DOES FOOD SAFETY INFORMATION IMPACT U.S. MEAT DEMAND?

NICHOLAS E. PIGGOTT AND THOMAS L. MARSH

A theoretical model of consumer response to publicized food safety information on meat demand is developed with an empirical application to U.S. meat consumption. Evidence is found for the existence of pre-committed levels of consumption, seasonal factors, time trends, and contemporaneous own- and cross-commodity food safety concerns. The average demand response to food safety concerns is small, especially in comparison to price effects, and to previous estimates of health related issues. This small average effect masks periods of significantly larger responses corresponding with prominent food safety events, but these larger impacts are short-lived with no apparent food safety lagged effects on demand.

Key words: food safety information, demand system, U.S. meat demand.

Food safety concerns in the United States have dramatically increased in the past decade with regard to incidences of contaminated meat products. Concerns have arisen because contaminated meat products can result in serious risk to the well being and health of consumers. Contamination comes from a myriad of sources, including but not limited to, outbreaks of *Listeria monocytogenes*, *Escherichia coli* (E. coli), and *Salmonella* (Centers for Disease Control and Prevention). Food safety problems are not isolated to the United States as other unsafe contaminates in meats have emerged across the world, including highly publicized outbreaks of *Bovine Spongiform Encephalopathy* (BSE) in Europe. The potential impacts of publicized food safety events on consumer's demand for meat products in the United States include own-effects on the demand for the contaminated meat involved as well as cross-effects impacting the demand for other meats. The objective of this article is to investigate whether publicized food safety concerns surrounding beef, pork, and poultry (chicken and turkey) have impacted meat consumption. Food safety indices are constructed separately for beef, pork, and poultry allowing for the investigation of separate own- and cross-commodity impacts from food safety concerns.

Investigating the impact of food safety information reported in the media and product recall information on demand for food and agricultural markets has been a topic of considerable interest to economists, such as Brown; Johnson; Smith, van Ravenswaay, and Thompson; van Ravenswaay and Hoehn; Robenstein and Thurman; Lusk and Schroeder; McKenzie and Thomsen; Thomsen and McKenzie; and Dahlgran and Fairchild. Public information pertaining to food safety and health concerns through the media have previously been shown to affect demand, for example, van Ravenswaay and Hoehn; Smith, van Ravenswaay, and Thompson; and Dahlgran and Fairchild. Several of these studies have been concerned with the U.S. meat market and analyzing how public information concerning health information and product recalls impact futures markets and publicly traded companies. Robenstein and Thurman found no discernible impact on daily red meat futures prices from negative health information surrounding consumption of red meat. Lusk and Schroeder found that beef and pork recalls have only a marginal impact on daily live cattle and lean hogs futures prices. This scenario was supported by the results of Thomsen and McKenzie that Class 1 recalls translate into losses to shareholders of public meat and poultry processing firms reducing wealth by 1.5–3%. Although the latter study was not

---

Nicholas E. Piggott is associate professor, Department of Agricultural and Resource Economics, North Carolina State University, and Thomas L. Marsh is associate professor, Department of Agricultural Economics, Kansas State University.

The authors wish to acknowledge the useful input of Kerry Smith and editor Ian Sheldon on earlier drafts of this paper and partial financial support from the President's Faculty Development Award, Kansas State University.

Amer. J. Agr. Econ. 86(1) (February 2004): 154–174

concerned with the effect on demand explicitly, the estimated reduction in shareholder wealth is consistent with the market anticipating an adverse impact. Dahlgran and Fairchild found that adverse publicity about *salmonella* contamination of chicken depressed demand for chicken, but the effects were small, less than 1%, with consumer's soon forgetting this adverse publicity and reverting back to previous consumption levels.

Previous studies have investigated the impact of food safety on meat demand using a single-index for food safety information. For instance, Burton and Young, as well as Burton, Young, and Cromb, focused on the effects of food safety on meat demand in England using a single-index based on the number of newspaper articles generated about BSE. Flake and Patterson focused on the effect of a single food safety index on meat demand in the United States constructed from the number of Associated Press articles on E. coli, salmonellosis, and BSE. Reported results suggest that the effects of food safety on U.S. meat demand were modest and dominated by factors related to health information. These studies investigated the food safety hypothesis using a single food safety index constructed from journal articles and the popular press to reflect consumer information specific to the selected contaminant(s). In contrast, the basic hypothesis of this current research is to investigate consumer response to information about *bundles* of contaminants reported *individually* for beef, pork, and poultry based on a comprehensive list reported by the United States Department of Agriculture (USDA) Food Safety Inspection Service (FSIS).[1]

The current article contributes to the economic and empirical literature related to food safety in several ways. An economic model of consumer response is specified that links public food safety information to quality, allowing for the possibility of separate own- and cross-commodity effects from food safety information. Food safety impacts are decomposed into direct and indirect impacts for pre-committed and total levels of meat consumption. The direct and indirect effects delineate between a pure food safety effect, independent of prices and income, and an indirect expenditure effect, respectively, that comprise the total effect on demand. Also provided are several empirical contributions. Constructing original food safety indices for beef, pork, and poultry allows for a comprehensive economic analysis of the own- and cross-effects from food safety events. Results indicate food safety indices provide statistically significant own- and cross-effects on meat demand and that autocorrelation disappears with the inclusion of food safety variables. The economic significance of the demand response to food safety information being found to be small provides several meaningful messages for policy-makers.

The remainder of the article is organized as follows. The next section specifies a theoretical model of consumer response to food safety information. The prevailing pattern of U.S. meat consumption and details of food safety indices are discussed. Attention then turns to the consumer demand model and specification issues including functional form and incorporating food safety indices. Next, hypothesis tests concerning the statistical significance of the food safety impacts on meat demand and model specification are reported. Estimated economic effects including price, expenditure, and food safety elasticities are then discussed. Finally, the article closes with some concluding remarks concerning the impact that food safety concerns have had on U.S. meat demand and suggestions for further research.

Theoretical Model of Consumer Response to Food Safety Information

Let **r** be a vector of public information indexing food safety concerns related to meat, where r_k represents an index associated with the kth meat. This public information may include food recalls of contaminated meat or other issues relating to safety concerns such as BSE. We maintain that **r** represents a measure for meat quality (**q**), with larger (smaller) values of r_k reflecting lower (higher) quality q_k of the kth meat type, that is, $\mathbf{q} = q(\mathbf{r})$ where $\frac{\partial q_k}{\partial r_k} < 0$ and $\frac{\partial q_k}{\partial r_j} = 0 \forall k \neq j$.[2,3] For simplicity

---

[1] Testing consumer response to a bundle of contaminants has justification. For example, Hayes et al. observed that the average value of risk reduction did not vary with the magnitude of risk reduction, regardless of elicitation method (contingent valuation survey or experimental auction) and type of risk (pesticide residues or microbial pathogens).

[2] Crafton, Hoffer, and Reilly argued that consumers perceive automobile product recalls as a proxy for low quality. In this research it is maintained that food safety information, which includes product recalls as a subset, is also a proxy for low quality. Hooker and Caswell, as well as Mojduszka and Caswell, also define food safety to be an attribute of product quality.

[3] The presence of uncertainty surrounding quality, whether a consumer might actually be exposed to a contaminated product, or the possibility that some risk mitigating measures may be undertaken, e.g., thorough cooking, are both factors that may impact the

neither dynamic affects associated with **r**, that is, lagged values, nor cross-commodity impacts between food quality and safety concerns are specified in the theoretical model. These restrictions are relaxed in the empirical section of the article. To conform with previous economic literature, we first formulate and discuss the consumer's maximization problem in terms of meat quality and then link these results to the food safety indices.

