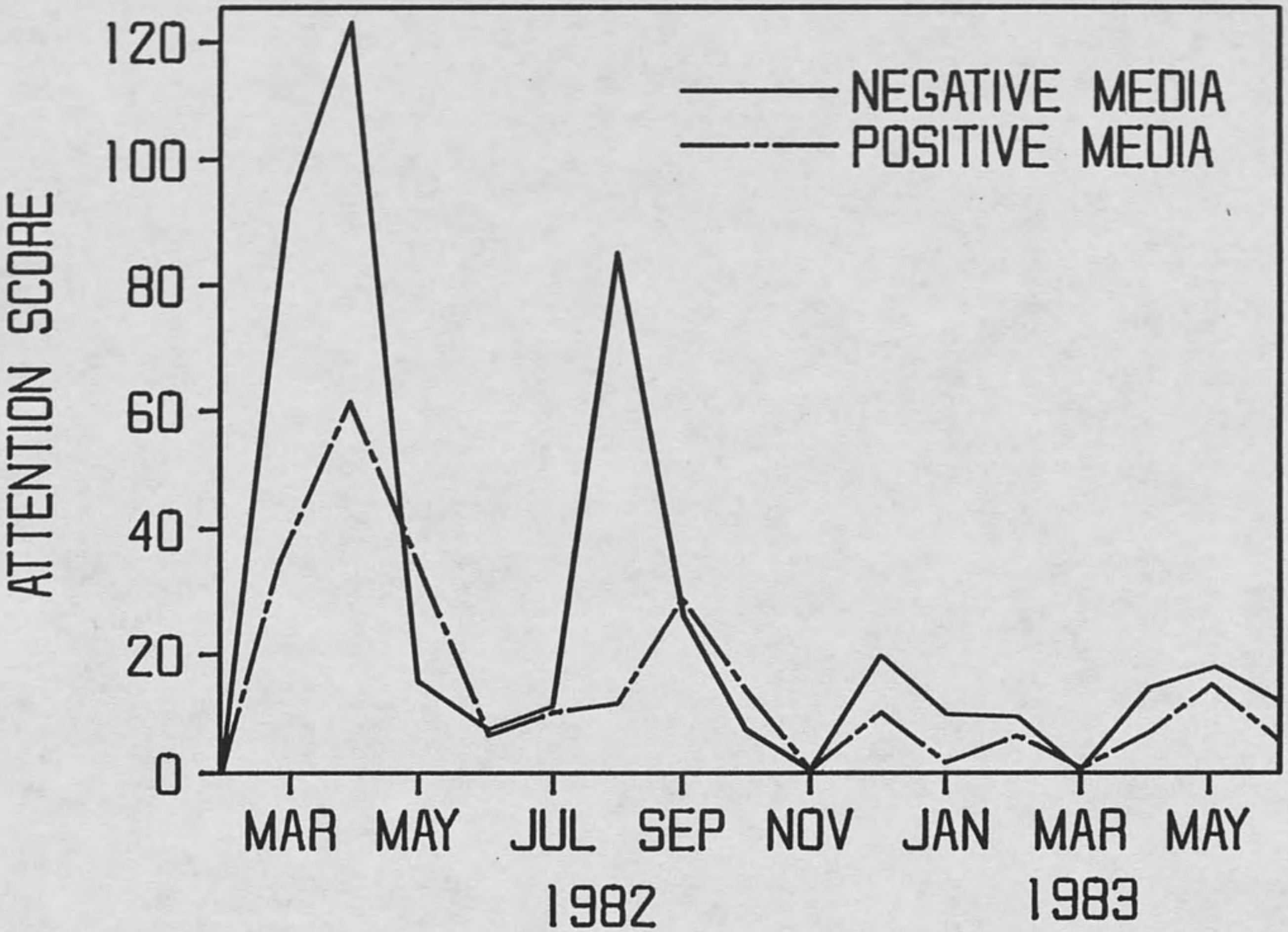

Figure 1 **Negative and positive media coverage, February 1982–June 1983.**

effect on sales, regardless of the way it was originally coded. Thus it included a variable, "total media," which is the sum of the two. This model follows from the hypothesis that any news coverage of the incident would heighten awareness of it and, thus, have a negative effect on sales. Model III follows from the hypothesis that positive media coverage may not be viewed as credible by consumers.[6] Thus the model assumes that positive media had no effect; it is excluded from the model with the "negative media" variable remaining.

