The Impacts of Food Safety Information on Meat Demand: A Cross-Commodity Approach Using U.S. Household Data

Nicholas E. Piggott[1]
Department of Agricultural and Resource Economics
North Carolina State University

Mykel R. Taylor[2]
Department of Agricultural and Resource Economics
North Carolina State University

Fred Kuchler[3]
Economic Research Service
U.S. Department of Agriculture

Selected Paper
AAEA Annual Meeting
July 29 – August 1, 2007
Portland, Oregon

---

[1] Associate Professor: Department of Agricultural and Resource Economics, Box 8109, North Carolina State University, Raleigh, NC 27695-8109. E-mail: nick_piggott@ncsu.edu
[2] Graduate Research Assistant: Department of Agricultural and Resource Economics, Box 8109, North Carolina State University, Raleigh, NC 27695-8109. E-mail: mrtaylor@ncsu.edu
[3] Economist: Diet, Safety, and Health Economics Branch, Economic Research Service, Room N2097, 1800 M Street NW, Washington, DC 20036-5831. E-mail: fkuchler@ers.usda.gov

Introduction

Food safety in the U.S. meat industry is of special concern for many groups of people. Consumers of meat face possible adverse health effects from consumption of contaminated meat products. The meat industry faces not only the threat of litigation due to product contamination, but must deal with potentially strong market reactions from food safety information released to the public. Government agencies, such as the Food Safety and Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA), are also concerned with food safety events because they are charged with choosing and achieving particular levels of food safety, and food safety events call into question their success.

The reaction of consumers to food safety information is an important aspect of a food safety event. It would be expected that the primary meat commodity affected by a food safety event, such as a recall or other safety announcement, would suffer from a decrease in demand. However, the degree to which demand falls and the period of time over which demand is affected is an empirical question. The demand response of consumers toward other meat commodities is also a key issue, with important price feedback effects possible. These own- and cross-commodity demand effects play an important role in both the industry and the USDA understanding the economics of a food safety event. Studying and understanding the demand response in the meat industry to food safety information provides a useful model for looking at cross-commodity effects when close substitutes exist and may be applied to other food commodities facing similar food safety events.

The focus of this paper is to investigate whether publicized food safety information from the printed media on beef, pork, chicken, and turkey impacts the demand for these commodities. We follow the modeling and estimation procedure put forth by Piggott and Marsh in their 2004 study of food safety impacts on meat and poultry demand using quarterly aggregate disappearance data. The study builds upon their analysis, as well as other research, by employing household level data on meat purchases collected by the Nielsen Company.

The availability of household level data affords the opportunity to investigate the robustness of previous work that has been limited to the use of aggregated data. Furthermore, household level data can be aggregated in a variety of ways, thereby expanding the options for demand estimation. For example, it is possible to estimate the demand for chicken and turkey separately, rather than as a composite poultry commodity. It is also possible to aggregate the data to a monthly periodicity. Estimation using monthly data may reveal shorter periods of decline and recovery in meat demand that cannot be detected using annual or quarterly data. Finally, demand system approach to modeling will allow for the investigation of potential cross-commodity effects from food safety information. The use of household level data offers the potential of providing a richer dataset that may offer additional insight into the underlying economic relationships as compared with the quarterly disappearance data employed by previous researchers.

Demand and Food Safety

An early study of food safety impacts on consumer demand was conducted by Brown who looked at the effect of a health hazard "scare" from herbicide residue on cranberries in 1959. Information on the food safety event was considered to be a negative form of advertising. Brown argued that while positive advertising can decrease the price elasticity of demand through increasing customer loyalty, negative information may cause an increase in the price elasticity. The adverse effects on cranberry demand were tested using comparisons of price elasticities of demand for the periods before, during, and after the event. No significant effect on price elasticities was found.

The use of media indices to measure the impact of food safety information on demand has been seen in several demand studies. Smith, van Ravenswaay, and Thompson considered the effect of media publicity following a case of heptachlor contamination of fresh fluid milk in Hawaii using monthly data on milk purchases. Significant negative effects on milk purchases were found from negative news coverage. However, positive news coverage did not appear to affect purchases, indicating that statements by the media assuring consumers of the safety of certain milk products were heavily discounted.

Dahlgran and Fairchild studied the effect of adverse media coverage from salmonella contamination on the demand for chicken. Their model incorporated adverse media publicity from television and print as a form of negative advertising, where publicity included both the number of occurrences and percent of population exposed to the coverage. Weekly market-level data on quantity and prices of chicken were used to allow measurement of short-run effects on the price of chicken. Their results did indicate a negative demand response to adverse media, however, the effect quickly died out in a matter of weeks. Unlike paid advertising, media coverage of food safety events can quickly die out as other news events take priority in programming. This lack of frequent message repetition was considered by the authors to be a possible reason for the absence of long-run alterations in demand.

Burton and Young analyzed the effects of Bovine Spongiform Encephalopathy (BSE) on meat demand in Great Britain using media indices incorporated into a dynamic AIDS model. The analysis used quarterly data on quantity and expenditures for beef, lamb, pork, and poultry. The model considered publicity on BSE to be a form of negative advertising and measured its effect using an index of media coverage. The index included both the number of articles per quarter and the cumulative number of articles to date for each quarter. BSE publicity was shown to have both significant short-run and long-run effects on consumer expenditures on beef and among the other meats with a decline in market share for beef of 4.5 percent by the end of 1993.

A recent study by Piggott and Marsh analyzed the impact of food safety information on demand for beef, pork, and poultry using aggregate data on quarterly U.S. per capita disappearance of meat. They developed a theoretical model that incorporated meat quality into the demand for meat. The model also explicitly considered both own- and cross-product effects of quality on quantity demanded. Meat quality, in their model, was inversely related to the occurrence of food safety information in the media. The media index for food safety information measured bundles of contaminants reported individually for beef, pork, and poultry. Their findings indicated that impacts of food safety events on demand for meat were relatively small and did not last beyond the period in which the event occurred.

Kuchler and Tegene found similar results to Piggott and Marsh using data on weekly household purchases of beef. Weekly purchases of fresh beef were found to have declined in response to the December 2003 discovery of BSE in Washington State. However, these effects were short-lived with beef purchases recovering within 2 weeks after the announcement.

Theoretical Model

The basic demand function is derived from the consumer maximization problem under the assumption of expenditures on meat and poultry being weakly separable from expenditures on all other goods. Using the model developed by Piggott and Marsh, the problem is specified as

(1) $$\max_{\mathbf{x},\lambda} U(\mathbf{x},\mathbf{q}) + \lambda(M - \mathbf{p}'\mathbf{x}) ,$$

where $\mathbf{x}$ is a vector of quantities of meat consumed, $\mathbf{q}$ is a measure of meat quality ($q_k = k^{th}$ meat quality), M is total expenditures on meat, $\mathbf{p}$ is the vector of prices, and λ is the Lagrange multiplier. Piggott and Marsh make the following assumptions on the utility function: $U_{x_i} > 0$, $U_{q_i} > 0$, $U_{x_i q_i} > 0$, $U_{x_i q_i q_i} < 0 \ \forall i$, and concavity of U with respect to $\mathbf{x}$. It is also assumed that $\mathbf{q}$ is a function of food safety information, $\mathbf{r}$, where $\frac{\partial q(r)}{\partial r} < 0$ and $\frac{\partial q_k}{\partial r_j} = 0$ if $k \neq j$. The solution to the utility maximization problem gives the Marshallian demands

(2) $\mathbf{x}^m(\mathbf{p}, M, \mathbf{q})$.

The dual cost minimization problem is

(3) $\min_{\mathbf{x},\mu} \ \mathbf{p'x} + \mu(u\text{-}U(\mathbf{x}, \mathbf{q}))$,

where μ is the Lagrange multiplier. The solution to this problem gives the Hicksian demands

(4) $\mathbf{x}^h(\mathbf{p}, u, \mathbf{q})$.

The Marshallian and Hicksian demands are used to determine the comparative statics of the consumer's decision.

Piggott and Marsh develop the following comparative statics results for the impact of meat quality (measured implicitly by food safety information) on demand for meat. The Marshallian effect on demand for x_i from a change in the quality of the k^{th} good, q_k, is

(5) $$\frac{\partial x_i^m}{\partial q_k} = -\left(\frac{1}{\lambda}\right) \sum_{j=1}^{N} \left(\frac{\partial x_i^h}{\partial p_j}\right) U_{x_j q_k},$$

where $U_{x_j q_k}$ is the marginal utility of good *j* with respect to a change in the quality of the k^{th} good. Piggott and Marsh show that under the following assumptions, the comparative static of own effects of a quality change can be signed: (1) $U_{x_j q_k} > 0$ if $k = j$ (i.e., an increase in the quality of a good will increase the utility of that good) and (2) when *j* and *k* are net complements (substitutes) then $U_{x_j q_k}$ for $k \neq j$ will be positive (negative). Given these assumptions, it can be shown that $\frac{\partial x_k^m}{\partial q_k} > 0$. However, even with very restrictive assumptions, the sign of the cross-quality effects cannot be determined. Since $q(\mathbf{r})$ and $\frac{\partial q(r)}{\partial r} < 0$, the Marshallian demands can be re-written as

(6) $\mathbf{x}^m(\mathbf{p}, M, \mathbf{q}(\mathbf{r})) = \mathbf{x}^m(\mathbf{p}, M, \mathbf{r})$,

and the comparative static signs are opposite for $\mathbf{r}$.