Let the consumer's utility function be represented by $U(\mathbf{x}, \mathbf{q})$ where $\mathbf{x}$ is the vector of the quantity of meat consumed. Plausible assumptions include $U_{x_i} > 0$, $U_{q_i} > 0$, $U_{x_i q_i} > 0$, $U_{x_i q_i q_i} < 0 \, \forall i$ and concavity of U with respect to $\mathbf{x}$.[4] The utility maximization problem under the assumption that expenditure on meat is weakly separable from expenditures on other goods is

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

where λ is the Lagrange multiplier, M is total expenditure on meat, and $\mathbf{p}$ is the vector of prices. The solution of the first order conditions (FOC) gives the Marshallian demands $\mathbf{x}^m(\mathbf{p}, M, \mathbf{q})$. The dual cost minimization problem can be expressed as

$$(2) \qquad \min_{\mathbf{x},\mu} \mathbf{p}'\mathbf{x} + \mu(u - U(\mathbf{x}, \mathbf{q}))$$

where μ is the Lagrange multiplier. Here, the solution of the FOC yields the Hicksian demands $\mathbf{x}^h(\mathbf{p}, u, \mathbf{q})$. These dual relationships provide the framework for discussing comparative static behavior of the consumer motivating the empirical section of the paper.

We wish to investigate how changes in meat quality impact demand for meat, that is, $\frac{\partial x_i^m}{\partial q_k}$. Of particular interest is whether the initial assumptions concerning U are sufficient to sign comparative static relationships unambiguously or whether more stringent assumptions are necessary. Differentiating the FOC in (1) with respect to q_k provides the Marshallian effect from a change in quality of the kth good. Conveniently, the Marshallian effect on the demand for the ith good, x_i, from a change in quality of the kth good, q_k, can be shown to be expressed as (Barten, p. 37, Bockstael and McConnell, p. 1245)

$$(3) \qquad \frac{\partial x_i^m}{\partial q_k} = -\left(\frac{1}{\lambda}\right) \sum_{j=1}^{N} \left(\frac{\partial x_i^h}{\partial p_j}\right) U_{x_j q_k}.$$

Equation (3) proves useful in identifying several conditions under which it is possible to sign the comparative static $\frac{\partial x_i^m}{\partial q_k}$. First, consider the own-effect comparative static of

$$(4) \qquad \begin{aligned} \frac{\partial x_k^m}{\partial q_k} &= -\left(\frac{1}{\lambda}\right) \sum_{j=1}^{N} \left(\frac{\partial x_k^h}{\partial p_j}\right) U_{x_j q_k} \\ &= \frac{\partial x_k^h}{\partial p_1}\left[\left(-\frac{1}{\lambda}\right) U_{x_1 q_k}\right] + \cdots \\ &\quad + \frac{\partial x_k^h}{\partial p_k}\left[\left(-\frac{1}{\lambda}\right) U_{x_k q_k}\right] \cdots \\ &\quad + \frac{\partial x_k^h}{\partial p_N}\left[\left(-\frac{1}{\lambda}\right) U_{x_N q_k}\right]. \end{aligned}$$

Each element of the sum on the right hand side of (4) possesses an intuitive interpretation. The term $-(\frac{1}{\lambda})$ translates the change in marginal utility of x_j with respect to q_k, $U_{x_j q_k}$, into an imputed change in price of good x_j with respect to q_k, or $[-(\frac{1}{\lambda})U_{x_j q_k}] = \Delta p^*_{j q_k}$.[5] For example, if a decrease in quality of good x_k increases marginal utility of good x_j, $U_{x_j q_k} < 0$, then $\Delta p^*_{j q_k} > 0$, which yields an increase in the imputed price for an individual consuming good x_j. Further, if goods x_j and x_k are net substitutes (complements), then the sign of $(\frac{\partial x_i^h}{\partial p_j})[-(\frac{1}{\lambda})U_{x_j q_k}]$ is positive (negative) and it adds positively (negatively) to $\frac{\partial x_k^m}{\partial q_k}$.

From (4) it is evident the initial assumptions are not sufficient alone to sign the comparative static effects. Signing this relationship unambiguously requires either further restricting cross-marginal utility effects or, under some circumstances, knowledge of the Hicksian cross-price effects. Constraining the cross-marginal utilities to zero ($U_{x_j q_k} = 0 \, \forall \, j \neq k$) reduces the comparative static in (4) to $\frac{\partial x_k^m}{\partial q_k} = -(\frac{1}{\lambda}) \frac{\partial x_k^h}{\partial p_k} U_{x_k q_k} > 0$ under the initial assumptions. However, imposing

---

demand response to food safety information. These additional considerations are not taken into account in this theoretical framework or in the empirical application and are acknowledged as potential limitations.

[4] These assumptions on the utility function are consistent with Foster and Just, who also maintain that information about food contamination is inversely related to food quality.

[5] The term virtual prices is used in the literature on rationed goods. Madden identifies virtual prices as those prices which would make the levels of the rationed goods equal to the optimal quantities in the unrationed cost minimization problem.

$U_{x_j q_k} = 0 \, \forall \, j \neq k$ is likely to be unduly restrictive. Further inspection reveals $\frac{\partial x_k^m}{\partial q_k} > 0$ can be inferred under the less stringent condition of $\frac{\partial x_k^h}{\partial p_j}[(-\frac{1}{\lambda})U_{x_j q_k}] > 0 \; \forall j \neq k$. This condition requires that if an increase (decrease) in the marginal utility of the *j*th good occurs with an increase in q_k, that x_j be a net complement (substitute) to x_k. This less stringent condition appears quite plausible although not required by utility maximization. Finally, consider a more general condition from which to sign the comparative static $\frac{\partial x_k^m}{\partial q_k}$. Let the number of positive terms (N_1) and negative terms (N_2) on the right hand side of (4) (excluding the own-effect) be written as $N = 1 + N_1 + N_2$. Define the positive and negative partial sums as $S_{N_1}^+$ and $S_{N_1}^-$ and rewrite (4) as[6]

$$(5) \qquad \frac{\partial x_k^m}{\partial q_k} = \left[\frac{\partial x_k^h}{\partial p_k} \left(-\frac{1}{\lambda} \right) U_{x_k q_k} + S_{N_1}^+ \right] + S_{N_2}^-.$$

Equation (5) indicates that the sign of the comparative static $\frac{\partial x_k^m}{\partial q_k}$ depends on the magnitude of the positive sum of the own-effect and positive cross-effects relative to the sum of the negative cross-effects.

Next, consider the expression for the cross-effect comparative static of

$$(6) \qquad \begin{aligned} \frac{\partial x_i^m}{\partial q_k} &= -\left(\frac{1}{\lambda}\right) \sum_{j=1}^{N} \left(\frac{\partial x_i^h}{\partial p_j} \right) U_{x_j q_k} \\ &= -\left(\frac{1}{\lambda}\right) \left[\frac{\partial x_i^h}{\partial p_1} U_{x_1 q_k} + \cdots \right. \\ &\quad + \frac{\partial x_i^h}{\partial p_i} U_{x_i q_k} + \cdots \frac{\partial x_i^h}{\partial p_k} U_{x_k q_k} \\ &\quad \left. + \cdots + \frac{\partial x_i^h}{\partial p_N} U_{x_N q_k} \right]. \end{aligned}$$

The initial assumptions are once again not sufficient to sign this expression unambiguously. Further, the unduly restrictive condition of $U_{x_j q_k} = 0 \, \forall \, j \neq k$ is not even sufficient. Although, this condition reduces the comparative static to $\frac{\partial x_i^m}{\partial q_k} = -\left(\frac{1}{\lambda}\right) \frac{\partial x_i^h}{\partial p_k} U_{x_k q_k}$, the sign hinges on whether x_i and x_k are net substitutes or complements.[7] For completeness, note that equation (6) can be rewritten and interpreted similarly to (5) but with no own-effect.