To apply the J test, the following sets of regressions were run:

(6) Model I vs. II, $$Y = W\beta^* + X\delta_0^* + \alpha_1(Z\hat{\gamma} + X\hat{\delta}_1) + u$$

(7) Model I vs. III, $$Y = W\beta^* + X\delta_0^* + \alpha_2(N\hat{\theta} + X\hat{\delta}_2) + u$$

(8) Model II vs. III, $$Y = Z\gamma^* + X\delta_1^* + \alpha_3(N\hat{\theta} + X\hat{\delta}_2) + u.$$

The expression in parentheses in equation (6) is the estimate of equation (4) and the expression in parentheses in equations (7) and (8) is the estimate of equation (5).

Preference among the alternative specifications is determined by the statistical signifcance of parameter α in equations (6), (7), and (8). The computed t-statistics for α_1, α_2 α_3 are 7.37, 6.59, and -3.10, respectively, and all are significantly different from zero at the 1% level. The results suggest that Models I (eq. 3) and II (eq. 4) are misspecified when compared to Model III (eq. 5). Thus, based on this test the model specified with negative media is preferred.

MODEL RESULTS

Based on the theoretical framework and J test results, the following model was estimated:

(9) $$Q_t = \alpha + BX_t + A(L)N_t + \varepsilon_t,$$

where t = 1,...,78 monthly observations, Q_t is the quantity of fluid milk sales; α is an unknown intercept term (and is modified by a set of dummy variables representing the different months of the year); and X_t is a matrix of demand shifters with corresponding unknown parameters B. The matrix X_t includes: DPM, the deflated (by Honolulu consumer price index) retail price of whole milk in paper half gallons; SUB, the deflated price of milk substitute (fruit drink); INC, the deflated per capita personal income; TRND, the trend variable (1,2...) to account for demographic, habit, and other changes over time; DV, the dummy variable that is zero before the March 1982 contamination and 1.0 thereafter; N_t is a vector of variables which measure negative media coverage; A(L) is a polynomial lag structure of the media variable and ε_t is unknown stochastic residual.

The results of the estimation are presented in Table 1. All coefficients have the anticipated sign and all information terms are significant at the 1% level. The theory suggests that the coefficients on current and lagged negative media (absolute values) should be negative. Similarly, the coefficient on the dummy variable representing other information sources is negative as predicted. Also, because of a high degree of multicollinearity among the lagged media variables the lag structure was constrained to follow a second-order Almon polynomial.

The estimated lagged effect of negative media exhibits a geometrically declining shape with the greatest impact occuring in the month of information release. Higher order polynomials as well as additional lagged terms for media were added to the regression, but the estimated coefficients were statistically insignificant.

The estimated own-price elasticity of demand was -0.70. This is well within the range of estimated fluid milk price elasticities of -0.66 to -0.73 reported by Kinnucan. The cross-price elasticity of the substitute (fruit drinks or juices) was estimated to be .34, and the income elasticity was conditioned to be 0.27.[7]

The sum of the coefficients of current and lagged negative media coverage was -0.0445. Evaluated at the mean, the combined direct and carryover media elasticity was -0.066. This estimate is opposite to and three times larger than the estimate of Thompson, Eiler, and Forker for the direct and carryover elasticity of generic milk promotion in New York City. These results suggest that negative information about a contamination incident has a greater impact relative to positive information.