Empirical Demand Model

In order to capture both own- and cross-price effects on demand from food safety information, a demand system must be specified that is consistent with consumer theory. The demand system chosen for this study is a standard demand model that is generalized to include pre-committed quantities (Piggott and Marsh). The generalized specification allows for the use of demographic translating to incorporate non-price and non-income demand shifters into the system. The model is derived from the following generalized expenditure function

(7) $E(\mathbf{p}, u) = \mathbf{p}'\mathbf{c} + E^*(\mathbf{p}, u)$,

where **p** is an vector of *N* prices, **c** is a vector of *N* pre-committed quantities, and *u* is utility. The first term of the expenditure function, $\mathbf{p}'\mathbf{c}$, are the consumer's pre-committed expenditures on *N* goods. This term can be interpreted as the minimum level of expenditure required to attain a minimum subsistence level of consumption. The second term, $E^*(\mathbf{p}, u)$, are the supernumerary expenditures. These are the remaining expenditures that a consumer may allocate across *n* competing goods.

Sheppard's Lemma may be applied to (7) to obtain the demand equations

$$(8) \qquad \begin{aligned} x_i &= c_i + x_i^*\left[\mathbf{p}, M^*\right] \\ &= c_i + x_i^*\left[\mathbf{p}, M - \sum_{i=1}^{N} c_i p_i\right] \quad \text{for } i = 1,...,N \end{aligned} ,$$

where x_i is the quantity demanded for the *i*th meat good, c_i is the pre-committed quantity of the *i*th meat good, $x_i^*[\mathbf{p}, M^*]$ is the supernumerary quantity of the *i*th meat good, $M^* = M - \sum_{i=1}^{n} c_i p_i$ is supernumerary expenditure, and *M* is total expenditure on *N* goods. The share form of the model in equation (8) is as follows

$$(9) \qquad w_i = \left(\frac{p_i c_i}{M}\right) + \left(\frac{M^*}{M}\right) w_i^*[\mathbf{p}, M^*] ,$$

where $w_i = \frac{p_i x_i}{M}$ is the group expenditure share for meat *i* and $w_i^* = \frac{p_i x_i^*}{M^*}$ is the supernumerary expenditure share of meat *i*.

Distinguishing between the pre-committed and the supernumerary terms in the demand equation is important because the pre-committed quantities are not a function of prices or expenditure. This allows the demand equation to be augmented with demand shifters that are not related to prices or income. Augmentation of demand equations with demand shifters is done using the Pollak and Wales demographic translating procedure. The use of demographic translating does not impose any restrictions on the signs of the coefficients of the demand shifters in any given demand equation. However, there is a restriction imposed on the system due to the specification of the expenditures. The restriction requires that the sum of changes in the expenditures on pre-committed quantities must be equal and opposite in sign to the supernumerary expenditures. The restriction leaves the total level of expenditures unchanged.

For this model, the pre-committed quantities (c_i) are augmented to include food safety and seasonal dummy variables. Intuitively, one would expect that any changes in meat demand due to a food safety event would be independent of prices or income. Another source of price and income independent demand shifts is the seasonal fluctuation in demand for meat and poultry. Augmenting the c_i's to include variables for food safety information and seasonal effects gives the following

$$(10) \qquad \tilde{c}_i = c_{i0} + \sum_{k=1}^{3} \theta_{ik} qd_k + \sum_{m=0}^{L} \phi_{i,m} bf_{t-m} + \pi_{i,m} pk_{t-m} + \kappa_{i,m} py_{t-m} \;,$$

where qd_k (k=1,2, and 3) are quarterly seasonal dummy variables, bf_{t-m} are beef food safety indices, pk_{t-m} are pork food safety indices, and py_{t-m} are poultry food safety indices that have been lagged m periods. The coefficients to be estimated are the c_{i0}'s, θ_{ik}'s, $\phi_{i,m}$'s, $\pi_{i,m}$'s, and $\kappa_{i,m}$'s. The length of time that food safety information may affect demand is not known a priori. Therefore, the appropriate value for L will is determined empirically.

Following Piggott and Marsh, the model used in this study is the generalized version of the Almost Ideal Demand System (GAIDS) first proposed by Bollino. The model includes pre-committed as well as supernumerary quantities and is specified in share form as follows

$$(11) \qquad w_i = \left(\frac{p_i c_i}{M}\right) + \left(\frac{M^*}{M}\right)\left(\alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{M^*}{P}\right)\right) + e_i \;,$$

where

$$\ln P = \delta + \sum_{j=1}^{N} \alpha_j \ln p_j + \frac{1}{2}\sum_{k=1}^{N}\sum_{j=1}^{N} \gamma_{kj} \ln p_k \ln p_j$$

and p_i is the per unit price of the *i*th meat good. The notation *i,j* = *b* for beef, *p* for pork, *c* for chicken, and *t* for turkey. The coefficients c_i, α_i, γ_{ij}, β_i, and δ will be estimated and e_i is a random error term. Theoretical restrictions can be imposed on this demand model through the use of parameter restrictions. Homogeneity is imposed by $\sum_{j=1}^{N} \gamma_{ij} = 0$, adding-up is imposed by $\sum_{i=1}^{N} \beta_i = 0$ and $\sum_{i=1}^{N} \alpha_i = 1$, and symmetry is imposed by $\gamma_{ij} = \gamma_{ji} \quad \forall i \neq j$. The model is estimated after replacing the c_i's in equation (11) with the $\tilde{c}_i$'s from equation (10) to include food safety and seasonal effects.

Data

Household Consumption Data

The Nielsen Homescan panel is a nationwide panel of households that record all their retail food purchases. Individuals collect purchase data by scanning the universal product codes (UPCs) of the items they purchase. Each item is recorded by a scanning device at home after every shopping trip. The purchase data are subsequently uploaded via computer to Nielsen's database. Data include detailed product information, date of purchase, total quantity, and total expenditure on every item purchased. Not all food products are marked with a UPC code. These items are referred to as random-weight products and include foods such as fresh meat and poultry or fresh fruits and vegetables. Random weight items are recorded by using a code book provided by Nielsen that contains product descriptions and unique codes that can be scanned by the individual.

The sample of households included in the Nielsen Homescan panel was selected such that it would closely match the distribution of U.S. food consumers. The dataset is a stratified random sample that was selected based on both geographic and demographic targets. Participation in the panel ranged from a low of 7,124 households in 1999 to 8,833 households in 2004. Participation in this sample is defined as having participated for at least 10 of twelve months of the year.

The products of interest for this study are fresh beef and veal, fresh pork, fresh chicken, and fresh turkey. We focused on fresh products and excluded from consideration any processed products because it is difficult to determine the extent to which processed products are perfect substitutes for fresh meats. Also excluded from these groups are frozen meat and poultry. By restricting the sample to fresh products, it may be possible to limit stock effects in the demand analysis.[1] All the products used in the demand analysis are random-weight items. While some fresh meat is sold in fixed-weight packages (i.e., with a UPC code), the majority of fresh meat and poultry products are sold as random-weight items. Each observation is a separate product purchase and includes the total quantity purchased in pounds, the total amount spent on the item in dollars, a product description (e.g. ground beef-bulk, rib eye steak, pot roast), and the date of purchase. Prices per unit of product were subsequently calculated by dividing total expenditure by total quantity.

The daily purchase data include products bought over the years 1998 to 2005. Initial inspection of the data indicated possible outlier observations or reporting errors. Therefore, several rules were developed to deal with these observations. First, observations where the total quantity purchased is less than 0.25 lbs were deleted from the dataset. Second, very low prices are present in the dataset due to the use of coupons for some purchases. Coupon value could

[1] Stock effects, due to infrequency of product purchases, may be larger for frozen versus fresh products. For example, fresh meat has a shelf life of days, while frozen meat can be stored for much longer periods of time. Also, if consumers view fresh meat as being of a different quality than frozen meat, then the two groups could also be considered weakly separable in a complete demand system analysis.

range from zero up to 100 percent of the total price of a product, making some prices were equal to zero. Therefore, observations were deleted if the price per unit was not greater than $0.01/lb. The data also contained some extremely high per unit prices. These may be due to recording errors or possibly highly specialized meat purchases (e.g. mail order or home delivery). In order to determine a reasonable rule for deleting high prices, the individual products within each commodity group were analyzed to determine their respective price distributions. For each commodity, the upper one percent of the distribution of the highest priced product was used as a cut off value. This cut off price is $33.78/lb for beef, $18.14/lb for pork, and $20.27/lb for chicken and turkey. After these data cleaning rules were implemented, the final sample for beef and veal consists of 1,301,210 observations and pork purchases total 390,842 observations over the entire sample period. The final sample of chicken purchases is 600,229 observations and 124,028 observations for turkey purchases.

The data were aggregated across consumers to create a monthly times series of per person consumption, expenditure, and retail prices for beef and veal, pork, chicken, and turkey. Summary statistics of these data are displayed in table 1 and plots of the consumption, expenditure, and price series shown in figures 1 through 3, respectively. Per person consumption of each commodity is relatively constant over the sample period. However, turkey displays a dramatic increase in the month of November each year. During the same month, beef consumption drops slightly, indicating the substitution of beef for turkey in November. The large seasonal variation in consumption of turkey is apparent in the monthly consumption data. This variation indicates that quarterly disappearance data for poultry may be masking the strong seasonal effects of turkey versus chicken and supports the estimation of a demand system with separate equations for chicken and turkey.