Given the above assumptions, linking results about quality to public information indexing food safety concerns related to meat is straightforward. Applying a chain rule relationship, the comparative static results for food safety concerns become $\frac{\partial x_i^m}{\partial r_k} = \frac{\partial x_i^m}{\partial q_k} \frac{\partial q_k}{\partial r_k}$ where it is maintained that $\frac{\partial q_k}{\partial r_k} < 0$. Under this formulation the food safety information comparative static results $\frac{\partial x_i^M}{\partial r_k}$ are inversely related to those described above for quality $\frac{\partial x_i^M}{\partial q_k}$. Further, recognizing this functional relationship between quality and food safety information yields the Marshallian demand equations $\mathbf{x}^m\,(\mathbf{p}, M, \mathbf{q}(\mathbf{r})) = \mathbf{x}^m\,(\mathbf{p}, M, \mathbf{r})$.

Finally, equation (4) provides important insight into the potential limitations of selecting a single measure of quality across all N goods. For instance, if $q_1 = \cdots = q_N = q^*$ then consumer's marginal utility is limited to $U_{x_i q_1} = \cdots = U_{x_i q_N} = U_{x_i q^*}$, implying that quality impacts on marginal utility are identical across all N goods. For the current article, we conjecture that a single measure of meat quality across beef, pork, and poultry imposes unduly limiting restrictions on consumer responsiveness. Formulating individual quality measures for each of the N goods avoids such stringent restrictions on consumer's marginal utilities. In practice, this calls for the use of a complete demand system incorporating *separate* public information indices of food safety concerns for each meat type into *each* demand equation in the system.

U.S. Meat Demand

The effects of non-price and non-income variables on aggregate meat demand in the U.S. have been studied extensively across competing consumer demand models.[8] Factors such

---

[6] Here,

$$S_{N_1}^+ = \sum_{\substack{j=1 \\ j \neq k}}^{N} \delta_{kj}^+ \left(\frac{\partial x_k^h}{\partial p_j} \right) \left[\left(-\frac{1}{\lambda} \right) U_{x_j q_k} \right] > 0$$

and

$$S_{N_2}^- = \sum_{\substack{j=1 \\ j \neq k}}^{N} \left(1 - \delta_{kj}^+ \right) \left(\frac{\partial x_k^h}{\partial p_j} \right) \left[\left(-\frac{1}{\lambda} \right) U_{x_j q_k} \right] < 0$$

where $\delta_{kj}^+ = 1$ if $(\frac{\partial x_k^h}{\partial p_j})[-(\frac{1}{\lambda})U_{x_j q_k}] > 0$ and 0 otherwise.

[7] For further insight, see Madden who generalizes definitions of substitutes and compliments to applications of demand rationing and Carson, Flores, and Hanemann who provide further extensions to substitutions and complementarity in valuation of public goods.

[8] A significant amount of effort has been expended by agricultural economists explaining changes in U.S. meat consumption

as health information, generic advertising, and selected demographics have been included in demand models as possible determinants contributing to structural changes in meat demand (e.g., Kinnucan et al.; Gao and Spreen; McGuirk et al.; Brester and Schroeder; Ward and Lambert; Jensen and Schroeter). More specifically, McGuirk et al. found that both health information and a changing labor force contributed to structural change in meat demand from 1960 to 1988. An index for cholestrol awareness had statistically significant impacts on beef (negative) and pork and poultry (positive) with estimated elasticities for beef, pork, and poultry of −0.08, 0.08, and 0.12 in 1998, respectively. Kinnucan et al. examined the effects of health information and generic advertising simultaneously on U.S. meat demand over the period 1976–93. This study reconfirmed McGuirk et al.'s findings that health information concerning cholesterol had statistically significant impacts on beef (negative) and poultry (positive) with estimated elasticities for beef and poultry of −0.681 and 1.659, respectively. A striking feature of these results was the finding that these elasticities for health concerns are larger in magnitude than own-price effects. Furthermore, Kinnucan et al. found the effects of generic advertising to be mostly statistically insignificant, small in comparison to health concerns, and fragile to sample size. This finding concerning advertising confirmed the findings of Brester and Schroeder that generic beef and pork advertising had no effect on beef and pork demand and negatively affected poultry demand.

Food safety concerns are distinctly different than those related to health and other issues. For instance, the impacts from cholesterol are not as easily detected and require long periods of sustained consumption to be expressed.[9] In contrast, food safety includes both acute and chronic concerns. An "outbreak" of contaminated meat products can result in immediate (noticeable) short-run, long-run, or even fatal illness after consumption. Outbreaks are characterized by unanticipated and sudden food safety events that shock demand and are followed by an outpouring of public information. Drawing on the theoretical model, we maintain that consumers perceive this publicized food safety information as being inversely related to product quality and react accordingly. In doing so, we can test whether consumer response to media events of outbreaks is spread across time periods or rapidly dissipates. Further, the potential exists to test the influence of (*a*) "pure" food safety effects independent of price or expenditure as well as indirect effects among meats; and (*b*) cross-commodity substitution or adverse spillover effects from food safety among competing meats.

Food Safety

Following earlier studies on meat safety (Burton and Young; Burton, Young, and Cromb; Flake and Patterson), food safety indices are constructed based on newspaper articles from the popular press. In contrast to the above studies, food safety indices are constructed separately for beef, pork, and poultry. Data for the series were obtained by searching the top fifty English language newspapers in circulation from 1982 to 1999 using the academic version of the Lexis-Nexis search tool.[10] Keywords searched were *food safety* or *contamination* or *product recall* or *outbreak* or *salmonella* or *listeria* or *E. coli* or *trichinae* or *staphylococcus* or *foodborne*.[11] From this information base, the search was narrowed to collect beef, pork, and poultry information

---

patterns and in particular whether there has been structural change in demand. An incomplete list of notable work in this area includes Chavas; Moschini and Meilke (1984, 1989); Wohlgenant; Dahlgran; Thurman; Eales and Unnevehr (1988, 1993); Chalfant and Alston; and Gao and Shonkwiler. A fair assessment of this body of work is that the evidence has been mixed. That is, there is still *no consensus* concerning whether changes in demand can be explained by prices and incomes alone or whether there are other factors that are responsible. The dichotomy of results that has evolved between whether there has been a structural change or not appears to be sensitive to, not surprisingly, choices concerning the methodological approach adopted and data used. These differences in results and lack of agreement has also given rise to other important research in demand analysis concerning methodological and specification choices and the critical role they can have on inferences relating to modeling structural change (Alston and Chalfant, 1991a, 1991b).

[9] Dahlgran and Fairchild point out the critical role that time plays in studies that are concerned with longer term-health. They also pose the question if longer-term effects exists, then it should follow that warnings of immediate dangers associated with consumption should also cause immediate declines?

[10] Although the exact analytical techniques used by Lexis-Nexis to execute a search are proprietary, www.nexis-lexis.com provides a more detailed discussion of relevancy rankings and other aspects of the search tool.

[11] In this manner we collected an information set containing newspaper reports on food safety, outbreaks, contamination, and recalls at the federal and regional levels. The specific list of contaminants included as part of the information set was based on those listed in the USDA's Food Safety Inspection Service's meat product recall data base. See www.fsis.usda.gov.

