Review of Agricultural Economics—Volume 31, Number 4—Pages 734–750
DOI: 10.1111/j.1467-9353.2009.01464.x

Consumer Response to a Food Safety Shock: The 2006 Food-Borne Illness Outbreak of *E. coli* O157: H7 Linked to Spinach

Carlos Arnade, Linda Calvin, and Fred Kuchler

A retail demand model measured the impact of the Food and Drug Administration's 2006 announcement warning consumers about *E. coli* O157: H7 contamination in spinach. Model results indicated that bulk lettuces were shock substitutes (in contrast to price substitutes) as consumers purchased fewer spinach products and more bulk lettuce of all types. Results also showed that consumers initially moved away from bagged salads without spinach; but consumer confidence rebounded quickly and expenditures rose. Over a period of sixty-eight weeks, retail expenditures decreased 20% for bagged spinach and 1% for bulk spinach. Retail expenditures for all leafy greens declined just 1%.

On September 14, 2006, the U.S. Food and Drug Administration (FDA) announced that consumers should not eat bagged spinach. Epidemiological evidence pointed to bagged spinach as a possible cause of an ongoing multistate food-borne illness outbreak of the potentially deadly bacterium *Escherichia coli (E. coli)* O157: H7 (Calvin). The next day FDA expanded the warning to include all fresh spinach. FDA had never before made such a sweeping statement about any U.S.-grown produce item. Stores and restaurants immediately removed spinach from their shelves and menus. Spinach harvesting and marketing ceased and there was no U.S. spinach on the market for five days. After FDA determined that bagged baby spinach was the only contaminated product and lifted its warning, consumers did not immediately return to their previous consumption patterns.

FDA's announcement was unique in several ways. Typically, by the time an outbreak associated with fresh produce is detected and the contaminated item is identified, the outbreak is over and the product in question has long since been consumed or discarded. As a result, there is usually no benefit to warning consumers about consumption of contaminated fresh fruit and vegetables, and such

■ *Carlos Arnade, Linda Calvin, and Fred Kuchler are agricultural economists with the Economic Research Service, U.S. Department of Agriculture.*

warnings are rare. In contrast, this warning occurred while the event appeared to be ongoing and, in effect, created a daily conversation between FDA and the public that continued for more than two weeks. By the end of the outbreak, consumers in twenty-six U.S. states and one Canadian province had fallen ill, resulting in 204 illnesses, 104 hospitalizations, thirty-one cases of Hemolytic Uremic Syndrome (a serious complication), and 3 deaths. The media coverage following the FDA announcement was extensive and a survey shortly after the outbreak found that 87% of American consumers were aware of the problem with contaminated spinach (Cuite et al.). On September 29, FDA announced, "spinach on the shelves is as safe as it was before this event" (Shin). At that time, it was not clear what message consumers took away from the statement.

Some aspects of consumer response to the outbreak were obvious. Amid massive publicity and a temporary closure of the U.S. fresh spinach market, all fresh spinach sales declined. The announcement raised consumers' assessments of health risks from consuming spinach, but theory does not point to a unique long-run response. The magnitude and duration of consumers' response depended on how they revised their risk perceptions in the face of both clear-cut and ambiguous safety information. In this article, we estimated the impact of the food safety shock on a group of spinach and lettuce products.

Almost Ideal Demand System (AIDS) models have been used previously to investigate consumer response to food safety information because the system of equations accounts for cross-commodity responses (Piggot and Marsh). To measure consumers' response to changing risk information, economists have often included counts of news media reports as explanatory variables in food demand studies (Beach et al.; Dahlgran and Fairchild; Piggot and Marsh). These studies reveal how much media attention influences food demand; however, they are not intended to address the market impacts of a particular food safety event. The Richards and Patterson strawberry demand study did focus on a specific food-borne illness outbreak but with the goal of evaluating consumer response to varying types of news media information. Other researchers have examined particular food safety events (Calvin, Avendaño, and Schwentesius; Kuchler and Tegene), but have not used formal demand systems. Our particular problem is different from some studies in that there is no ambiguity about the timing of the onset of market impacts (Carter and Smith). In the spinach case, the FDA announcement clearly defined the pre- and postannouncement periods.

This analysis employed a two-stage AIDS model to investigate the impact of the FDA announcement of an *E. coli* outbreak linked to spinach. The model separated the effect of prices and trends from the impact of the FDA announcement shock. The primary objective of this model was to determine the influence of the spinach shock on demand for several related leafy green products. Estimating a system of equations rather than a single equation allowed for the analysis of the size and direction of cross-product responses to the announcement.

The lower stage model included six closely related leafy green products—spinach and lettuce products. For closely related goods such as lettuce, theory does not indicate the direction of consumer response to a food safety issue related to spinach. Consumers might have turned from spinach to other leafy greens. Such products are defined here as shock substitutes. Although other leafy greens were not implicated in the outbreak, identical packaging and brand names, along

with contiguous shelving in grocery stores, could have led consumers to conclude that they were equally risky. Consumers might have reasoned that all other leafy greens were produced under similar growing and packing conditions, and consumption of these products would have fallen along with spinach. These products are defined as shock complements.

The lower stage model held total expenditures on leafy greens constant. The upper stage AIDS model estimated consumer demand for all leafy greens and all other fresh vegetables. Here, total expenditures on leafy greens could change in response to the food safety shock.