Food Safety Information

Following Piggott and Marsh, food safety is measured using commodity-specific indices of newspaper articles. Relevant articles were found using the Lexis-Nexis search engine. The article queries were constructed using the keywords *food safety* or *contamination* or *product recall* or *outbreak* or *salmonella* or *listeria* or *E. coli* or *trichinae* or *staphylococcus* or *foodborne*. From these search results, the articles were further queried for commodity-specific information using the search terms *beef* or *hamburger*; *pork* or *ham*; and *chicken*, *turkey*, or *poultry*. These results were aggregated linearly to construct a monthly series of newspaper articles that can be used as a proxy for food safety information available to the public. Summary statistics for each commodity index are shown in table 1.

The indices for beef, pork, and poultry are shown in figure 4. The level of food safety articles is relatively constant during most months, with noticeable spikes in articles for beef in March 2001, December 2003, and January 2004. The large number of articles in March 2001 corresponds to an outbreak of foot and mouth disease in Europe, while the large number of articles in December 2003 and January 2004 are a result of the discovery of a BSE-positive cow in Washington State.

The large spikes in the poultry index in January through February of 2004 and October through November of 2005 correspond to outbreaks of avian influenza in several Asian countries as well as reports of poultry to human infection that was often fatal. There was also a large amount of news articles covering the U.S.'s policy for dealing with avian influenza if it was found in domestic flocks.

The index for pork is made up of much fewer articles, but still displays some spikes in new coverage. These periods of increased food safety are usually correlated with beef and/or poultry events. Despite the absence of a large food safety event specific to pork, the sample period did contain instances of pork products being subject to recalls due to *listeria* and *salmonella*.

Estimation and Results

The empirical model specified in equation (11) assumes weak separability of the meat products beef and veal, pork, chicken, and turkey from all other goods a person consumes. Consumption of each meat product depends on expenditures on the meat group, prices of products within the group, food safety information, and seasonal demand shifters. The models were estimated using iterated non-linear seemingly unrelated regression (ITSUR) estimation techniques. Singularity of the demand system requires one equation to be dropped (turkey) and the other equations estimated (beef, pork, and chicken). Several hypothesis tests were conducted using adjusted likelihood ratio (LR) tests (Bewley). These include testing the joint significance of the food safety variables and any distributed lag effects of food safety information over time. Tests of alternative specifications to correct for autocorrelation were also conducted. All the test statistics reported use a 5% significance level.

Tests for Autocorrelation

Hypothesis tests of various specifications of the **R** matrix are presented in table 2. The three specifications tested were: (1) a null **R** matrix ($N\text{-}R^{matrix}$) with all elements equal to zero, implying no autocorrelation; (2) a diagonal **R** matrix ($D\text{-}R^{matrix}$) with diagonal elements restricted to be equal and off diagonal elements equal to zero, specifying no cross-correlation; and (3) a full **R** matrix (F-R^{matrix}) where all the elements are non-zero (Berndt and Savin). Tests of the different specifications for models with and without food safety variables failed to reject a null hypothesis of no autocorrelation. Therefore, the estimation results discussed below are from models using the N-R^{matrix}.

Food Safety Variables

In order to determine whether food safety information impacts demand, the model was specified with contemporaneous food safety variables (L=0) and without the food safety variables. Likelihood ratio tests of the joint significance of the food safety variables were conducted for each autocorrelation specification and are presented in table 2. In each case, the results indicated a failure to reject the null hypothesis of no food safety variables. This result differs from the Piggott and Marsh study, which found in favor of contemporaneous food safety effects. While the food safety indices used in this study are very similar to those used by Piggott and Marsh, there were differences in the periodicity of the data (monthly versus quarterly) and the sample period analyzed. It appears that the statistical significance of the food safety variables is sensitive to these differences.

Model Estimates

The estimated coefficients from the models with and without food safety variables are listed in table 3. The number of coefficients that are statistically significantly different from zero is similar for the two models, as are the R^2 values for the individual equations. The coefficients for the pre-committed quantities (c_{i0}'s) are all non-negative and statistically significantly different from zero at the 5% level, with the exception of beef. This finding is consistent with the idea that there are subsistence levels of consumption of each meat independent of prices and incomes and any other seasonal influence. The pre-committed quantity estimates from the model without food safety variables are 1.189 pounds per person for pork, 2.368 pounds per person for chicken, and 1.385 pounds per person for turkey.

Most of the coefficients for the seasonal (quarterly) dummy variables are statistically significantly different from zero. The second and third quarter coefficients for turkey are both statistically significant and large in magnitude compared to beef, pork, and chicken. This result fits well with the raw data, which showed a large seasonal fluctuation in turkey consumption with the highest levels occurring in November and December each year of the sample.

The total, pre-committed, and supernumerary quantities for each meat product predicted by the model with no food safety variables are listed in table 4. When compared to the sample mean of monthly pork consumption, shown in table 1, pre-committed purchases make up approximately 75.0% of total consumption. For chicken and turkey, pre-committed purchases are approximately 88.5%, and 63.3% of total consumption. The predicted quantities indicate that pork, chicken, and turkey purchases are predominately pre-committed. However, beef purchases appear to be made primarily from supernumerary expenditures. This result is economically significant because, the pre-committed quantities of pork, chicken, and turkey are not impacted by prices, income, and other demand shifters. However, the supernumerary beef purchases will be impacted by these factors.

Figures 5-8 display the predicted pre-committed quantities for beef, pork, chicken, and turkey, respectively, calculated at each observation. In panel (a) of each figure, the pre-committed quantities are graphed using the constant level of consumption ($c_{i,0}$), which is independent of demand shifters, and the total pre-committed quantities ($\tilde{c}_i$) that are a function of seasonal dummy variables. The constant $c_{i,0}$ quantities measure the level of pre-committed consumption over the sample that is not affected by demand shifters. The $\tilde{c}_i$'s, however, include the seasonal variables and indicate that pre-committed consumption does vary for each of the commodities.

Panel (b) of each figure shows the supernumerary quantities (x_i^*) calculated at each observation. For pork, chicken, and turkey the predicted supernumerary per person consumption is less than a pound for nearly all periods in the sample. The notable exception to this is turkey. It appears that the majority of the turkey purchased from supernumerary expenditures each year is occurring in the months of November and December (i.e., the Thanksgiving and Christmas holidays), while at other times of the year supernumerary turkey consumption is negligible. The majority of beef consumption is predicted to be from supernumerary expenditures. The per person consumption of beef ranges from a high of 2.43 to a low of 1.85, but at all times is significantly higher than the pre-committed quantities. One noticeable feature of the beef supernumerary consumption is the downward trend over the sample period. While the level of total per person consumption of beef appears relatively flat in the graphs of the raw data, as seen in figure 1, retail prices are trending upward (figure 3). Therefore, it seems plausible that the level of supernumerary consumption, which is affected by prices, may be declining in response.

The results for the levels of pre-committed consumption differ from the Piggott and Marsh study in that pre-committed quantities of beef were estimated to be approximately 85.7% of average consumption, with pre-committed quantities of pork and poultry being approximately 57.4% and 53.1%, respectively. One aspect of demand for meat and poultry products that is not measured by the household data used to estimate this model is consumption of food away from home. The aggregate disappearance data used by Piggott and Marsh includes all meat and poultry consumed in restaurants as well as meat bought at the grocery store and prepared at home. Demand for beef, pork, and poultry eaten away from home may be significantly different from consumption of these foods prepared at home, causing the predicted amounts of pre-committed versus supernumerary quantities to differ between the two studies.

The majority of the estimated coefficients of the food safety variables are not statistically significantly different from zero. The only own-food safety coefficient that is statistically significant and has the expected negative sign was beef. This result indicates that higher number of articles on food safety issues regarding beef will decrease demand for beef. The other own-food safety coefficient that is statistically significant is the pork index with a positive, and unexpected, sign.

The sign of the cross-product effect of food safety variables was not clear *a priori*. If the sign is positive, then consumers substitute away from the product with higher numbers of articles and toward the other product. If the sign is negative, this may indicate a "spillover" effect whereby the increased number of articles negatively affects products that are not directly involved in a food safety event. The beef food safety index has a statically significant negative effect on pork demand, while the pork food safety index has a positive effect on pre-committed quantities of turkey. All other cross-product effects were not statistically significantly different from zero.

Elasticities

The sample average estimates of the Marshallian and Hicksian price elasticities, expenditure elasticities, and food safety elasticities are shown in table 5. The elasticities were calculated at every observation and are reported for both the models with and without food safety variables. The elasticities are very similar across the two models. For the model without food safety variables, the Marshallian own-price elasticities are -0.563 for beef, -0.951 for pork, -0.785 for chicken, and -1.460 for turkey. Also listed in table 5 are the percent of observations that satisfy the curvature requirements of a negative semidefinite Slutsky matrix. For both models, 100% of the observations satisfy curvature requirements, indicating the model is consistent with theory.

The direct and total food safety elasticities listed in table 5 are based on the elasticities described in Piggott and Marsh. The direct elasticities measure the demand response of pre-committed quantities to food safety information. For example, the direct elasticity for the beef food safety index (bf_t) measures the percentage change in the pre-committed quantities of the ith good from a 1% increase in the index. The total elasticity measures the percentage change in total quantity demanded of the ith good to a 1% change in the beef food safety index and is a share-weighted sum of the direct and indirect elasticity.