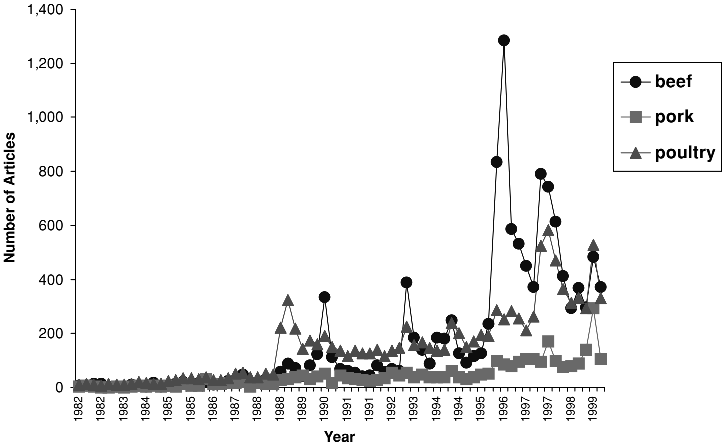

Figure 1. Beef, pork, poultry food safety media articles, 1982(1)–1999(3)

separately by using additional terms (*a*) *beef* or *hamburger*, (*b*) *pork* or *ham*, and (*c*) *chicken*, *turkey*, or *poultry*, respectively. The newspaper articles were then linearly aggregated to construct quarterly beef, pork, and poultry media indices.[12]

Overall, the food safety indices reveal higher incidences of food safety concerns for beef than pork or poultry over the sample period. Figure 1 plots the beef, pork, and poultry indices. During the period of 1982–88, the number of reported food safety articles for each series remained small. Beginning in 1988 the number of articles increased significantly with periods of dramatic peaks in information dominated by the beef series. Table 1 reveals that the beef series exhibits the highest mean of 174.2 and most variation in the number of articles with a standard deviation of 245.0. Next is the poultry series with a mean of 153.0 articles and standard deviation of 135.7. The pork series has a mean of 43.1 articles and standard deviation of 46.9. The maximum number of reported articles per quarter for beef was 1,283 in 1996(2), for poultry 582 in 1997(4), and for pork 292 in 1999(4). Not surprisingly, peaks in the beef, poultry, and pork series relate to important events in the recent history of meat food safety events.

In 1990, a BSE outbreak was reported in Europe yielding an increase in food safety related articles for beef with 334 articles in the second quarter. The 1993 first quarter peak of 387 articles coincided with an isolated E. coli outbreak in the state of Washington. In 1996, BSE news resurfaced after scientists in Europe linked BSE in beef to a variant Creutzfeldt-Jakob disease (CJD) in humans. More than 1,200 related articles were reported in the second quarter of 1996 alone. The 1997 peak in media reports was related to a massive recall of beef contaminated with E. coli that occurred in the midwest United States. Other important events in the meat industry during the late 1990s included USDA's final rule on Pathogen Reduction/Hazard Analysis and Critical Control Point (PR/HACCP) systems. The PR/HACCP rule requires meat and poultry plants under Federal inspection to take responsibility for reducing the contamination of meat and poultry products with pathogenic bacteria.

Poultry has also played an important role in meat safety events reported by newspapers. Of the three series, poultry exhibited the first peak of media information during the third and fourth quarters of 1988. This was related to a *salmonella* outbreak in chickens and eggs resulting from providing chickens feed with animal remains. From 1982 through the third

---

[12] By linear aggregation, we mean the raw numbers of observed articles were linearly summed with equal weighting for each quarter over the study period. Linear aggregation is consistent with the food safety indices used by Burton and Young, Burton, Young, and Cromb, and the health indices used by Kinnucan et al., Capps and Schmitz, and McGuirk et al. We recognize that other media sources outside of newspaper reports provide food safety information to the public. We also recognize that this method does not measure or differentiate the information content or severity of the food safety event. Insofar as other media not being taken into account or accounting for the severity of individual events remain key factors in meat demand, the empirical demand model specified ahead would be misspecified. However, encouraging empirical findings, and in particular autocorrelation (often symptomatic of model misspecification) of residuals not being significant statistically in the preferred model suggest that this might not be the case. Although, it is outside the scope of this study, testing the impacts across alternative media sources and developing a method to appropriately take account of the informational content and severity of the event is encouraged for future research.

Table 1. Summary Statistics of Quarterly Data, 1982(1)–1999(3)

Variable	Average	Std. Dev.	Minimum	Maximum
Beef consumption (lbs/capita)	17.703	1.421	15.792	20.818
Pork consumption (lbs/capita)	12.712	0.677	11.334	14.329
Poultry consumption (lbs/capita)	19.553	2.983	13.674	24.767
Retail beef price ($/lb)	2.638	0.240	2.227	3.004
Retail pork price ($/lb)	2.066	0.242	1.678	2.481
Retail poultry price ($/lb)	0.901	0.087	0.721	1.051
Meat expenditure ($/capita)	90.444	7.802	75.650	106.840
Beef expenditure share	0.516	0.039	0.433	0.586
Pork expenditure share	0.289	0.014	0.265	0.321
Poultry expenditure share	0.195	0.030	0.133	0.246
Beef food safety	174.211	244.951	3.000	1,283.000
Pork food safety	43.113	46.888	0.000	292.000
Poultry food safety	153.042	135.714	6.000	582.000

quarter of 1988, the average number of articles per quarter was 26.3. After the third quarter of 1988 and through the third quarter of 1999 the average number of articles per quarter sharply increased to 230.8. More recently a bird fluenza outbreak in poultry throughout Hong Kong and China led to 582 newspaper articles in the last quarter of 1997.

Pork had fewer media reports than either beef or poultry. The number of articles has steadily increased since 1982, but more slowly relative to the other series. From 1982 through the third quarter of 1988 the average number of articles per quarter was 9.0, while the average number of articles per quarter from the third quarter of 1988 to the third quarter of 1999 had increased to 64.0. The maximum number of articles for one quarter peaked at 292 in 1999(2), which coincides with a pork dioxin outbreak in Europe. Nevertheless, meat safety issues in pork products remain important to consumers and industry as pork has been linked to outbreaks of *listeria* and other potentially dangerous contaminants.

Identifying selected components and trends of the indices provides further insight into food safety concerns. Over the study period, 56, 67, and 31% of the articles in the beef, pork, and poultry indices, respectively, were not specific to a particular meat type. From 1982–89 to 1990–99, the average number of beef-only articles increased by 29%, while the pork- and poultry-only articles decreased by 15 and 11% between the same periods. The percentage of articles pertaining to regulations about food safety were relatively stable over the study period, averaging 20, 18, and 18% for beef, pork, and poultry, respectively. From 1982 to 1999, the BSE articles made up 21% of the food safety articles for the beef index, increasing from 2% during the 1982–89 period to 36% in 1990–99. These statistics highlight the concerns and changes in food safety as represented by newspaper information.

Demand Model

Capturing the own- and cross-commodity impacts on demand from food safety concerns, as well as the pure food safety and indirect expenditure effects, motivate the subsequent model specification. Like traditional own/cross price effects and price/income effects, these food safety effects can be addressed within a theoretically consistent consumer demand system. We attempt to accomplish this by using a standard demand model generalized to include pre-committed quantities and then adopt a demographic translation procedure. Consider the generalized expenditure function

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

where $\mathbf{p}$ is an N-vector of prices, $\mathbf{c}$ is an N-vector of pre-committed quantities, and u is utility. The generalized expenditure function is decomposed into two terms. The first term is the pre-committed expenditure $\mathbf{p}'\mathbf{c}$, which can be interpreted as the minimum subsistence expenditures the consumer commits in order to attain a minimal subsistence level. The second term is the supernumerary expenditure $E^*(\mathbf{p}, u)$, the remaining expenditures to be allocated among the N competing goods. This specification is appealing because several underlying hypotheses about meat consumption and food safety concerns can be examined.

Applying Shephard's Lemma to (7) and making use of dual identities yields

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

The ith quantity demanded (x_i) is made up by the pre-committed quantity (c_i) and the supernumerary quantity ($x_i^*[\mathbf{p}, M^*]$), where $M^* = M - \sum_{i=1}^{N} c_i p_i$ is supernumerary expenditure and M is total expenditure on the N goods. The distinction between the two components of consumption is important, since the pre-committed quantities are independent of prices and expenditure, whereas the supernumerary quantities are not.

To capture potential changes in demand in response to non-price and non-income variables, it seems natural to augment the c_i's to be functions of demand shift variables. Augmenting the c_i's to depend on demand shifters is not new, Pollak and Wales used this approach referring to it as demographic translation. Intuitively, this translating approach is appealing since one plausible outcome of food safety concerns is that consumers might decide to change consumption decisions irrespective of prices and income levels. In addition, because U.S. quarterly meat demand exhibits seasonal patterns and trends in consumption over time, it is also appropriate to consider the inclusion of seasonal dummy and time trend variables as additional demand shifters that also augment these pre-committed quantities.