Table 1. Estimates of Fluid Milk Demand in Oahu

Variable	Coefficient	t-value
CONSTANT	5.43	3.34**
JAN	0.26	1.63
FEB	0.29	1.88
MAR	0.16	1.02
APR	0.49	3.17**
MAY	0.52	3.36**
JUN	- 0.22	1.45
JUL	- 0.32	2.02*
AUG	- 0.02	0.15
SEP	0.63	4.03**
OCT	0.44	2.80**
NOV	0.22	1.45
DPM	- 4.27	2.19*
SUB	3.63	1.48
INC	0.00031	a
TRND	- 0.0047	2.25*
DV	- 0.39	2.11*
N_t	- 0.0212	12.14**
N_{t-1}	- 0.0134	11.08**
N_{t-2}	- 0.0072	5.86**
N_{t-3}	- 0.0028	3.02**

R^2 = 0.93; Adjusted R^2 = 0.91; DW = 1.79

a Since the model was estimated conditionally on income, no t-value is reported.

* Significant at the 95% confidence level.

** Significant at the 99% confidence level.

VALUE OF LOST SALES

Utilizing the estimated demand equation, monthly projections of Class I milk sales in the absence of contamination were compared to the estimated actual sales patterns during the period March 1982 to June 1983. The difference represents an estimated Class I sales loss of 41.7 million pounds with a 95% confidence interval of plus or minus 16.8 million pounds.[8] This loss was 29% of projected Class I milk sales.[9]

However, producers were compensated for 36.2 million pounds of contaminated milk that were dumped in 15 of the 16 months after the incident (USDA, DIP, 1983 and 1984). Subtracting the amount of milk dumped from the estimate of Class I sales losses yields an estimate of uncompensated sales losses of 5.6 million pounds of Class I milk.

Since producers would have earned \$21.09 per hundredweight for selling the 5.6 million pounds of Class I milk, revenues of \$1.2 million were lost. However, this estimate of uncompensated losses overstates the true opportunity cost because uncontaminated milk that could not be sold as Class I milk could be sold as Class Ia, export, Class II, or salvaged milk.[10] Thus, the true opportunity cost is the difference between the price producers actually earned and the Class I price they would have earned otherwise. Using the Class I and Class II price differential to approximate the opportunity cost, uncompensated losses are estimated to have been \$422,000.[11] Assuming the 95% confidence interval on the estimate of uncompensated loss is equal to the interval on the estimate of sales loss (i.e., 16.8 million pounds), the upper bound estimate of the uncompensated loss is \$1.7 million, while the lower bound estimate is zero.[12]

Although the \$422,000 uncompensated sales loss seems small when compared to the compensated loss, it amounts to over \$26,000 per producer. Furthermore, lost sales were not the only losses that producers experienced as a result of the heptachlor incident. Other costs included herd replacement costs, losses of herd productivity, legal costs, and other clean-up costs. Therefore, although producers were compensated \$8.6 million for the dumped milk, it is unlikely that this compensation covered all producer losses from the incident.

CONCLUSIONS

The estimate of the amount of Class I milk that could have been sold, but was not because of the heptachlor incident, was 41.7 million pounds. Producers were compensated for 36.2 million pounds that were dumped due to contamination. The remaining 5.6 million pounds represents an estimate of uncompensated Class I sales losses of $422,000, which amounts to over $26,000 per producer in Oahu.

The model used to estimate sales losses demonstrates the importance of negative media coverage in explaining consumer response to bans and recalls of a food product. Like Swartz and Strand's study, this result suggests the importance of accurate information in avoiding unnecessary losses following such incidents. However, the finding that positive media coverage had no effect on consumer purchases leads us to question Swartz and Strand's conclusion that the observed consumer response can be corrected by more accurate information on the quality of a product. Although government officials repeatedly assured Oahu consumers that milk remaining on store shelves was safe, consumers appeared to have heavily discounted their statements. This implies that public statements by producers or government to assure the public may be of limited usefulness, at least in the short run.

Media variables did not account for the total effect of the contamination incident. The dummy variable was included to represent other sources of information on product quality; it was negative and significant. Since the dummy variable is a crude proxy for these other effects, it may be useful to consider more accurate ways of representing diffusion of information about a contamination incident or any incident where product quality has changed.

Finally, some of the downward trend in purchases appears to be due to habit change which was facilitated, but not caused by, the contamination incident. This result may have occurred because of the length and scope of the Oahu incident. After 15 months, sales were still not back to their pre-contamination levels, though they were approaching them.