Unique to both models was the addition of variables meant to capture the changing nature of the consumer response to FDA's announcement about *E. coli* contamination. This was accomplished by adding a variety of shock variables and testing for transitory and permanent demand impacts. These models were structured to estimate both magnitude and duration of the response.

The next section describes the data. Model specification follows. Results of the model estimation are discussed. The model is used to simulate the impact of the outbreak on consumers' expenditures for individual leafy greens and all leafy greens. The effects of the shock on prices of individual leafy greens and expenditures of total leafy greens are accounted for in the simulations. The article ends with brief conclusions.

Data

This analysis used national, weekly, point-of-sale retail scanner data for the period from 2004 through 2007—140 weeks before the spinach shock and sixty-eight weeks afterward (including the week of the outbreak announcement).[1] Retail point-of-sale scanner data came from FreshLook Marketing. Data included weekly totals of expenditures, quantities purchased, and prices (unit values). Information Resources, Inc. (IRI) served as FreshLook Marketing's data source on consumer-packaged goods such as bagged salads. The database contains weekly sales by price lookup codes for random-weight products such as bulk produce and universal product codes for consumer-packaged goods such as bagged salads.[2]

The data were aggregated into six leafy green products: bagged spinach, bulk spinach, bagged salads without spinach, bulk iceberg lettuce, other bulk lettuce, and romaine hearts. The bagged spinach category included: bagged spinach intended as salad; bagged salads with spinach, including bagged spring mix, which often contains spinach; and bagged spinach that may have been intended for microwaving but could be consumed as a salad. Bulk spinach included bulk spinach and bulk spring mix. Other bulk lettuce included everything except iceberg—romaine, leaf, bibb, Boston, butter, and hydroponic lettuce, among others. These newer components of the lettuce market were considered separately from iceberg lettuce because they might be more likely substitutes for spinach than iceberg lettuce. Value-added romaine hearts included both bagged and unbagged products.

Even when aggregated, many of these categories still represented small shares of total leafy greens retail sales. In 2005, the year before the outbreak, spinach and products containing spinach accounted for 9% of leafy greens sales in terms of volume (table 1). Bagged salads without spinach accounted for 47% of retail

Table 1. Leafy greens retail market sales, by share and change in sales volume

Commodity	Share of Leafy Greens Sales Volume	Change in Sales Volume	
			Jan–Aug
	2005	2004–5	2005–6
		Percentage	
Bagged spinach	7	7	11
Bulk spinach	2	−8	−3
Salads without spinach	47	1	−6
Bulk iceberg lettuce	24	−3	−6
Other bulk lettuce	13	−2	−3
Romaine hearts	7	13	10
All leafy greens	NA	1	−3
All other vegetables	NA	3	0

Source: IRI and FreshLook Marketing.
NA = not applicable.

sales followed by bulk iceberg lettuce with a 24% share. Other bulk lettuce and romaine hearts made up the remaining 20%. Bagged salads and other value-added products have transformed the leafy greens industry as consumers shifted to these labor-saving products. Between 2004 and 2005, quantities purchased of all the bagged products and value-added romaine hearts were increasing while sales of all the bulk leafy greens were either stagnant or declining. In the first eight months of 2006, similar trends prevailed as in the same period of the previous year except that salads without spinach declined 6%.

Demand Models

Both lower and upper stage models were specified as linear approximations of AIDS models (LA-AIDS). Each share equation in the estimated lower stage demand system was

$$S_i = \alpha_i + \sum_{j=1}^{6} \beta_{ij} \ln(P_j) + \lambda_i \ln(E/PS) + \gamma_i \cos(2\pi t/52) + \delta_i \sin(2\pi t/52) + v_i t + u_i + \varepsilon_i$$

where S_i were expenditure shares for the six products. The variables $\ln(P_j)$ were log prices and E/PS was total expenditures on leafy greens, E, deflated by the price index of leafy greens. Following conventional practice, the models included Stone's price index (PS) to represent higher order components of the AIDS model, thus ensuring the models remained linear in parameters

$$PS = \sum_{j=1}^{6} S_j \ln(P_j).$$

The trigonometric variables controlled for seasonal changes in demand (Arnade and Pick).[3] Consumption trend across years was represented by t. The variable u_i represented the set of food safety shock variables, which are discussed below. The restriction $\beta_{ij} = \beta_{ji}$ was imposed to ensure symmetry. Homogeneity was imposed by the restriction $\sum_{j=1}^{6} \beta_{ij} = 0$. Adding up implied that for each j, $\sum_{i=1}^{6} \beta_{ij} = 0$, $\sum_{i=1}^{6} \alpha_i = 1$, and $\sum_{i=1}^{6} \lambda_i = 0$. We also allowed for adding up of the seasonal terms so that $\sum_{i=1}^{6} \gamma_i = 0$ and $\sum_{i=1}^{6} \delta_i = 0$. The adding-up restrictions were used, along with symmetry and homogeneity restrictions to obtain the parameters of the dropped (romaine hearts) equation.