The translating procedure can be implemented in the context of any complete demand system and is quite flexible.[13] Augmenting the pre-committed quantities to depend on demand shifters does not necessarily imply any restrictions on parameters of the prospective demand shifters for any particular good. There are no adding up restrictions on a particular food safety index across pre-committed quantities. So in principle, a particular food safety variable can have a negative or positive effect on each meat's pre-committed quantity. The only required restriction accompanying this translating procedure is that the sum of changes in expenditures on pre-committed quantities must be equal and opposite to changes in supernumerary expenditures, leaving total expenditures unchanged.

Modifying the pre-committed quantities, the c_i's, to depend linearly upon time variables and food safety indices implies the following augmentation of the model outlined in (8) of:

$$(9)\qquad \tilde{c}_i = c_{i0} + \tau_i t + \sum_{k=1}^{3} \theta_{ik}\, qd_k + \sum_{m=0}^{L} \phi_{i,m} bf_{t-m} + \pi_{i,m} pk_{t-m} + \kappa_{i,m} py_{t-m}$$

where t is a linear time trend set equal to 1 for the initial time period; qd_k ($k = 1, 2,$ and 3) are quarterly seasonal dummies; 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 all lagged m periods.[14] The parameters that must be estimated are the c_{i0}'s, τ_i's, θ_{ik}'s, $\phi_{i,m}$'s, $\pi_{i,m}$'s and $\kappa_{i,m}$'s.[15] There is no way to know a priori how long a particular food safety "event" may impact demand. This is an empirical question that can be investigated econometrically by testing alternative lag lengths to determine the appropriate choice of L. This issue is pursued in more detail in the Model Results section of the paper.

Generalized Almost Ideal Demand Model

The share form of the demand functions in (8) can be written as

$$(10)\qquad w_i = \left(\frac{p_i c_i}{M}\right) + \left(\frac{M^*}{M}\right) w_i^*[\mathbf{p}, M^*]$$

---

[13] Pollak and Wales make the point that this procedure is general in that it can be used in conjunction with any complete demand system since it does not require that the original demand system has any particular functional form.

[14] The time trend serves as a proxy for other influences on demand that have not been explicitly accounted for in the model. Figure 1 reveals that the food safety indices exhibit some slight upward trends over the sample and so therefore some correlation exists between the linear trend and each of the food safety indices, respectively. Because of this correlation, omitting these linear time trends may lead to falsely attributing the influence of these other factors captured by the time trends to the food safety indices. On the other hand, including these linear trends may result in attributing some of the variation in demand incorrectly to the time trend understating the food safety impacts. However, there is a significant amount of variation in the food safety indices over the sample, providing some confidence that one should be able to reasonably delineate the impacts of food safety information from other influences on demand that are proxied by the inclusion of this time trend.

[15] The c_{i0}'s are constants and measure the pre-committed quantity over the sample that is not influenced by the demand shifters. Pollak and Wales recommend including such constants since failure to do so when they do indeed exist (they are part of the "true" model) could result in a demand shift variable with little variation appearing to be statistically significant as it would be a proxy for this omitted constant.

where w_i is expenditure share of meat type i ($w_i = \frac{p_i x_i}{M}$) and w_i^* is supernumerary expenditure share of meat type i ($w_i^* = \frac{p_i x_i^*}{M^*}$).

In applied demand analysis, the use of locally flexible functional forms is popular since they are thought to do decent job of approximating the "true" underlying demand model. Arguably the most popular choice in applied demand analysis has been to employ the Almost Ideal (AI) model (Deaton and Muellbauer) when estimating a complete system of demand equations.[16] The AI model has been used extensively since it is a locally flexible functional form; is appropriate for aggregate and individual consumer analysis; and allows restrictions from theory such as homogeneity, adding-up, and symmetry to be imposed. Assigning the $w_i^*(\mathbf{p}, M^*)$'s to be of the AI form can be seen as a generalization of the AI model, first proposed by Bollino, analogous to the generalization of the Cobb-Douglas to the Linear Expenditure System except that the marginal budget shares are of the AI form rather than constants. Doing so culminates in a complete demand system that allows non-price and non-income variables to be incorporated in a translating procedure (functions of the $\tilde{c}_i$'s) which is flexible but also maintains the underlying consistency of the original demand system (the AI model) with economic theory.[17] This model that incorporates pre-committed quantities into the AI model was coined as the Generalized Almost Ideal demand system (GAI) model by Bollino and can be expressed in share form as

$$(11)\quad w_i = \left(\frac{p_i c_i}{M}\right) + \left(\frac{M^*}{M}\right)\left(\alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j + \beta_i \ln\left(\frac{M^*}{P}\right)\right) + e_{\mathrm{i}}$$

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 equal to per unit price of meat type i. Here $i, j = b$ for beef, p for pork, and c for poultry. The coefficients c_i, α_i, γ_{ij}, β_i, and δ and are parameters to be estimated and e_i is the random error term. Demand restrictions derived from economic theory can be imposed using parameter restrictions with homogeneity being imposed by $\sum_{j=1}^{N} \gamma_{ij} = 0$, adding up conditions by $\sum_{i=1}^{N} \beta_i = 0$ and $\sum_{i=1}^{N} \alpha_i = 1$, and symmetry $\gamma_{ij} = \gamma_{ji} \forall i \neq j$. To test hypotheses about the effect of time (seasonality and time trends) and food safety information on demand via the translating procedure we replace the c_i's in (11) with $\tilde{c}_i'$s defined in (9).

Meat Data and Estimation Procedure

Meat data used in the analysis are quarterly observations over the period 1982(1)–1999(3), providing a total of 71 observations. The basic quantity data are per capita disappearance data from the United States Department of Agriculture (USDA), Economic Research Service (ERS) supply and utilization tables for beef, pork, and poultry (broiler, other-chicken, and turkey) published in the *Red Meats Yearbook* and *Poultry Yearbook* with data after 1990 taken from updated revisions of these publications made available online. The beef price is the average retail choice beef price, the pork price is average retail pork price, and the poultry price was calculated by summing quarterly expenditures on chicken, using the average retail price for whole fryers, and quarterly expenditures on turkey, using the average retail price of whole frozen birds, divided by the sum of quarterly per capita disappearance on chicken and turkey. All of the price variables are published in the same United States Department of Agriculture, Economic Research Service sources with the original sources identified as the ERS (Animal Products branch) for the beef and pork prices (variable names BFVRCCUS and PKVRCCUS, respectively) and the Bureau of Labor Statistics, United States Department of Labor for the whole fryers (chicken) and whole frozen bird

---

[16] A recent search of "www.webofscience.com" using keywords "Almost Ideal Demand System" revealed at least 156 papers that either discuss or implement this model.

[17] Care must be taken in deciding how to incorporate demand shifters into complete demand systems to avoid some not so obvious problems that can arise. For instance modifying the intercepts of the AI model (the α_i's) which has previously been a common approach, following the suggestion of Deaton and Muellbauer, has the unfortunate implication that estimated economic effects (elasticities) are no longer invariant to units of measurement (Alston, Chalfant, and Piggott). One possible solution that was offered by these authors to avoid invariance problems in the AI model is to adopt the generalized model that allows for pre-committed goods and utilize a translation procedure, and allowing the pre-committed goods to be functions of demand shifters—the specification that is adopted herein.

(turkey) prices.[18] Food safety variables for beef, pork, and poultry used in the analysis are quarterly data over the same period, constructed as discussed in the previous section. Finally, effects of time on meat demand are incorporated in the model through the use of quarterly demand shift (binary) variables for seasonality and a linear trend variable as discussed in the previous section. Table 1 provides descriptive statistics of the non-binary variables.