The coefficients of the food safety variables were not jointly statistically significantly different from zero. However, it is still useful to consider the economic significance of the food safety elasticities, especially relative to the influence of price effects. The elasticities of each food safety variable may also provide information because some of this variables were individually statistically significantly different from zero. The magnitudes of the direct and total food safety elasticities are noticeably smaller than most of the price and expenditure elasticities, suggesting that price and expenditure effects have a greater impact on consumers' purchase decisions. The elasticity of the beef index with respect to pre-committed quantities of beef has the expected negative sign and is one of the impacts that was individually statistically significantly different from zero. The elasticity indicates that a 1.9% decline in pre-committed beef quantities would occur from a 10% increase in the beef food safety index. The food safety indices for pork and poultry also have a negative effect on pre-committed quantities of beef. The own- and cross-effect elasticities of all the other commodities are positive.

The signs of the total elasticities do not necessarily correspond with those of the direct elasticities. The total elasticities measure both the direct food safety effect on pre-committed quantities as well as an indirect effect. This indirect effect accounts for reallocation of pre-committed expenditure and the supernumerary expenditure effect. For example, an increase in a food safety index can cause a reallocation of expenditure from pre-committed to supernumerary and, subsequently, an expenditure effect on supernumerary quantities. The total elasticities vary in sign for the own- and cross-commodity effects of the beef, pork, and poultry food safety indices. The total elasticity of the beef food safety index with respect to beef quantity is negative and indicates a 0.04% decline in overall beef quantity demanded from a 10% increase in the beef food safety index. This total effect is much smaller than the direct effect of -1.9%, suggesting strong indirect effects on the supernumerary beef quantities. This result seems reasonable given the large magnitude of the predicted supernumerary quantities demanded relative to the pre-committed quantity of beef. The total impacts of the pork and poultry food safety indices on beef consumption are less negative than the direct effects. This is a result of the indirect supernumerary effect on beef quantity demanded being positive and offsetting some or all of the negative effect on pre-committed quantities.

The total impact on pork and chicken quantities demanded from each of the food safety indices is smaller in magnitude, or in some cases negative, as compared to the positive direct effect. For these commodities, the supernumerary effect is negative and causes the total effect of an increase in the food safety indices of beef, pork, and poultry to decrease total quantity demanded of pork and chicken. As noted previously, however, the magnitudes of all the food safety elasticities are small and given the lack of joint statistical significance of the estimated coefficients of the food safety variables may not provide much economic insight.

Conclusion

The potential impacts of a food safety event on consumer demand for meat and poultry is of significant concern to meat and poultry producers, packers, processors, retail businesses, and the USDA. Estimates of the magnitude of consumer response, as well as the length of time that demand is impacted by information about a food safety event gives these groups important information that can be used to plan for and respond to possible future events.

Previous research by Piggott and Marsh used aggregate-level quarterly data to investigate these impacts. Their results indicated a statistically significant impact, although small in magnitude and relatively short-lived. This study extends their work by using household level data aggregated to the commodity level for beef, pork, chicken, and turkey. The data are aggregated to a monthly series and provide an opportunity to investigate whether food safety effects might be stronger over shorter time periods.

Results from estimation of the demand model indicate that consumers have relatively high levels of pre-committed quantities of pork, chicken, and turkey. However, beef consumption appears to be primarily from supernumerary expenditures. The estimated coefficients for the food safety variables are not jointly statistically significant in explaining the quantity of meat and poultry demanded. These results are in direct contrast to the Piggott and

Marsh study, where high levels of beef quantities were predicted to be pre-committed and food safety variables had some (although small and short-lived) explanatory power.

The lack of robustness across alternative approaches reveals and highlights that inferences concerning food safety impacts on demand may be fragile to the consumption data employed (aggregate versus household panel), the periodicity employed (monthly versus quarterly) , or other auxiliary hypotheses used in estimation. The distinction between household panel data, and its perceived richness, versus aggregate disappearance data are well known and understood. However, the way in which these differences impact inference and estimated economic effects is not. As discussed in the paper, the use of household panel data resulted in an underlying demand system that was consistent with theory with curvature satisfied globally and non-negative pre-committed and supernumerary quantities. While this result is extremely encouraging, this same model was unable to verify and confirm previous findings concerning the impact of food safety information on demand.

Other auxiliary hypotheses between the studies, which could shed light on the differences, involve our use of a model where the demand for chicken and turkey are estimated separately rather than as a poultry commodity. The statistically significant coefficients for the dummy variables were large in magnitude relative to beef, pork, and chicken and indicate that a poultry aggregate may mask strong seasonal fluctuation in turkey consumption. The time period analyzed in our study only overlaps the Piggott and Marsh data by two years. As a result, there may be differences in the relative magnitude or frequency of food safety events occurring during the two sample periods being analyzed that could affect the explanatory power of the food safety variables in the model.

Table 1. Summary Statistics of Monthly Data[a]

Variable	Average	Std. Dev.	Minimum	Maximum
Year	2002	2.303	1998	2005
Month	6.500	3.470	1	12
Beef expenditure share	0.387	0.023	0.312	0.425
Pork expenditure share	0.214	0.012	0.187	0.241
Chicken expenditure share	0.223	0.012	0.186	0.238
Turkey expenditure share	0.176	0.035	0.142	0.281
Retail beef price ($/lb)	2.604	0.375	1.987	3.394
Retail pork price ($/lb)	2.229	0.149	1.806	2.482
Retail chicken price ($/lb)	1.382	0.150	0.995	1.613
Retail turkey price ($/lb)	1.455	0.238	0.768	1.870
Beef consumption (lbs/capita)	2.475	0.147	2.100	2.855
Pork consumption (lbs/capita)	1.585	0.129	1.360	1.914
Chicken consumption (lbs/capita)	2.674	0.226	2.261	3.381
Turkey consumption (lbs/capita)	2.187	1.154	1.219	5.802
Meat expenditure ($/capita)	16.540	1.545	14.081	21.012
Beef food safety	154.740	100.830	56.000	724.000
Pork food safety	53.042	39.323	19.000	333.000
Poultry food safety	201.698	109.830	98.000	738.000

[a] Sample size equals 96 observations.

Table 2. Hypothesis Tests for Significance of Food Safety Variables and Autocorrelation Variables

	Autocorrelation Corrections			Lag Length for Food Safety	
	H_0: N-R^{matrix} H_a: D-R^{matrix}	H_0: D-R^{matrix} H_a: F-R^{matrix}	H_0: N-R^{matrix} H_a: F-R^{matrix}		H_0: No-FS H_a: $L = 0$
Model				*Model*	
No-FS	1.309	8.521	9.789	N-R^{matrix}	7.899
$L = 0$	1.140	7.774	8.876	D-R^{matrix}	7.760
				F-R^{matrix}	7.171
df	1	3	4	*df*	12
$\chi_{0.5,df}$	3.841	15.510	16.920	$\chi_{0.5,df}$	21.030

Table 3. Estimated Coefficients for the GAIDS Model with and without Food Safety Information Variables

Coefficient	No Food Safety N-R^{matrix}	With Food Safety N-R^{matrix}
δ	-0.161	-0.006
	(3.331)	(2.609)
α_b	1.302	1.359
	(1.046)	(0.928)
α_p	0.097	0.031
	(0.266)	(0.290)
α_c	-0.099	-0.156
	(0.201)	(0.210)
γ_{bb}	-0.251	-0.309
	(0.368)	(0.369)
γ_{bp}	0.001	0.052
	(0.101)	(0.122)
γ_{bc}	0.073	0.100
	(0.085)	(0.094)
γ_{pp}	-0.213	-0.279*
	(0.112)	(0.129)
γ_{pc}	0.113*	0.116*
	(0.039)	(0.037)
γ_{cc}	-0.263*	-0.298*
	(0.121)	(0.124)
β_b	-0.429*	-0.491*
	(0.154)	(0.145)
β_p	0.118	0.162*
	(0.082)	(0.079)
β_c	0.049	0.074
	(0.063)	(0.063)
c_{b0}	0.472	0.348
	(1.066)	(1.061)
c_{p0}	1.189*	1.356*
	(0.260)	(0.248)
c_{c0}	2.368*	2.491*
	(0.380)	(0.357)
c_{t0}	1.385*	1.392*
	(0.267)	(0.253)
θ_{b1}	0.073	0.062
	(0.058)	(0.055)
θ_{b2}	-0.023	-0.034
	(0.056)	(0.052)
θ_{b3}	-0.131*	-0.148*
	(0.045)	(0.043)
θ_{p1}	-0.035	-0.051
	(0.057)	(0.049)
θ_{p2}	-0.099	-0.111*
	(0.056)	(0.048)
θ_{p3}	-0.178*	-0.182*
	(0.067)	(0.064)

Note: Numbers in parentheses are the estimated standard errors and a * denotes coefficients that are statistically significantly different from zero at the 5% level.

Table 3. Estimated Coefficients for the GAIDS Model with and without Food Safety Information Variables, cont.