Shock Variables

Consumer response to the announcement could take many forms. The response could be permanent or transitory. Transitory responses could begin decaying immediately or could grow before decaying. Since these responses were not known a priori, the model employed a set of five shock variables that allowed the data to reveal the nature of both permanent and transitory effects of the FDA announcement on retail food demand.[4] A standard dummy variable (zero prior to the announcement and one beginning at the time of the announcement) was included in each expenditure share equation. If only the dummy variables were significant, the model would indicate that the shift in demand due to the shock was permanent and at least some consumers did not return to their preannouncement purchase patterns.[5] In addition, if only the standard dummy variables were significant, the sign of each coefficient would indicate whether a product was a shock substitute (positive coefficient) or complement (negative coefficient).

Transitory shifts admit a wide variety of possible patterns and the model included four transitory shock variables. Two decay variables were used to capture the possibility that the full impact of the shock occurred the week of the announcement but began to decay immediately with all consumers eventually returning to their preannouncement purchase patterns. The variables were zero before the announcement, one at the time of the announcement, and decayed to zero in the postannouncement period. One such variable allowed for rapid change while the other allowed for slow change, thereby bounding the likely decay rate.[6] Including these variables could show the demand for, say, spinach shifted inward immediately but gradually returned to its preannouncement level as consumers became convinced that the problem had been resolved.

The last two shock variables, the increase/decay variables, allowed for the possibility that the full impact of the demand shift might not be fully felt immediately. The two variables were zero prior to the announcement and one at the time of the announcement. Then the variables rose in the weeks following the announcement, before beginning their decay to zero.[7] Again, one variable changed rapidly and the other slowly. These shock variables would reflect the case that the initial FDA statement altered consumers' purchase decisions, but later FDA statements and media reports also contributed to their level of concern.

If the demand shift were transitory, shock variables indicating a temporary pattern of changing demand might be statistically significant while standard dummy variables would not. If only one of the four transitory shock variables were significant, the sign on the coefficient would be sufficient to determine if the product

was a shock substitute or complement. Together, all five shock variables accommodated a wide range of consumer behavior. The estimated coefficients on each variable weighted their importance. The possibility that coefficients could be zero allowed for tests for which type of shock variable, if any, best represented consumer response (permanent, decay, or increase/decay) to the food safety shock.

Aggregate Leafy Greens Demand Model

Consumers may have changed their overall vegetable diets, purchasing less leafy greens in aggregate and substituting other fresh vegetables. A LA-AIDS model representing the upper stage of consumer demand was also specified and estimated. The upper stage demand model consisted of two equations—one represented all leafy greens and the other represented all other fresh vegetables. The form of the model was identical to the lower stage model for individual leafy green vegetables, including the same shock variables. As with the consumer consumption shifts among individual leafy green products, shifts away from the entire class of leafy green vegetables could be permanent or transitory. Following the standard LA-AIDS model estimation procedure, one equation, the all other fresh vegetable equation, was dropped.

Model Estimation Results

Table 2 shows the results of the individual leafy greens model, estimated with iterative seemingly unrelated regression. The *t*-statistics for most coefficients were significant. Only the equation for salads without spinach did not have a significant own-price coefficient. The expenditure index and Stone's price index were significant in all but the bulk iceberg lettuce share equation.

Table 3 shows price elasticities (conditional on leafy greens expenditures) and expenditure elasticities.[8] These elasticities were estimated using formula iii of Green and Alston, with share data evaluated at the means. All own-price elasticities were negative. Bagged and value-added products displayed more price responsiveness than the less expensive bulk products, suggesting that prices may induce some consumers to switch among product forms.

While including five shock terms in each equation allowed for significant flexibility in modeling consumer response, it ran the risk of overparameterizing these events. Testing determined if each of the three types of shock term (permanent, decay, and increase/decay) belonged in the model. Each of the three types of shock variables were tested jointly in all five equations and again tested equation by equation. A standard likelihood-ratio test, which produces a χ^2 statistic, compared the general unrestricted model with all the shock variables included to restricted models where the coefficients on the shock terms of interest were set equal to zero.

Table 4 reports the results of these tests. The first three test statistics refer to joint tests. For example, in the first row, when setting all the permanent dummy variables to zero, the χ^2 statistic (100.06) was significant, indicating that removing the dummy variables that captured permanent effects from the model would significantly reduce model fit. For each type of transitory shock variable, rapid and slow decay options were tested together (hence 10 degrees of freedom). All the