In the empirical analysis, meat is treated as a weakly separable group comprising beef, pork, and poultry (chicken and turkey) in which consumption of an individual meat item depends only on the expenditure of the group, the prices of the goods within the group, and certain introduced demand shifters. Models were estimated using iterated non-linear estimation techniques. Due to the singular nature of the share system one of the equations must be deleted (poultry) with the remaining equations being estimated (beef and pork). Theoretical restrictions such as homogeneity and symmetry were imposed as a maintained hypothesis. Inferences concerning whether food safety concerns had affected demand were investigated using small-sample adjusted likelihood ratio (*LR*) tests (Bewley) requiring models be estimated with and without food safety variables incorporated.[19] To investigate whether these impacts were distributed over time the statistical significance of additional lags of these food safety variables was also investigated. Finally, *LR* tests were also carried out to test the alternative specifications for autocorrelation. All tests use a significance level of 5% and reported elasticities are the means of elasticities calculated at every observation.

Hypothesis Tests and Model Results

Columns 1, 2, and 3 in table 2 report estimates of coefficients, standard errors, and summary statistics from the GAI model without food safety variables and with the three alternative autocorrelation corrections: (*a*) a null **R** matrix (N–R^{matrix}) with all elements restricted to zero, specifying no autocorrelation; (*b*) a diagonal **R** matrix (D–R^{matrix}) wherein all diagonal elements are restricted to be identical and all off-diagonal elements are restricted to zero; and (*c*) a full R matrix (F–R^{matrix}) where all elements of **R** matrix are non-zero.[20] These coefficient estimates reveal positive pre-committed quantities of beef (c_{b0}'s), pork (c_{p0}'s), and poultry (c_{c0}'s) with one exception the estimate of c_{c0} (but it is not statistically significantly different from zero) in the model with F–R^{matrix}. All of the seasonal (θ_{ik}'s) and trend coefficients (τ_i's) are statistically significantly different from zero (except θ_{b1}) across models supporting the argument that there have been changes in meat consumption patterns that can be explained by seasonal patterns and underlying trends. Given the strong statistical support for these intertemporal variables it was decided to include the seasonal and time trend variables as a maintained hypothesis in the models that investigate the impact of food safety information.[21]

Autocorrelation is only detected in models without food safety variables. The tests of the alternative autocorrelation corrections shown in table 3 confirm the presence of first order autocorrelation in the residuals. A model that does not correct for autocorrelation (N–R^{matrix}) is rejected against the alternatives of either D–R^{matrix} and F–R^{matrix}. The results of further hypothesis tests shown in table 3 reveals failure to reject the D–R^{matrix} specification against the alternative F–R^{matrix} for models that omit food safety (No-FS). Hence, a diagonal matrix with identical elements is adequate to correct for autocorrelation when food safety variables are omitted.

To investigate whether food safety concerns have impacted meat consumption, contemporaneous (current) and lagged food safety variables were considered in the model to allow for possible dynamic effects. That is, the possibility that the impacts of a given "media event" as captured by the food safety indices may be spread over more than one quarter was investigated.[22] The current levels of the food safety indices were first considered, testing whether their coefficients were jointly statistically significantly different from zero. The results of the *LR* tests shown in table 3 reveal that for all forms of the autocorrelation specification, the

---

[18] The data are available upon request.

[19] All reported likelihood ratio tests reported throughout the article have been adjusted for small-sample size (Bewley). Details are provided in the notes for table 3.

[20] See Berndt and Savin, as well as Piggott et al. and Holt and Goodwin, for further discussion related to the alternative autocorrelation corrections in demand systems.

[21] Individual and combined tests of null hypotheses that the coefficients measuring seasonality and trends on the pre-committed quantities were jointly equal to zero were consistently rejected.

[22] A priori there is no way of knowing how long effects on consumption of a given "media event" will last, i.e., the length of the lag, *L*, this is an empirical question.

Table 2. Estimated Coefficients for the Generalized Almost Ideal Model with and without Food Safety Variables

	No Food Safety			With Food Safety		
	$\text{N–R}^{\text{matrix}}$	$\text{D–R}^{\text{matrix}}$	$\text{F–R}^{\text{matrix}}$	$\text{N–R}^{\text{matrix}}$	$\text{D–R}^{\text{matrix}}$	$\text{F–R}^{\text{matrix}}$
δ	8.089*	59.420	7.409*	32.820	37.437	32.824
	(2.581)	(79.565)	(2.754)	(26.739)	(32.474)	(28.643)
α_b	3.410*	17.692	2.669	14.665	15.523	14.196
	(1.663)	(18.093)	(1.748)	(9.845)	(10.878)	(10.222)
α_p	−1.174	−6.821	−0.713	−5.472	−5.617	−5.010
	(0.806)	(7.966)	(0.715)	(4.175)	(4.506)	(4.144)
γ_{bb}	4.491*	6.449	3.407*	9.747*	9.012*	9.091*
	(1.311)	(4.119)	(1.315)	(3.765)	(3.856)	(3.820)
γ_{bp}	−2.047*	−2.544	−1.204	−3.715*	−3.297	−3.252
	(0.766)	(1.964)	(0.720)	(1.758)	(1.755)	(1.725)
γ_{pp}	1.054*	0.981	0.520	1.379	1.155	1.110
	(0.430)	(0.927)	(0.358)	(0.811)	(0.791)	(0.769)
β_b	0.789*	0.311*	0.749*	0.496*	0.451*	0.480*
	(0.127)	(0.129)	(0.154)	(0.123)	(0.119)	(0.128)
β_p	−0.379*	−0.128*	−0.296*	−0.201*	−0.176*	−0.184*
	(0.072)	(0.054)	(0.083)	(0.053)	(0.050)	(0.054)
c_{b0}	17.098*	11.126*	16.256*	15.170*	14.791*	14.968*
	(1.549)	(2.278)	(2.045)	(0.942)	(0.983)	(1.021)
c_{p0}	1.115	5.472*	2.700	7.294*	7.395*	7.421*
	(2.486)	(1.915)	(2.719)	(0.990)	(1.010)	(1.037)
c_{c0}	1.254	7.980*	−3.463	10.383*	10.317*	9.819*
	(4.784)	(3.482)	(7.508)	(2.164)	(2.178)	(2.403)
θ_{b1}	0.144	0.073	0.118	0.066	0.046	0.062
	(0.132)	(0.147)	(0.138)	(0.108)	(0.108)	(0.109)
θ_{b2}	0.794*	0.736*	0.786*	0.644*	0.628*	0.626*
	(0.135)	(0.169)	(0.147)	(0.109)	(0.113)	(0.113)
θ_{b3}	0.957*	0.912*	1.010*	1.015*	1.004*	1.003*
	(0.137)	(0.150)	(0.146)	(0.107)	(0.106)	(0.110)
θ_{p1}	−0.983*	−1.023*	−1.007*	−0.987*	−0.998*	−0.987*
	(0.121)	(0.112)	(0.096)	(0.098)	(0.095)	(0.094)
θ_{p2}	−1.426*	−1.443*	−1.425*	−1.431*	−1.430*	−1.437*
	(0.130)	(0.138)	(0.111)	(0.106)	(0.108)	(0.106)
θ_{p3}	−1.136*	−1.153*	−1.095*	−1.082*	−1.089*	−1.095*
	(0.119)	(0.110)	(0.097)	(0.097)	(0.093)	(0.094)
θ_{c1}	−2.435*	−2.425*	−2.423*	−2.482*	−2.481*	−2.479*
	(0.113)	(0.102)	(0.106)	(0.099)	(0.095)	(0.098)
θ_{c2}	−1.740*	−1.700*	−1.722*	−1.806*	−1.795*	−1.804*
	(0.118)	(0.126)	(0.122)	(0.107)	(0.109)	(0.109)
θ_{c3}	−1.253*	−1.251*	−1.223*	−1.258*	−1.251*	−1.256*
	(0.112)	(0.099)	(0.107)	(0.100)	(0.096)	(0.099)
τ_b	0.035*	0.069*	0.041*	0.029*	0.032*	0.031*
	(0.009)	(0.027)	(0.011)	(0.011)	(0.012)	(0.012)
τ_p	0.070*	0.083*	0.061*	0.073*	0.074*	0.071*
	(0.010)	(0.020)	(0.011)	(0.010)	(0.011)	(0.010)
τ_c	0.150*	0.173*	0.168*	0.157*	0.161*	0.161*
	(0.012)	(0.020)	(0.014)	(0.011)	(0.012)	(0.012)
ϕ_{b0}	–	–	–	−1.38E-03*	−1.48E-03*	−1.51E-03*
	–	–	–	(4.91E-04)	(4.97E-04)	(4.97E-04)
ϕ_{p0}	–	–	–	−2.41E-03*	−2.44E-03*	−2.38E-03*
	–	–	–	(3.70E-04)	(3.77E-04)	(3.70E-04)
ϕ_{c0}	–	–	–	−2.90E-04	−4.70E-04	−4.60E-04
	–	–	–	(3.20E-04)	(3.59E-04)	(3.61E-04)
π_{b0}	–	–	–	−5.20E-04	1.05E-04	−8.00E-05
	–	–	–	(3.23E-03)	(3.26E-03)	(3.31E-03)
π_{p0}	–	–	–	−3.02E-03	−2.60E-03	−2.56E-03
	–	–	–	(3.13E-03)	(3.37E-03)	(3.25E-03)