	No Food Safety		With Food Safety
Coefficient	N-R^{matrix}		N-R^{matrix}
θ_{c1}	0.017		0.018
	(0.042)		(0.038)
θ_{c2}	-0.072		-0.073*
	(0.044)		(0.039)
θ_{c3}	-0.105*		-0.106*
	(0.049)		(0.048)
θ_{t1}	-0.090		-0.109
	(0.126)		(0.112)
θ_{t2}	-0.238*		-0.258*
	(0.122)		(0.107)
θ_{t3}	-0.459*		-0.465*
	(0.174)		(0.166)
φ_{b0}	--	--	-3.80E-04*
			(1.71E-04)
φ_{p0}	--	--	-4.10E-04
			(2.11E-04)
φ_{c0}	--	--	-1.60E-04*
			(1.63E-04)
φ_{t0}	--	--	-7.60E-04
			(5.19E-04)
π_{b0}	--	--	1.09E-03
			(8.46E-04)
π_{p0}	--	--	1.55E-03
			(6.71E-04)
π_{c0}	--	--	5.34E-04
			(4.95E-04)
π_{t0}	--	--	2.48E-03
			(1.41E-03)
κ_{b0}	--	--	7.40E-05
			(1.02E-04)
κ_{p0}	--	--	3.05E-06
			(1.48E-04)
κ_{c0}	--	--	1.32E-04
			(1.09E-04)
κ_{t0}	--	--	5.70E-05
			(3.78E-04)
LL	685.920		690.534
R^2 beef	0.847		0.858
R^2 pork	0.705		0.718
R^2 chicken	0.790		0.797
DW beef	2.125		2.142
DW pork	1.591		1.652
DW chicken	1.903		1.912

Note: Numbers in parentheses are the estimated standard errors and a * denotes coefficients that are statistically significantly different from zero at the 5% level.

Table 4. Predicted Quantities Demanded for Models with and without Food Safety Information Variables

	No Food Safety			With Food Safety		
	Total	**Pre-Committed**	**Supernumerary**	**Total**	**Pre-Committed**	**Supernumerary**
Beef	2.471	0.452	2.020	2.471	0.332	2.140
	(0.145)	(0.074)	(0.120)	(0.145)	(0.086)	(0.120)
Pork	1.586	1.110	0.476	1.586	1.290	0.296
	(0.129)	(0.068)	(0.126)	(0.129)	(0.081)	(0.125)
Chicken	2.668	2.327	0.341	2.668	2.481	0.187
	(0.219)	(0.051)	(0.216)	(0.219)	(0.056)	(0.220)
Turkey	--	1.186	1.011	--	1.207	0.990
	--	(0.174)	(1.210)	--	(0.188)	(1.212)

Note: Numbers in parentheses are the estimated standard errors.

Table 5. Estimated Price, Expenditure, and Food Safety Elasticities for Models with and without Food Safety Information Variables

Variable	No Food Safety		With Food Safety	
	Average	Std. Dev.	Average	Std. Dev.
Marshallian Price				
η_{bb}	-0.563	0.034	-0.575	0.038
η_{bp}	-0.096	0.033	-0.093	0.050
η_{bc}	-0.030	0.051	-0.039	0.065
η_{bt}	0.072	0.095	0.062	0.105
η_{pb}	-0.386	-0.030	-0.362	0.032
η_{pp}	-0.951	0.072	-0.961	0.150
η_{pc}	0.026	-0.386	0.024	0.047
η_{pt}	0.139	0.026	0.148	0.047
η_{cb}	0.003	0.019	0.001	0.018
η_{cp}	0.173	0.059	0.167	0.064
η_{cc}	-0.785	0.109	-0.776	0.131
η_{ct}	0.129	0.041	0.133	0.040
η_{tt}	-1.460	0.193	-1.452	0.212
Expenditure				
η_{bM}	0.616	0.192	0.645	0.234
η_{pM}	1.172	0.088	1.152	0.125
η_{cM}	0.480	0.130	0.475	0.143
η_{tM}	2.264	0.189	2.228	0.208
Hicksian Price				
ε_{bb}	-0.322	0.051	-0.322	0.065
ε_{bp}	0.037	0.022	0.046	0.021
ε_{bc}	0.109	0.025	0.107	0.029
ε_{bt}	0.176	0.073	0.170	0.075
ε_{pb}	0.068	0.039	0.084	0.040
ε_{pp}	-0.702	0.106	-0.716	0.134
ε_{pc}	0.287	0.041	0.279	0.049
ε_{pt}	0.347	0.087	0.353	0.091
ε_{cb}	0.189	0.038	0.185	0.046
ε_{cp}	0.276	0.045	0.269	0.052
ε_{cc}	-0.678	0.100	-0.670	0.117
ε_{ct}	0.212	0.043	0.216	0.045
ε_{tb}	0.374	0.082	0.360	0.090
ε_{tp}	0.417	0.051	0.424	0.060
ε_{tc}	0.268	0.034	0.272	0.040
ε_{tt}	-1.059	0.135	-1.056	0.152

Notes: P_{NSD} is the percentage of observations that satisfy the curvature requirements of negative semi-definiteness of the Slutsky matrix. Estimates shown are the sample means of the elasticities computed at every data point using predicted expenditure shares.

Table 5. Estimated Price, Expenditure, and Food Safety Elasticities for Models with and without Food Safety Information Variables, cont.

	No Food Safety		With Food Safety	
Variable	Average	Std. Dev.	Average	Std. Dev.
Food Safety Direct Effect				
$\omega_{b,bf}$	--	--	-0.190	0.127
$\omega_{b,pk}$	--	--	-0.048	0.030
$\omega_{b,py}$	--	--	-0.010	0.006
$\omega_{p,bf}$	--	--	0.177	0.094
$\omega_{p,pk}$	--	--	0.063	0.041
$\omega_{p,py}$	--	--	0.011	0.008
$\omega_{c,bf}$	--	--	0.048	0.030
$\omega_{c,pk}$	--	--	4.76E-04	2.66E-04
$\omega_{c,py}$	--	--	0.011	0.006
Food Safety Total Effect				
$\psi_{b,bf}$	--	--	-0.004	0.011
$\psi_{b,pk}$	--	--	-0.005	0.007
$\psi_{b,py}$	--	--	0.005	0.006
$\psi_{p,bf}$	--	--	-0.001	0.012
$\psi_{p,pk}$	--	--	0.013	0.013
$\psi_{p,py}$	--	--	-0.005	0.006
$\psi_{c,bf}$	--	--	0.002	0.003
$\psi_{c,pk}$	--	--	-0.006	0.004
$\psi_{c,py}$	--	--	0.007	0.004
P_{NSD}	100.000		100.000	

Notes: P_{NSD} is the percentage of observations that satisfy the curvature requirements of negative semi-definiteness of the Slutsky matrix. Estimates shown are the sample means of the elasticities computed at every data point using predicted expenditure shares.

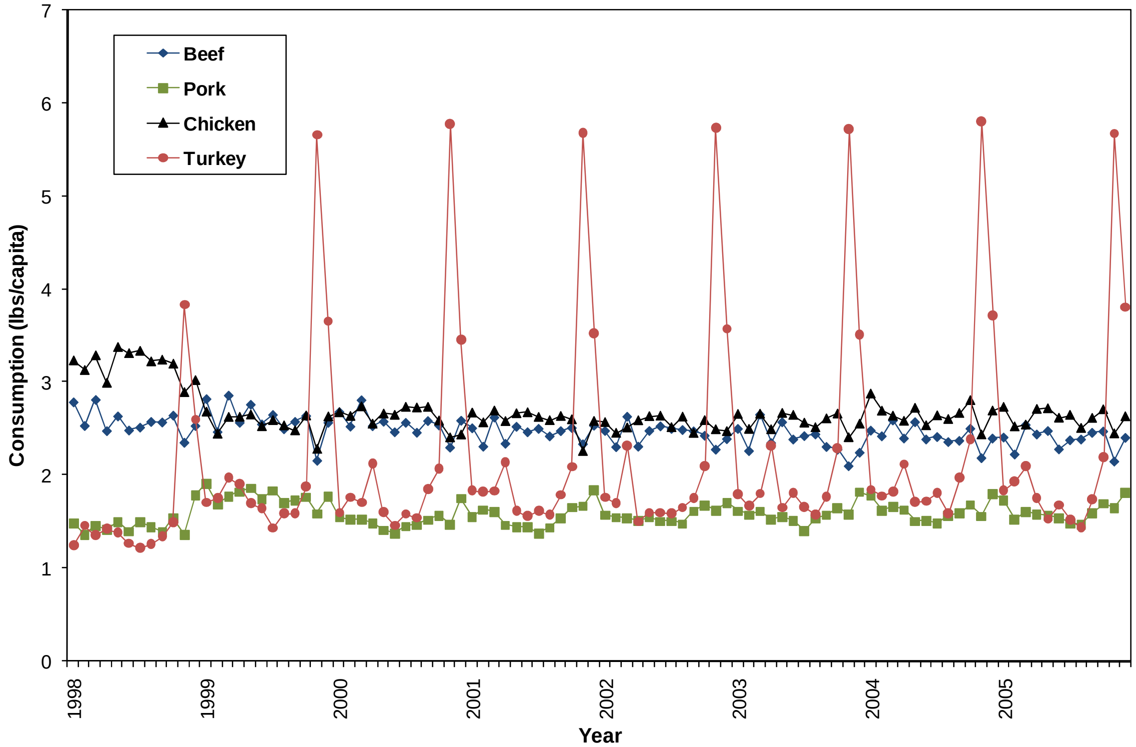

Figure 1. Monthly per person consumption of beef, pork, chicken, and turkey, 1998 to 2005