Table 2. Individual leafy greens demand model with spinach shock variables

Variable	Bagged Spinach		Bulk Spinach		Salads without Spinach		Bulk Iceberg Lettuce		Other Bulk Lettuce	
	Coeff.	*t*-Stat.	Coeff.	*t*-Stat.	Coeff.	*t*-Stat.	Coeff.	*t*-Stat.	Coeff.	*t*-Stat.
Constant	0.626	2.98	0.097	4.13	−0.344	−1.43	0.123	1.07	0.418	3.29
ln price of bagged spinach	−0.076	−5.71	−0.013	−7.83	0.094	7.58	−0.004	−0.68	−0.001	−0.22
ln price of bulk spinach	−0.013	−7.83	0.004	3.12	0.006	3.56	0.000	0.37	0.002	1.68
ln price of salads without spinach	0.094	7.58	0.006	3.56	0.006	0.37	−0.051	−7.92	−0.053	−7.87
ln price of bulk iceberg lettuce	−0.004	−0.68	0.000	0.37	−0.051	−7.92	0.047	8.54	0.006	1.45
ln price of other bulk lettuce	−0.001	−0.22	0.002	1.68	−0.053	−7.87	0.006	1.45	0.049	10.81
ln price of romaine hearts	0.000	0.07	0.001	0.70	−0.002	−0.50	0.002	0.58	−0.002	−0.71
ln expenditures	−0.024	−2.03	−0.004	−2.80	0.044	3.16	0.003	0.50	−0.017	−2.37
Stone's index	0.024	2.03	0.004	2.80	−0.044	−3.16	−0.003	−0.50	0.017	2.37
cos seasonal variable	0.003	2.87	0.000	0.79	0.005	3.94	−0.007	−11.86	−0.002	−2.49
sin seasonal variable	0.007	7.19	0.000	1.23	0.008	7.51	−0.009	−17.92	−0.001	−2.36
Trend	1.0E-04	5.30	−4.0E-05	−17.19	−4.0E-05	−2.08	−1.0E-04	−8.30	−2.0E-05	−2.51
Shock variables:										
Permanent	0.021	1.67	0.011	7.65	0.016	1.13	−3.0E-04	−0.04	−0.016	−2.12
Transitory										
Decay										
Rapid change	−0.009	−1.29	−0.001	−1.48	−0.001	−0.12	0.010	2.55	0.001	0.25
Slow change	−0.058	−3.91	−0.013	−7.65	−0.002	−0.09	0.010	1.20	0.024	2.68
Increase/Decay										
Rapid change	−0.026	−3.42	−0.002	−2.14	0.027	3.10	0.001	0.23	−0.004	−0.78
Slow change	−0.014	−1.56	0.001	0.79	−0.013	−1.28	0.007	1.54	0.018	3.31

Table 3. Individual leafy greens conditional price elasticities, expenditure elasticities, and average budget shares

Commodity	Bagged Spinach	Bulk Spinach	Salads without Spinach	Bulk Iceberg Lettuce	Other Bulk Lettuce	Romaine Hearts
			Conditional Price Elasticities[a]			
Bagged spinach	**−1.48**	−0.69	0.16	−0.03	0.02	0.01
Bulk spinach	−0.08	**−0.80**	0.01	0.00	0.02	0.02
Salads without spinach	0.68	0.47	**−0.99**	−0.39	−0.50	−0.05
Bulk iceberg lettuce	0.00	0.06	−0.11	**−0.65**	0.09	−0.02
Other bulk lettuce	0.01	0.12	−0.11	0.04	**−0.44**	0.01
Romaine hearts	0.01	0.07	−0.01	0.01	−0.01	**−0.98**
			Expenditure Elasticities[a]			
	0.85	0.78	1.08	1.03	0.80	0.98
			Average Share			
	0.16	0.02	0.54	0.14	0.09	0.06

[a]Price elasticities are conditional on leafy greens expenditures. Price and expenditure elasticities calculated using formula iii of Green and Alston using the means of the share data.

joint tests were significant, indicating all the shock variables should be included in the model. Shock terms were also tested equation by equation. The system of equations including all shock terms was estimated and compared to a model with the coefficients of one of the three shock variable types set equal to zero in one particular share equation. This process was repeated for all the shock variables, equation by equation. Since there was no particular sequence by which these equation-by-equation tests should be carried out, each of these restrictions were tested against the general model. These tests showed that dropping a shock variable would lead to a decline in model performance in twelve of fifteen cases. Altogether, test results suggested there was no reason to drop any shock variable; the shock impacts were both temporary and permanent. Consumers' response to the FDA announcement was complex and changing through time.

Upper Stage Results

The upper stage demand model with one equation for aggregate leafy greens was estimated with OLS regression. Likelihood-ratio tests identified which shock variables contributed to the model. Results revealed no evidence of a permanent impact; consumers temporarily reduced purchases of leafy greens, but eventually returned to their initial purchasing behavior (table 4). The decay shock variables did not contribute to the regression either. Only the increase/decay variables were significant.

Impact on Retail Expenditures

While the lower stage model was flexible enough to incorporate a wide array of consumer reactions to the shock, the test results did not lend themselves to a concise statistical characterization of consumer behavior. That is, tests revealed

Table 4. Test of shock variables for the individual leafy greens and aggregate leafy greens models