Table 2. (Continued)

	No Food Safety			With Food Safety		
	N–R^{matrix}	D–R^{matrix}	F–R^{matrix}	N–R^{matrix}	D–R^{matrix}	F–R^{matrix}
π_{c0}	–	–	–	7.22E-04	8.01E-04	6.13E-04
	–	–	–	(2.67E-03)	(3.26E-03)	(3.24E-03)
κ_{b0}	–	–	–	−2.07E-06	1.72E-04	1.77E-04
	–	–	–	(1.17E-03)	(1.20E-03)	(1.19E-03)
κ_{p0}	–	–	–	1.33E-03	1.41E-03	1.40E-03
	–	–	–	(1.08E-03)	(1.11E-03)	(1.09E-03)
κ_{c0}	–	–	–	−2.80E-03*	−2.53E-03*	−2.46E-03*
	–	–	–	(9.16E-04)	(1.01E-03)	(1.03E-03)
ρ	–	0.399*	–	–	0.113	–
	–	(0.087)	–	–	(0.092)	–
ρ_{bb}	–	–	0.017	–	–	−0.046
	–	–	(0.193)	–	–	(0.196)
ρ_{bp}	–	–	−0.214	–	–	−0.177
	–	–	(0.209)	–	–	(0.214)
ρ_{pb}	–	–	0.188	–	–	0.112
	–	–	(0.178)	–	–	(0.171)
ρ_{pp}	–	–	0.613*	–	–	0.251
	–	–	(0.190)	–	–	(0.190)
LL	593.410	599.531	602.450	616.425	616.900	617.151
R^2 beef	0.986	0.984	0.985	0.989	0.989	0.989
R^2 pork	0.892	0.901	0.905	0.931	0.930	0.931
DW beef	1.717	2.223	2.035	1.906	2.002	1.997
DW pork	1.258	1.908	2.075	1.814	1.929	1.986

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

contemporaneous food safety impacts were jointly statistically significantly different from zero. Given that contemporaneous food safety variables are important determinants in explaining consumption, we investigate whether this impact might also have extended beyond one quarter.

Appropriate Lag Length for Food Safety Effects

To investigate the possibility of a distributed lag effect, food safety variables were lagged and added to the model as unrestricted distributed lags. *LR* tests of including one period lagged food safety ($L = 1$) shown in table 3, reveal failure to reject the null hypothesis that coefficients on the lagged food safety variables are zero. This finding was consistent across all three forms of autocorrelation specification. This same procedure was repeated with two period lagged food safety variables ($L = 2$) with the same result—the lagged food safety variables were not jointly statistically significantly different from zero across all autocorrelation specifications. Thus, the impacts of food safety appear to be limited to being contemporaneous. Based on this finding, the coefficient estimates for models that include only the contemporaneous food safety variables for all three alternative autocorrelation specifications are reported in table 2 (columns 4, 5, and 6) for the models that include food safety. The estimates for the various forms of autocorrelation allows a comparison of how these specification choices impact estimated effects and illustrates the robustness of the food safety coefficients across autocorrelation specifications. From hypothesis tests of lag lengths for food safety and autocorrelation specifications, we infer that the preferred model (column 4 in table 2) includes contemporaneous levels of food safety indices and no autocorrelation correction (N–R^{matrix}).

The Preferred Model

Inspecting the estimated coefficients and summary statistics of the preferred model indicates that it adequately explains per capita consumption patterns over the sample period. The R^2 of 0.989 and 0.931 for the beef and pork equations, respectively, coupled with a large number of estimated coefficients that are individually statistically significantly different from zero, suggests that the model provides a good

Table 3. Hypothesis Tests for the Significance of Food Safety Variables and Autocorrelation Corrections

	Lag Lengths for Food Safety				Autocorrelation Corrections		
	H_0: $L = 0$ H_a: No-FS	H_0: $L = 1$ H_a: $L = 0$	H_0: $L = 2$ H_a: $L = 1$		H_0: N–R$^{\text{matrix}}$ H_a: D–R$^{\text{matrix}}$	H_0: D–R$^{\text{matrix}}$ H_a: F–R$^{\text{matrix}}$	H_0: N–R$^{\text{matrix}}$ H_a: F–R$^{\text{matrix}}$
Model				*Model*			
N–R$^{\text{matrix}}$	35.657*	14.160	7.891	No-FS	10.171*	4.728	14.641*
D–R$^{\text{matrix}}$	26.666*	13.458	8.131	$L = 0$	0.729	0.374	1.083
F–R$^{\text{matrix}}$	21.948*	14.049	9.464	$L = 1$	0.107	1.338	1.441
	–	–	–	$L = 2$	0.423	2.815	3.224
df	9	9	9		1	3	4
$\chi_{0.05,\text{df}}$	16.919	16.919	16.919		3.841	7.815	9.488

Notes: L denotes the lag length of unrestricted distributed lags for food safety included in each model; No-FS denotes a model with no food safety variables included; and *df* denotes degrees of freedom. Reported test statistics are adjusted likelihood ratio tests calculated by adjusting the usual LR test statistic $LR = 2(LL^U - LL^R)$ according to following: $LR^s = [(MT - k^u)/MT]LR$ as suggested by Bewley where LL^U and LL^R are the maximized log-likelihood value in the unrestricted and restricted models; M is the number of estimated equations; T is the sample size, k^u is the number of parameters in the unrestricted model. For completeness all hypothesis test were also re-calculated using the adjusted test statistic of $LR^{s'} = [(MT - 0.5[(k^u + k^r) - M(M + 1)])/MT]LR$ proposed by Moschini, Moro, and Green where k^r is the number of parameters in the restricted model but are not reported for brevity since there were no differences in the outcomes of the results. An * denotes a significant test statistic at the 5% level.

fit to the data. The absence of autocorrelation when the current levels of food safety variables are incorporated into the model is reassuring since its presence can also be symptomatic of a model misspecification. To better understand consumer response to food safety, we preformed LR tests on a host of null hypotheses about selected food safety hazards, alternative information content of food safety indices, and different functional forms.[23] These additional results supported our choice of the GAI model and provided further assurance that the results are reasonably robust across alternative model specifications.

Estimated coefficients for which we have a priori expectations about sign, comply well with these expectations and are predominately statistically significantly different from zero. The constant components of the pre-committed quantities (the c_{i0}'s) are all nonnegative, indicating that consumer's have some amount of pre-committed consumption independent of any demand shifters, prices, and income. Based on estimates from the preferred model, these constant components of the pre-committed quantities were estimated to be 15.170 pounds of beef, 7.294 pounds of pork, and 10.383 pounds of poultry. When compared to the sample means (shown in table 1) these estimates reveal that the constant component of the pre-committed quantities are a significant proportion of total consumption making up 85.7% for beef, 57.4% for pork, and 53.1% for poultry. These findings suggest that pork and poultry consumption might be more susceptible to changes in prices and meat expenditure than beef, with a larger component of total consumption stemming from supernumerary quantities.