FOOTNOTES

1 Estimated rather than actual sales were used to minimize errors in the estimation of sales loss. If actual sales were used, the standard error of the estimate of sales loss would be equal to the standard error on projected sales. If estimated sales are used, the standard error of the estimate of sales loss would be equal to the standard error on projected sales minus the standard error on estimated sales. The difference between the two standard errors is the error due to the variables representing the contamination incident.

2 The trend variable is included because per capita fluid milk consumption has been declining nation-wide during the last decade.

3 Newspaper coverage was used to approximate media coverage because data were unavailable from other sources. Two of the three major Oahu television networks were able to supply information on the number of news reports relating to the contamination incident, but not on their content. The intensity of television coverage was similar to newspaper coverage. The intensity of radio coverage was not assessed.

4 For example, an article reporting that milk contained residues of heptachlor above legally permissable levels would be coded negative. An article reporting a government announcement that dairy farms were clear of contamination would be coded positive. If the article contained both positive and negative information, each sentence was coded, and the sum of the codes determined the code given to the article. Coding rules are reported in Smith (1984).

5 For example, an article appearing on the front page of a section, above the fold, with a two-column headline would be assigned a weight of 3.

6 This hypothesis is supported by human information processing studies which suggest negative information overwhelms positive information in the development of beliefs and attitudes (Weinberger and Dillon).

[7] To test if the non-media parameters changed due to the contamination incident, each non-media variable was interacted with DV. The estimated t-ratios for each interaction term were not significantly different from zero at the 1% level, thus providing some evidence that the non-media parameters remained constant over the entire sample period.

[8] Confidence intervals were calculated using the standard errors on the negative media and dummy variables since the the standard errors on the other variables are common to both the projected and estimated values; hence, they cancel out.

[9] The 41.7 million pound loss understates the actual loss of Class I milk sales by Oahu producers because actual Class I milk purchases by Oahu consumers included purchases of imported milk and school use of imitation milk during the 16 month period. Imports plus school supply totaled 3.4 million pounds over the period. Thus, Oahu producers lost 45.1 million pounds of Class I milk sales. However, this portion of the loss to Oahu producers is offset by the gain to importers and imitation milk providers, so it is not included in the following value of lost sales calculation.

[10] Because heptachlor residues were believed to be contained only in fat, contaminated milk could be skimmed and sold as salvaged skim milk.

[11] Milk not sold as Class I can be sold as Class Ia, export, Class II, or salvaged milk. Class Ia and export bring the highest price, followed by the Class II price, and salvaged milk brings the lowest price. Consequently, the selection of Class II as the relevant alternative opportunity is somewhat arbitrary. However, actual sales data prior to and after the incident indicate that it is a good approximation.

[12] The lower bound estimate of sales loss is 24.9 million pounds. Because the amount of milk dumped (36.2 million pounds) exceeds this, the lower bound estimate of uncompensated sales loss is negative (i.e., -11.3 million pounds). Thus some of the milk dumped was probably Class II milk because it could not have been sold as Class I milk under normal conditions.

[13] The reported compensation of \$8,551,515 to producers divided by the reported 36,146,268 pounds dumped yields a compensated price of \$23.66 per hundredweight. This price exceeds the Class I price of \$21.09, suggesting that milk dumped resulted in a gain to producers of \$2.57 per hundredweight.

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Procedures: Working papers may address any issues in the food and agricultural marketing area as described in the NE-165: Private Strategies, Public Policy and Food System Performance, project statement. This research agenda is available from Professor Ronald Cotterill, Executive Director of NE-165 at the address given below. A prospective working paper should be forwarded to the Executive Director who will coordinate a review of the paper by two research peers. Alternatively authors may submit two independent peer reviews with their paper. Based upon independent reviewer comments the Executive Director may accept, accept with revisions, or reject the submission. If accepted the Executive Director will issue working paper covers, and a mailing list to the author who shall have responsibility for preparing and distributing copies to all persons and organizations on the mailing list. Additional copies of working papers are available from the author or from the office of the Executive Director at The University of Connecticut.

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