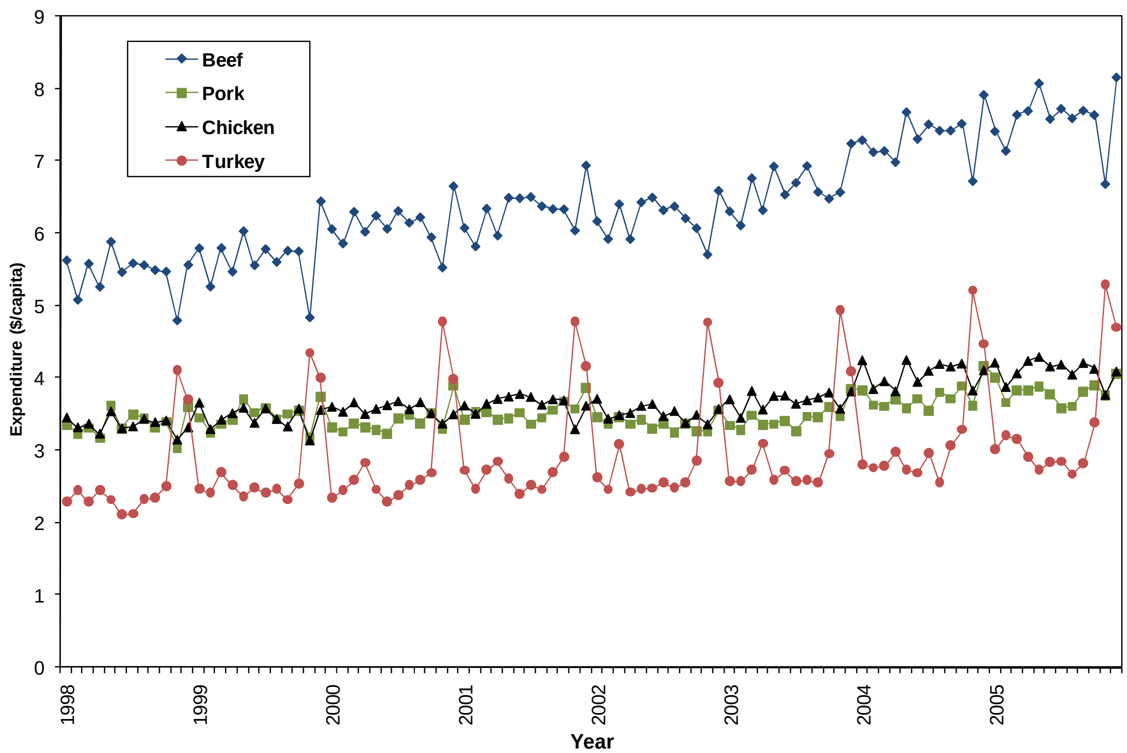

Figure 2. Monthly per person expenditure on beef, pork, chicken, and turkey, 1998 to 2005