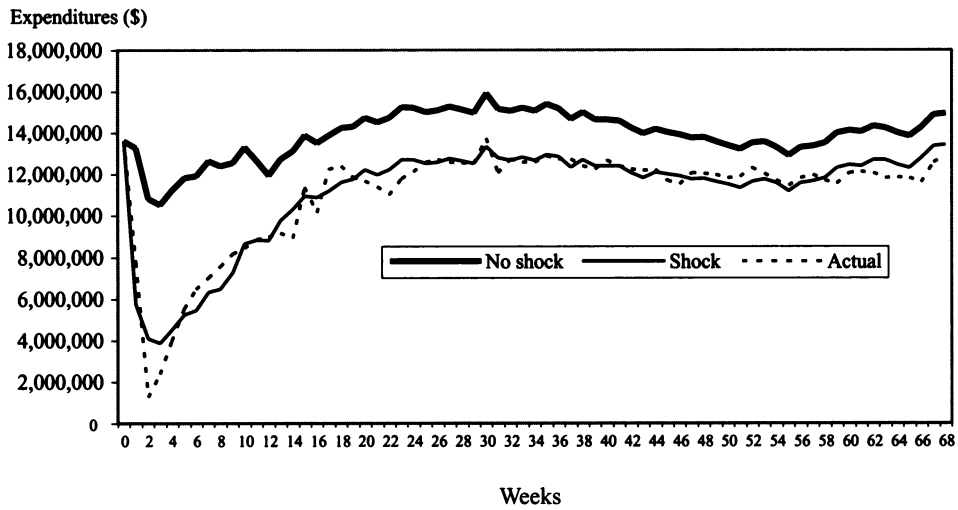
Equation	Shock Variable(s) Tested	χ^{2a}	Degrees of Freedom
Individual Leafy Greens Model			
All 5	Permanent	100.06***	5
All 5	Decay	96.78***	10
All 5	Increase/decay	135.98***	10
Bagged spinach	Permanent	2.92*	1
Bulk spinach	Permanent	55.68***	1
Salads without spinach	Permanent	1.34	1
Bulk iceberg lettuce	Permanent	0.01	1
Other bulk lettuce	Permanent	4.78**	1
Bagged spinach	Decay[b]	18.06***	2
Bulk spinach	Decay	59.68***	2
Salads without spinach	Decay	0.02	2
Bulk iceberg lettuce	Decay	8.88**	2
Other bulk lettuce	Decay	7.78*	2
Bagged spinach	Increase/decay[b]	99.80***	2
Bulk spinach	Increase/decay	9.56***	2
Salads without spinach	Increase/decay	20.84***	2
Bulk iceberg lettuce	Increase/decay	16.36***	2
Other bulk lettuce	Increase/decay	36.84***	2
Aggregate Leafy Greens Model			
Aggregate equation	Permanent	1.71	1
Aggregate equation	Decay	1.89	2
Aggregate equation	Increase/decay	12.60***	2

[a] Significance at 90%, 95%, and 99% is indicated by *, **, and ***, respectively.
[b] Here the rapid and slow variables are tested jointly for significance. This applies to each commodity.

each shock term to be significant in the lower stage model, so evaluating the coefficient on one particular shock variable alone would not reveal the true nature of consumer response to the announcement. Therefore, the model estimates were simulated with and without the entire set of shock variables. Simulation incorporated the combined effects of all shock variables and provided a visual check on model performance. While simulation does not provide a statistical test for whether a product is a shock substitute or complement, plotted results for simulated expenditures are compelling.

The goal was to map out the impact of the shock on consumers' expenditures for each product as well as for the combined group of leafy greens. Multiplying the predicted expenditure share of a product by total predicted expenditures on leafy greens provided the predicted expenditure on that product. Since the upper stage model showed that leafy greens expenditures were a function of the shock, the simulation required two measures of total expenditures. The shock simulation used predicted leafy greens expenditures from the upper stage model that included shock impacts. The no-shock simulation used predicted total leafy

Figure 1. Impact of spinach shock on bagged spinach expenditures



Note: Week zero is the week prior to and week 1 is the week of the announcement.

greens expenditures that did not include shock impacts. Thus, calculations treated total expenditures on leafy greens as varying, depending on whether shock or no-shock assumptions were in force. The impact of shocks on specific leafy green products included the lower stage model's direct impact of the spinach shock as well as the indirect impact of changing expenditures on all leafy greens.

In addition, this simulation also included any indirect impact the shock may have had on individual leafy green product prices. Prices were regressed on own lagged prices and the five shock variables. Tests revealed that the shock only affected bulk and bagged spinach prices.[9] The effect of the shock on prices for these two products was incorporated into the simulation in a manner similar to that used for total leafy greens expenditures.

Figure 1 shows three scenarios for expenditures on bagged spinach: simulated expenditures when all direct and indirect shock impacts were accounted for, simulated expenditures that assumed no shock occurred, and actual expenditures. Since the data are weekly and the five days when there was no spinach on the market were spread over two weeks, the figure does not show consumption falling to zero. Table 5 and figure 2 consolidate information on all six leafy greens, calculating the change in simulated expenditures with the shock as a percentage of simulated expenditures without the shock. All six commodities, with the exception of salads without spinach, showed a substantial and immediate response to the announcement. Most of the impact came in the weeks immediately after the announcement. The magnitude and duration of the impact varied by commodity. For example, the shock drove the difference in simulated expenditures (shock vs. no shock) for bagged spinach down 63% in the third week—the maximum gap observed. After twenty-six weeks, predicted expenditures with the shock were still 17% below where they would have been absent the shock. Even in week 68, the last week of the data set, the difference in predicted expenditures was still