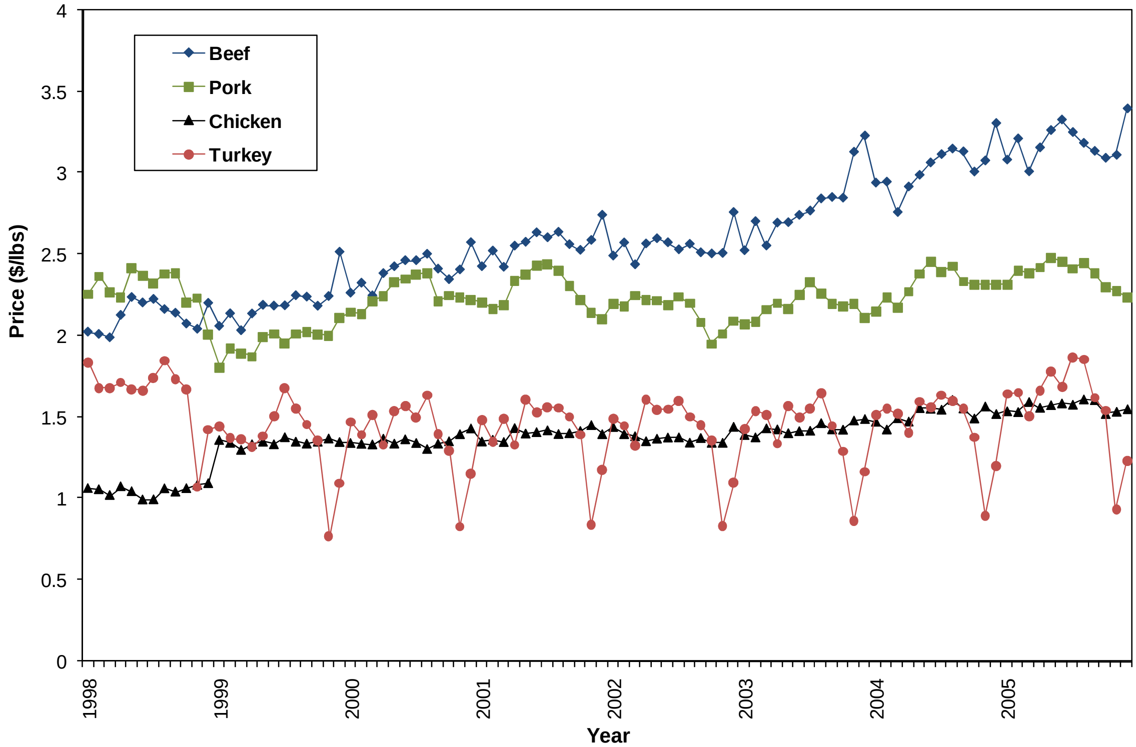

Figure 3. Retail price of beef, pork, chicken, and turkey, 1998 to 2005

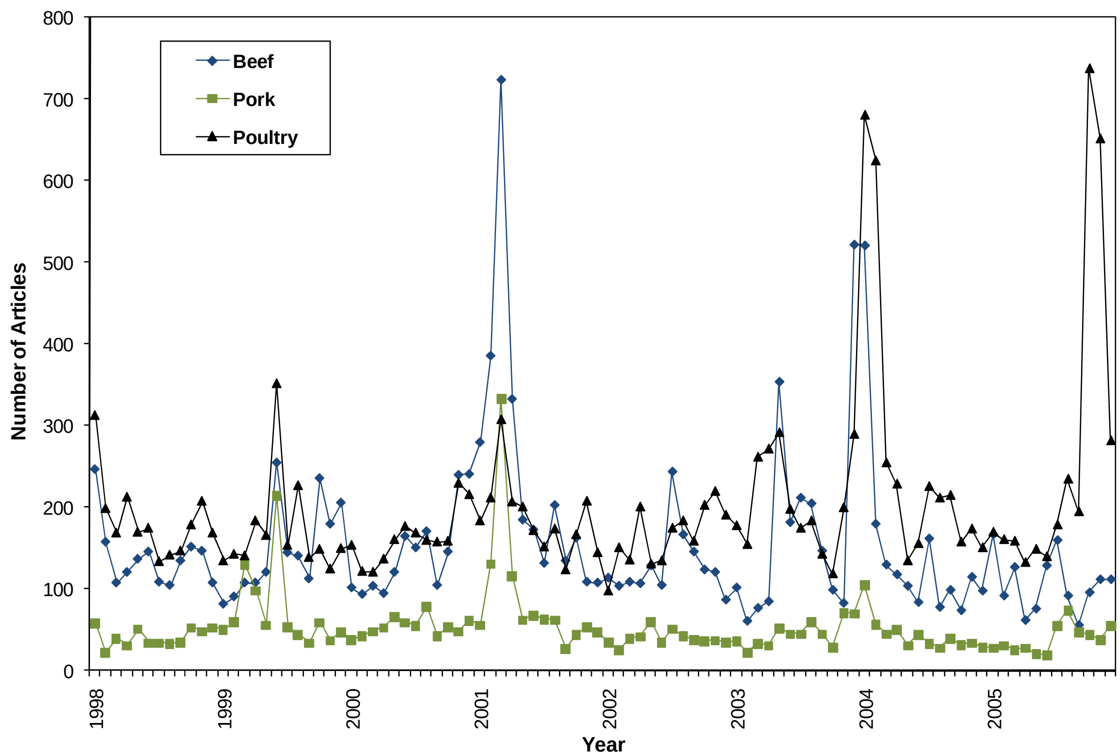

Figure 4. Beef, pork, and poultry food safety articles, 1998 to 2005

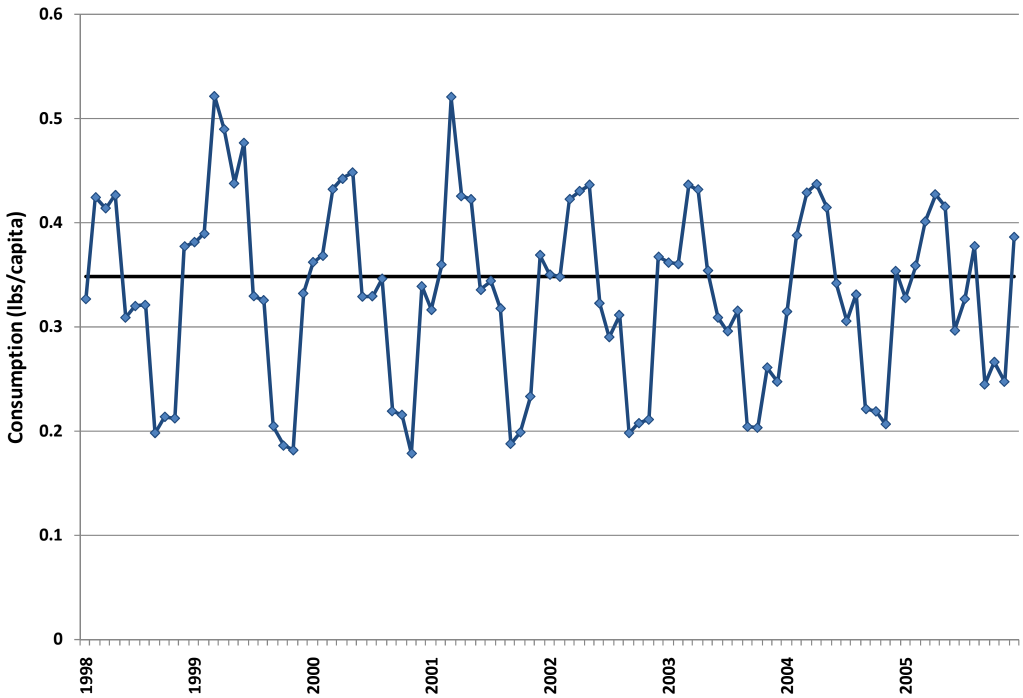

Figure 5a. Predicted pre-committed monthly per person quantities of beef

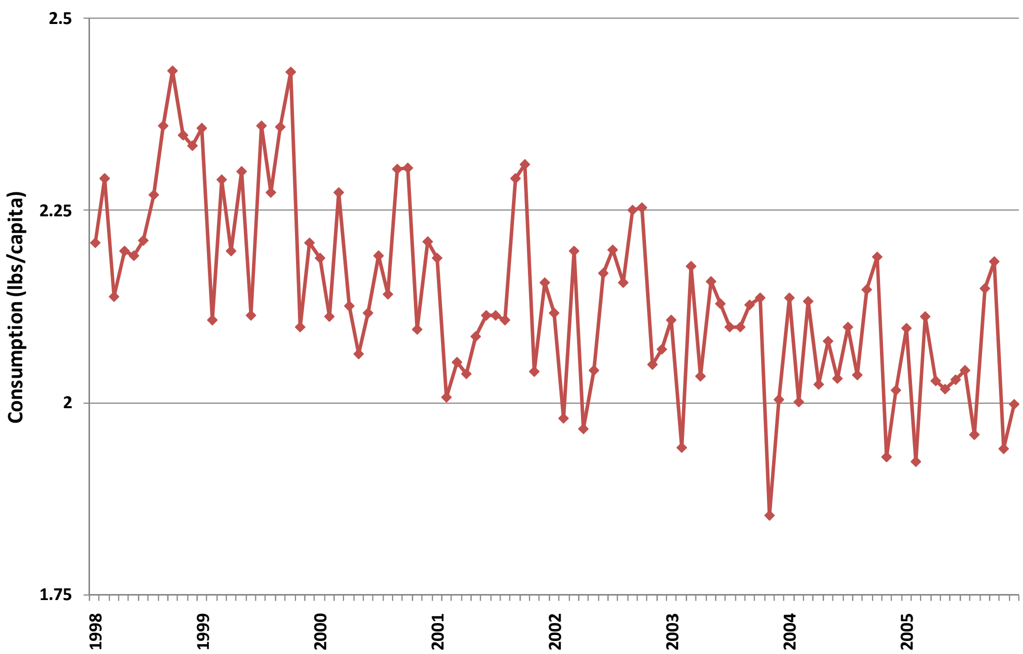

Figure 5b. Predicted supernumerary monthly per person quantities of beef

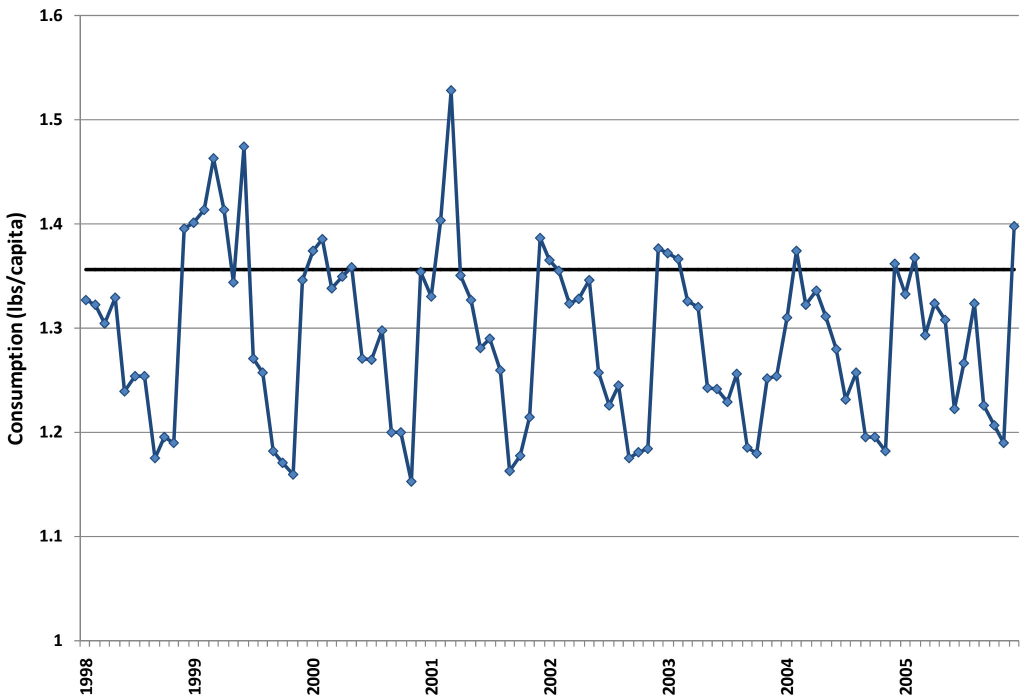

Figure 6a. Predicted pre-committed monthly per person quantities of pork

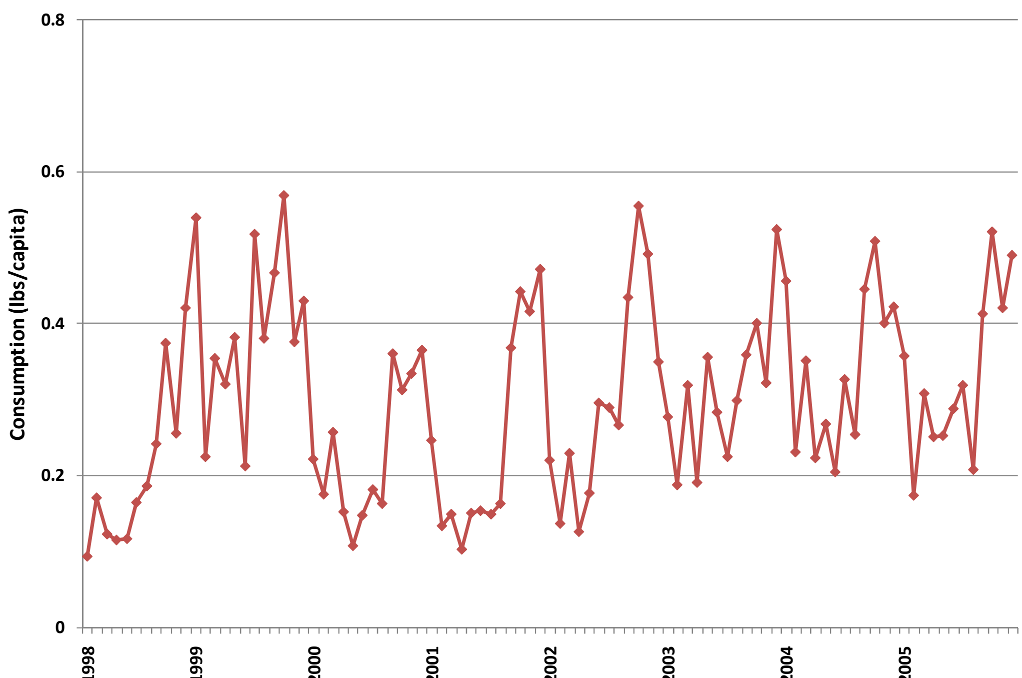

Figure 6b. Predicted supernumerary monthly per person quantities of pork

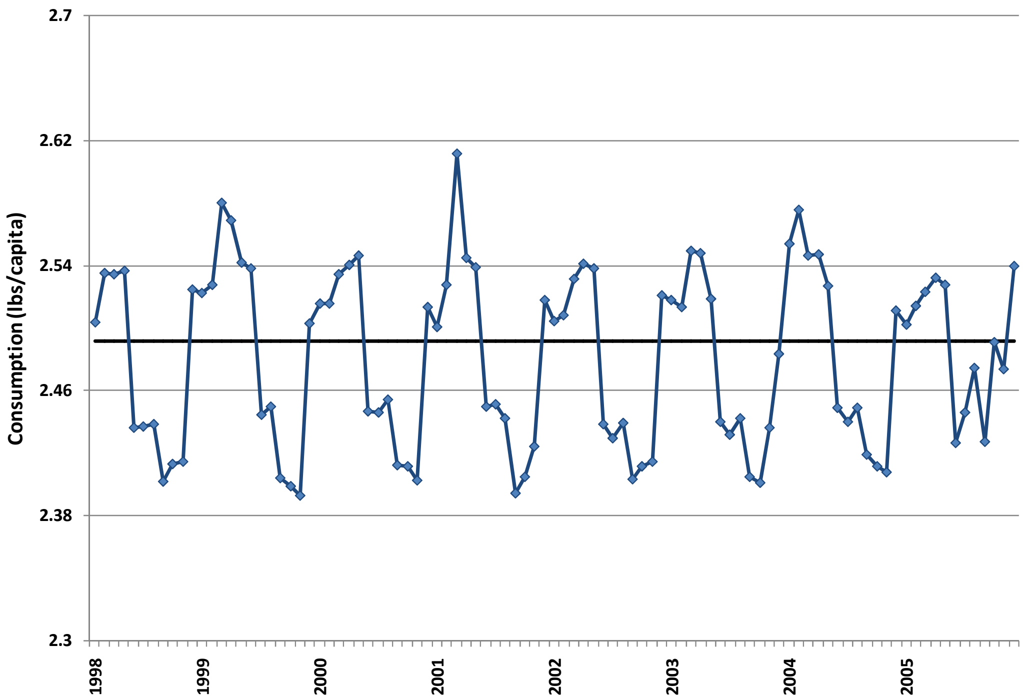

Figure 7a. Predicted pre-committed monthly per person quantities of chicken

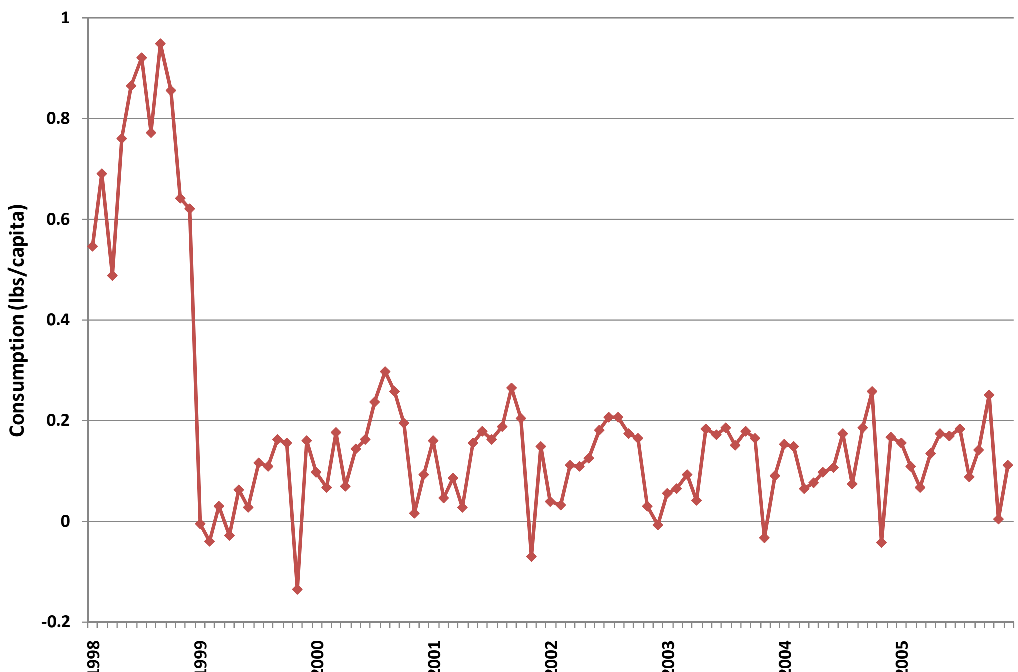

Figure 7b. Predicted supernumerary monthly per person quantities of chicken

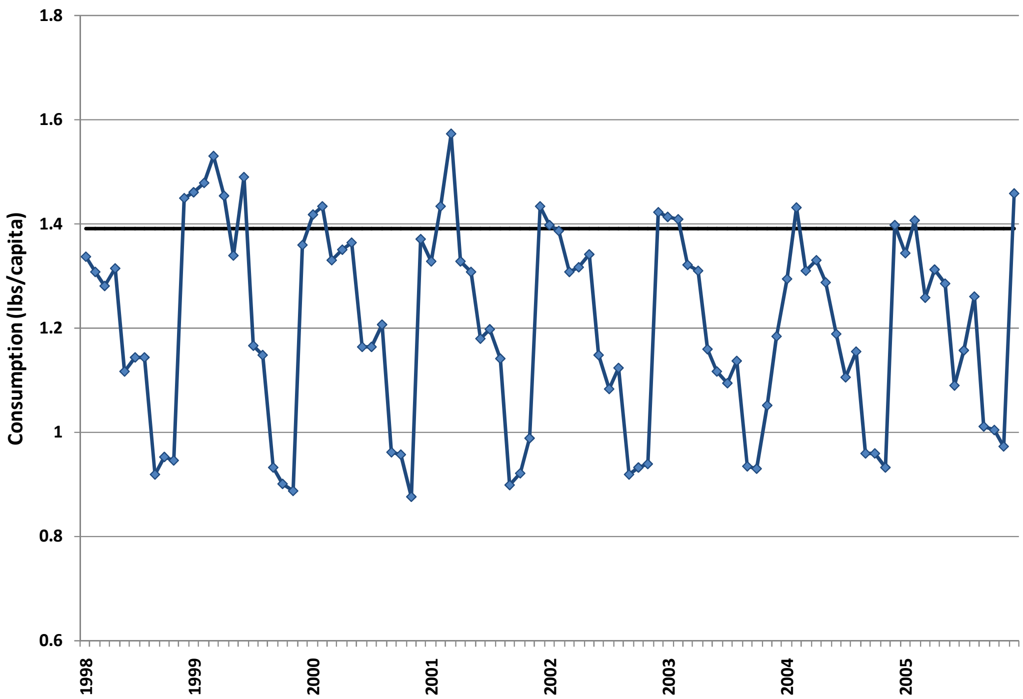

Figure 8a. Predicted pre-committed monthly per person quantities of turkey

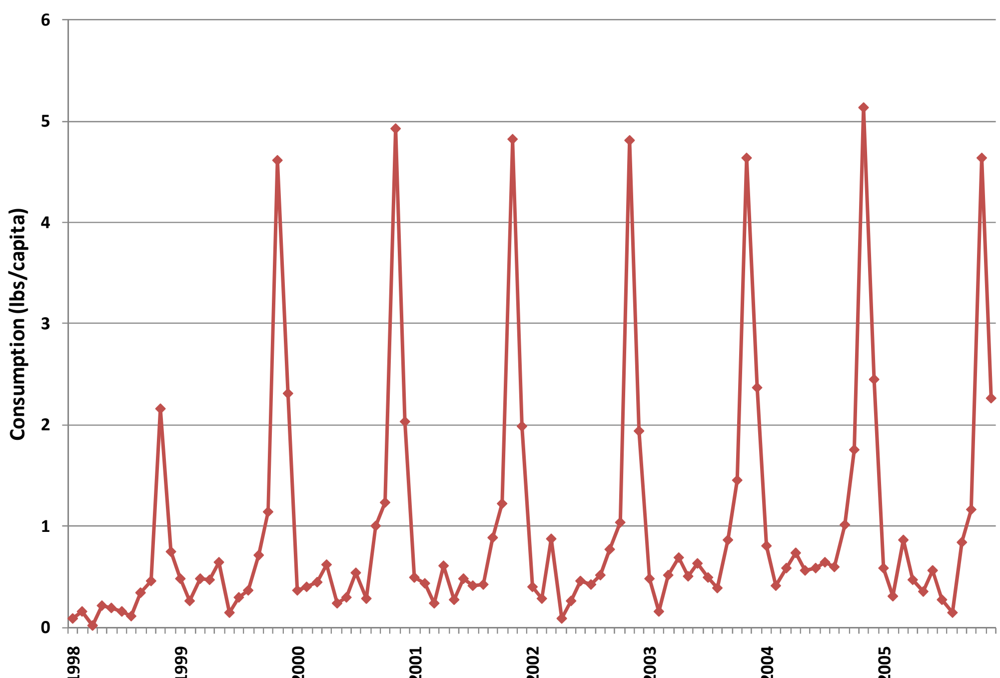

Figure 8b. Predicted supernumerary monthly per person quantities of turkey

References

Berndt, E.R., and N.E. Savin. 1975. "Evaluation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances." *Econometrica* 43(5-6):937-957.