Table 5. Difference in simulated leafy greens expenditures

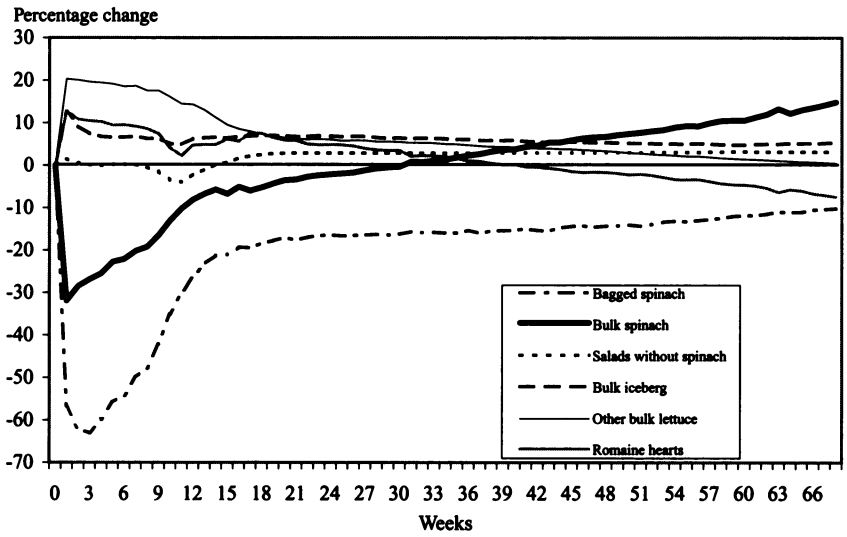
Commodity	Week[a]	Difference in Expenditures[b]
		Percentage
Bagged spinach		
	Maximum difference—week 3	−63
	Difference at week 26	−17
	Difference at week 68	−10
Bulk spinach		
	Maximum difference—week 1	−32
	Difference at week 26	−2
	Difference at week 68	15
Salads without spinach		
	Maximum difference—week 11	−4
	Difference at week 26	3
	Difference at week 68	3
Bulk iceberg lettuce		
	Maximum difference—week 1	13
	Difference at week 26	7
	Difference at week 68	5
Other bulk lettuce		
	Maximum difference—week 1	20
	Difference at week 26	6
	Difference at week 68	0
Romaine hearts		
	Maximum difference—week 1	13
	Difference at week 26	5
	Difference at week 68	−7
Total leafy greens		
	Maximum difference—week 1	−7
	Difference at week 26	0
	Difference at week 68	0

[a]The outbreak announcement was made on Thursday of week 1. A week is defined as the Monday through Sunday sales week.
[b]Difference in simulated expenditures (with and without a shock) as a percentage of simulated expenditure without a shock.

down 10%. Recall that bagged spinach sales were growing at a rapid rate prior to the outbreak so the simulated expenditures without a shock were increasing. The bagged spinach market did not seem to reach a new equilibrium by the end of 2007.

For bulk spinach, the first week after the outbreak showed the largest divergence: simulated expenditures were 32% below what they would have been in the absence of the announcement. At week 26, simulated expenditures were still down 2%. But by week 31, bulk spinach became a shock substitute with simulated expenditures above expenditures without a shock. Consumers seemed to have faced two concerns—safety of spinach in general and safety of bagged products in general. The contaminated product was bagged spinach. Also, during the

Figure 2. Percentage change in simulated expenditures with a shock with respect to expenditures without a shock



publicity after the FDA announcement, several prominent scientists were widely quoted in the media saying that the bagged salad production process was risky (Engle and Lin). Whether true or not, some consumers appear to have viewed bulk spinach as the less risky of the two products. The switch from bagged spinach back to bulk spinach at least temporarily reversed the long-term decline of this product. At the end of sixty-eight weeks, expenditures were 15% above where they would have been without the outbreak. Like bagged spinach, bulk spinach had not yet reached a new equilibrium by the end of 2007.

Bulk iceberg lettuce, other bulk lettuce, and romaine hearts were clearly shock substitutes with large increases in consumer expenditures on these products following the announcement. In the first week of the outbreak, simulated expenditures for these three products were 13–20% above simulated expenditures without a shock. By week 26, these lettuces were only 5–7% above what they would have been without the shock. Consumer expenditures on bulk iceberg lettuce appeared to reach a new equilibrium at about 5% above where they would have been without the shock. Consumer expenditures on other bulk lettuce continued a slow but persistent decline from its peak; at the end of the sixty-eight-week period, the difference in expenditures was approaching zero. Estimated expenditures on romaine hearts, based on the dropped equation, became a shock complement in week 41.

Bagged salads without spinach showed the most complicated response to the shock. In the first week of the outbreak, expenditures were up 1.5%—just barely a shock substitute. The change in expenditures hovered around zero for the first seven weeks followed by six weeks of being below expected expenditures—a shock complement. It is notable that this was the only lettuce product that decreased in expenditures shortly after the announcement. This provided more

evidence of consumer concerns regarding bagged products in general, not just spinach. By week 14, consumer expenditures increased above what they would have been without a shock and salads without spinach again became a shock substitute. Expenditures quickly settled into what appeared to be a permanent increase of about 3%. The change in expenditures over time could have been due to changing public information available to consumers.

Results from the upper stage model showed the impact of the announcement on total leafy greens expenditures was relatively small and short lived. After the announcement, simulated expenditures fell 7%. By week 16 the decline was less than 1% and by week 29 expenditures were the same with and without a shock. The response for total leafy greens expenditures was more moderate since some individual leafy greens expenditures increased and some decreased.

Discounted Shock Impact on Expenditures

Table 6 shows the cumulative effect of the shock on expenditures for each of the six leafy greens. Simulated expenditure differences were summed over the sixty-eight-week period that began with the announcement. The differences are in terms of the present value on January 1, 2008; this is an *ex post* perspective looking back from the end of the data series.[10] Total retail expenditures on bagged spinach declined $201.9 million after the FDA announcement, a decline of 20% from what expenditures would have been without a shock. Bulk spinach expenditures fell $0.6 million, a decline of 1% over the same time. The overall losses for bulk spinach included a loss of $3.8 million over the first thirty weeks of the outbreak followed by a gain of $3.2 million in the last thirty-eight weeks, as bulk spinach became a shock substitute. Expenditures for bagged salads without spinach increased $63.0 million or 2%. This included a net loss of $3.9 million in the first thirteen weeks of the outbreak (larger than the total loss of bulk spinach in thirty weeks) followed by a $66.9 million gain. Expenditures on bulk iceberg, other bulk lettuce, and romaine hearts increased 6%, 7%, and 2%, respectively. The sum of all changes in expenditures yielded a total decline in leafy greens expenditures of $60.6 million, a decline of 1% from what expenditures would have been without a shock.

Conclusions

FDA's announcement to consumers to not eat fresh spinach had the immediate potential to prevent additional consumers from becoming ill. Less certain were the future consumer response to this information and the cost to the produce industry. Some were concerned that FDA's announcement would cause consumers to fear all leafy green products or even produce in general. Results of this analysis show that consumers generally did respond specifically to FDA's announcement and did not panic about other vegetables. This analysis investigated the consumer response with a two-stage model of demand for six leafy green products—an upper stage aggregate demand model of all leafy greens and all other fresh vegetables plus a lower stage demand model of the individual leafy greens. The model incorporated prices, expenditures, seasonal trends, trends across years, and shock variables to represent the impact of FDA's announcement. By including five different shock variables, this flexible model made it possible to assess a complicated consumer response.

Table 6. Change in expenditures due to shock

	Bagged Spinach	Bulk Spinach	Salads without Spinach	Bulk Iceberg Lettuce	Other Bulk Lettuce	Romaine Hearts	Total
Present discounted value:				$ Million			
Expenditure changes due to the shock	−201.9	−0.6	63.0	42.3	31.0	5.7	−60.6
Expenditures without the shock	990.2	83.4	2,850.0	694.3	456.0	368.4	5,442.3
				Percentage			
Percentage change in expenditures due to shock	−20	−1	2	6	7	2	−1

The upper stage model revealed that the impact on demand for leafy greens as a whole was temporary; consumers substituted other vegetables for leafy greens for a short period. The long-run impact was confined to a shifting among leafy green vegetables, not a change in total leafy greens consumption. At the individual leafy green commodity level there were both temporary and permanent effects. The negative impact of the announcement about spinach was borne primarily by the spinach industry, while other leafy greens producers benefited. At the end of 2007, bagged spinach expenditures were still down 10% due to the shock. Bulk spinach expenditures declined initially but later became a shock substitute. Consumers appeared to be less reluctant to eat bulk spinach than bagged spinach. This concern about bagged products seems to have carried over to other leafy greens too. Bulk iceberg, other bulk lettuce, and romaine hearts were initially shock substitutes although only bulk iceberg appears to have experienced a permanent gain. At first, expenditures on bagged salads without spinach wobbled back and forth acting as both a shock substitute and complement as consumers considered the information reported by FDA and the media. Eventually, salads without spinach became a clear shock substitute. Spinach losses totaled $205.8 million. Gains to bulk spinach and net gains to other commodities totaled $145.2 million. Overall, total leafy greens expenditures declined 1% due to the shock.

The produce industry and FDA both benefit from a better understanding of consumer response to an outbreak. While spinach growers coped with market losses, they had to plan and many cut back production. In the event of a future outbreak, more information on potential consumer response would help growers plan better. Analysis of consumer response also helps FDA evaluate the benefits and costs of its response to the spinach outbreak and determine how best to protect human health at the minimum cost to growers. The finding that the negative consumer response was mostly limited to spinach, the commodity FDA targeted, is important, particularly since increasing consumption of fresh fruit and vegetables is a national nutrition objective.

Acknowledgments

The authors wish to thank Tomislav Vukina and two anonymous reviewers for their comments and suggestions. Any remaining errors are ours. The views expressed herein are those of the authors and do not necessarily reflect official USDA policy.

Endnotes

[1]Retail data were available, but foodservice data were not. While this was a limitation to the analysis, most fresh spinach goes through retail channels. For lettuce, the foodservice market is very important for hamburgers, sandwiches, and salads.

[2]FreshLook Marketing acquired data from U.S. grocery stores with sales above $2 million per store per year. The database contains records from approximately 15,000 stores, which provide 65% coverage for all grocery stores in terms of commodity value. Data were weighted to represent a U.S. total. The sample of stores does not include mass merchandisers such as Wal-Mart and Costco, farmer's markets, or natural food stores.

[3]Purchases of leafy greens displayed seasonal patterns. The number 52 ensured a single annual cycle for a model using weekly data. Varying the relative sizes of coefficients on the sine and cosine functions made it possible to account for any phase (which sets the location of a cycle within the calendar year) and amplitude.

[4]There were two almost simultaneous food-borne illness outbreaks several months later linked to iceberg lettuce consumed in two foodservice establishments. These shocks were initially included in

the model but it was not possible to separate the impacts of the various shocks. Lettuce industry experts reported that the iceberg shocks were almost unnoticed against the background of the ongoing spinach shock. In 2007, there were several recalls of leafy greens, but no reported illnesses and comparatively little media response.