Bewley, R. *Allocation Models: Specification, Estimation, and Applications*. Cambridge, MA: Ballinger, 1986.

Bollino, C.A. "GAIDS: A Generalized Version of the Almost Ideal Demand System." *Economic Letters* 33(1990): 127-29.

Brown, J. "Effect of a Health Hazard "Scare" on Consumer Demand." *American Journal of Agricultural Economics*. 51(1969): 676-678.

Burton, M. and T. Young. "The Impact of BSE on the Demand for Beef and Other Meats in Great Britain." *Applied Economics*. 28(1996): 687-693.

Dahlgran, R. and D. Fairchild. "The Demand Impacts of Chicken Contamination Publicity: A Case Study." *Agribusiness*. 18(2002): 459-474.

Deaton, A.S. and J. Muellbauer. "An Almost Ideal Demand System." *American Economic Review* 70(1980): 312-26.

Kuchler, F. and A. Tegene. "Did BSE Announcements Reduce Beef Purchases?" Economic Research Report, No. 34, Economic Research Service, December, 2006.

Piggott, N. and T. Marsh. "Does Food Safety Information Impact U.S. Meat Demand?" *American Journal of Agricultural Economics.* 86(2004): 154-174.

Pollak, R.A. and T.J. Wales. "Demographic Variables in Demand Analysis." *Econometrica* 49(1981): 1533-51.

Smith, M., E. van Ravenswaay, and S. Thompson. "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii." *American Journal of Agricultural Economics*. 70(1988): 513-520.