[5]If share variables contained unit roots, all shock impacts would be permanent. Unit root tests results were mixed. Augmented Dickey-Fuller (ADF) tests on share variables (with a constant) indicated that four of the six share variables were stationary. However, ADF did not reject nonstationarity for romaine hearts (the dropped equation); rejection for bulk spinach was very sensitive to the number of lagged variables included and whether tests were done at 5% or 10% confidence levels. Kwiatkowski-Phillips-Schmidt-Shin tests (null hypothesis—series is trend stationary) indicated bulk spinach and romaine hearts were nonstationary.

[6]Decay variables were constructed as $1 - (1 + e^{-rt})^{-1}$ and normalized to 1.0 at the announcement (week 1), where $r = 0.95$ for rapid decay and r = 0.01 for slow decay. The function embedded an exponential decay within a logistic function to remain within the unit interval. The rapid decay function fell to 0.001 by week 9. The slow decay was still at 0.676 at week 68, the end of the data series.

[7]The increase/decay variables were constructed as $(1 + e^{-rz})^{-1}$ *with* $z = 0.9t - 0.1t^2$ and normalized to 1.0 at the announcement, where $r = 0.95$ for the rapid decay and $r = 0.25$ for the slow decay. The rapid decay increased to 1.277 in weeks 4 and 5 before descending. By week 15, the variable was less than 0.001. The slow decay increased to 1.132 in weeks 4 and 5 before descending, and was less than 0.001 at week 23.

[8]It is well known that elasticity estimates derived from LA-AIDS may contain a bias. For the leafy greens model, correcting the bias by estimating a nonlinear model was not practical, given the relatively large number of products necessary to represent the leafy greens retail market. When the price index was estimated within the model, forty-three additional terms had to be included in each share equation (a constant, six linear terms, and thirty-six squared and cross-product terms). Most parameter estimates failed to converge and nearly exhausted degrees of freedom. Furthermore, none of the parameter estimates for interaction and higher order terms in the price index were significant. That is, estimates pointed to a linear price index, much like the Stone index.

[9]Price regressions used 5 lags to ensure that residuals were white noise. Employing an *F*-test (*F*[5,191]) to determine if shock variables jointly influenced price resulted in the following *F*-statistics: bagged spinach 3.186***, bulk spinach 15.590***, bagged salads without spinach 1.196, bulk iceberg lettuce 0.130, other bulk lettuce 0.897, and romaine hearts 1.510 (*** indicates the statistic is significant at the 0.01% level). The immediate impact of the shock variables was to increase retail prices of spinach, which may indicate that growers, uncertain about future consumer demand, cut back supply more than consumers cut back their demand. Retailers did not reduce prices to sell spinach.

[10]The present value is $PV = \sum_{t=1}^{68} \Delta X_t (1 + r)^{69-t}$, with the annual interest rate set at 0.07, or approximately 0.0013 on a weekly basis.

References

Arnade, C., and D. Pick. "Seasonality and Unit Roots: The Demand for Fruits." *Agr. Econ.* 18(January 1998):53–62.

Beach, R.H., F. Kuchler, E. Leibtag, and C. Zhen. *The Effects of Avian Influenza News on Consumer Purchase Behavior: A Case Study of Italian Consumers' Retail Purchases*. Washington, DC: U.S. Department of Agriculture, ERS,Econ. Res. Rep. ERR-65, August 2008.

Calvin, L. 2007. "Outbreak Linked to Spinach Forces Reassessment of Food Safety Practices." *Amber Waves* 5, no. 3(2007):24–31.

Calvin, L., B. Avendaño, and R. Schwentesius. *The Economics of Food Safety: The Case of Green Onions and Hepatitis A Outbreaks*. Washington, DC: U.S. Department of Agriculture, ERS, Econ. Res. Service Outlook Rep. No. VGS30501, November 2004.

Carter, C., and A. Smith. "Estimating the Market Effect of a Food Scare: The Case of Genetically Modified Starlink Corn," *Rev. Econ. Statist.* 89(August 2007):522–33.

Cuite, C., S. Condry, M. Nucci, and W. Hallman. *Public Response to the Contaminated Spinach Recall of 2006*. Policy Institute, Rutgers University, February 2007.

Dahlgran, R.A., and D.G. Fairchild. "The Demand Impacts of Chicken Contamination Publicity—A Case Study." *Agribusiness* 18(2002):459–74.

Engle, M., and R.-G. Lin. "Processing May Spread E. coli: Some Food Safety Experts Say the Mixing of Greens for Packaging May Increase the Risk of Contamination." *Los Angeles Times*, January 20, 2007, p. A1.

Green, R., and J.M. Alston. "Elasticities in AIDS Models." *Amer. J. Agr. Econ.* 72(May 1990):442–45.

Kuchler, F., and A. Tegene. *Did BSE Announcements Reduce Beef Purchases?* Washington, DC: U.S. Department of Agriculture, ERS, Econ. Res. Rep. 34, December 2006.

Piggot, N.E., and T.L. Marsh. "Does Food Safety Information Impact U.S. Meat Demand?" *Amer. J. Agr. Econ.*, 86(February 2004):154–74.

Richards, T.J., and P.M. Patterson. "The Economic Value of Public Relations Expenditures: Food Safety and the Strawberry Case." *J. Agr. Resource Econ.* 24(December 1999):440–62.

Shin, A. "Fresh Spinach Declared Safe to Eat—Self-Regulation Called Insufficient to Avoid Outbreak." *Washington Post*, September 30, 2006, p. D1.