Our a priori expectation is that the own-food safety coefficients for beef (ϕ_{b0}), pork (π_{p0}), and poultry (κ_{c0}) should be negative, consistent with food safety concerns about a specific meat adversely affecting the pre-committed quantity demanded for the meat involved. Expectations concerning the sign of the cross-commodity food safety coefficients are less transparent a priori. A positive coefficient is consistent with consumer's substituting pre-committed quantities for the meat tied to food safety events with pre-committed quantities of other meats, thereby offsetting the amount of the reduction in pre-committed expenditures. A negative coefficient is consistent with consumer's adverse reaction to the

---

[23] Testing consumer's response to different hazards, information content of food safety indices, and functional forms were included based on suggestions by anonymous referees. We offer a summary of results on selected issues, but realize any number of hypotheses could and need to be tested further in future research. First, we rejected a single food safety index, aggregated from the individual indices, in favor of the individual food safety indices. Second, consumer's response to BSE information was not statistically different from their response to the remaining other food safety information. Third, consumer's response to regulation information was not statistically different from other food safety information. Fourth, we partitioned each food safety index into two components: (a) an "exclusive component" of information about only that particular meat; and (b) an "inclusive component" that is the complement of the exclusive component. Our findings indicate there was no statistical difference between the original food safety indices and those which were partitioned into inclusive and exclusive components. And, fifth, we investigated whether our results were model-specific by employing a more general demand system the Globally Flexible Generalized Almost Ideal Demand (GFGAI) model that nests the GAI model (Piggott). Nested tests consistently failed to reject the more restricted GAI model against the GFGAI model. Complete results are available from the authors upon request.

pre-committed quantity of the meat involved, spilling over to other pre-committed quantities of other meats, thereby further reducing the amount of pre-committed expenditures.[24] The estimates in table 2 reveal all the own-food safety coefficients are negative and that the coefficients for beef (ϕ_{b0}) and poultry (κ_{c0}) are individually statistically significantly different from zero. The cross-commodity food safety coefficients vary in sign indicating that both substitution and spillover effects occur. The cross-effects of poultry food safety on pork pre-committed quantities (π_{c0}) and pork food safety on poultry pre-committed quantities (κ_{p0}) are positive, implying consumer's substitute pre-committed quantities of pork and poultry when the other has a food safety event. The remaining cross-effects are estimated to be negative, implying consumer's adverse reaction to the meat tied to the food safety event spillover over to the other meats. Noticeably, cross-effects on pork and poultry pre-committed quantities from beef food safety (negative) indicate beef food safety events appear to adversely impact the pre-committed quantities of all meats.

Estimated Economic Effects

Table 4 reports estimates of the sample averages for the Marshallian and Hicksian price elasticities, expenditure elasticities, and food safety elasticities calculated at every data point.[25] Elasticities are reported for all models shown in table 2, allowing a comparison of how autocorrelation specifications and whether food safety variables are included in the model effect price and expenditure elasticities. The Marshallian demand response to food safety elasticities are provided for the direct (on pre-committed quantities demanded) and total (on the total quantities demanded) effects on consumption. For example, consider the direct- and total-effect elasticities for the *i*th good with information concerning contaminated beef (bf_t). The direct elasticity measures the percentage change in pre-committed quantity of the *i*th good in response to a 1% increase in the food safety index bf_t, or equivalently $\omega_{i,bf_t} = \partial \ln \tilde{c}_{i,t} / \partial \ln bf_t$. The total elasticity includes the share-weighted sum of the direct and indirect elasticity given as

(12)

$$\psi_{i,bf_t} = \frac{\partial \ln x_{i,t}}{\partial \ln bf_t} = \left(\frac{\partial \ln \tilde{c}_{i,t}}{\partial \ln bf_t}\right)\left(\frac{\tilde{c}_{i,t}}{x_{i,t}}\right) + \left(\frac{\partial \ln x^*_{i,t}}{\partial \ln M^*_t}\right)\left(\frac{\partial \ln M^*_t}{\partial \ln bf_t}\right)\left(\frac{x^*_{i,t}}{x_{i,t}}\right).$$

The GAI model yields an indirect elasticity consisting of the product of a reallocation effect of pre-committed expenditure $\partial \ln M^*_t / \partial \ln bf_t = (bf_t / M^*_t)(-\sum_{j=1}^{N} p_{j,t}\phi_{j0})$ and a supernumerary expenditure effect, $\partial \ln x^*_{i,t} / \partial \ln M^*_t = (1 + \beta_i / w^*_{i,t})$. Marginal changes in food safety information for beef trigger a reallocation from pre-committed expenditure to supernumerary expenditure, which in turn induces a supernumerary expenditure effect on supernumerary quantities. Due to this indirect elasticity, the sign of the total elasticity cannot be inferred from the sign of the direct elasticity.[26]

The Marshallian own-price elasticities of demand in the preferred model (column 4) were estimated to be –0.924 for beef, –0.701 for pork, and –0.328 for poultry. These estimates fall within the ranges reported in a recent search of published price elasticities of meat demand by U.S. Environmental Protection Agency (EPA) (table 3–2 of −2.59 to −0.15 for beef, −1.234 to −0.070 for pork, −1.250 to −0.104 for broilers, and −0.680 to −0.372 for turkey. The model is also quite consistent with theory, with 98.59% of the observations satisfying the curvature requirements of negative semidefiniteness of the Slutsky matrix. Interestingly, comparisons across the rows of table 4 reveals that estimated price and

---

[24] The translating approach is flexible by not imposing any restrictions on the *direct* responses, therefore it is possible for all of the coefficients on say beef (the ϕ_{i0}'s) to be negative. Despite this flexibility for the direct responses, the *total* responses must still satisfy adding-up across equations (i.e., $\sum_{i=1}^{N} w_i \psi_{ik} = 0 \,\forall k$ see (12) for a definition of ψ_{ik}).

[25] The Marshallian price and expenditure elasticities were calculated using the following formula's

$$\eta_{ij} = -\delta_{ij} + \left(\frac{1}{Mw_i}\right)\left[c_i p_i (1 - w^*_i) + M^* \left(\gamma_{ij} - \beta_i \left\{\frac{c_i p_i}{M^*} + \alpha_i + \sum_{j=1}^{N} \gamma_{ij} \ln p_j\right\}\right)\right]$$

and

$$\eta_{iM} = 1 + \left[\frac{1}{M}\left(-c_i p_i + (M - M^*) w^*_i\right) + \beta_i\right] \Big/ w_i$$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ for $i = j$, $\delta_{ij} = 0$ for $i \neq j$). The formula for η_{ij} corresponds with the formula for the AIDS model in table 1 in Green and Alston when $c_i = 0 \,\forall i$. The Hicksian price elasticities were calculated using the elasticity form of the Slutsky equation ($\varepsilon_{ij} = \eta_{ij} + w_j \eta_{iM}$).

[26] See footnote 24.

Table 4. Estimated Price, Expenditure, and Food Safety Elasticities with Alternative Autocorrelation Corrections

	No Food Safety Variables			With Food Safety Variables		
	N–R$^{\text{matrix}}$	D–R$^{\text{matrix}}$	F–R$^{\text{matrix}}$	N–R$^{\text{matrix}}$	D–R$^{\text{matrix}}$	F–R$^{\text{matrix}}$
Marshallian Price						
η_{bb}	−0.907	−0.899	−0.937	−0.924	−0.911	−0.922
η_{bp}	−0.115	−0.123	−0.126	−0.104	−0.111	−0.112
η_{bc}	−0.087	−0.121	−0.108	−0.076	−0.083	−0.082
η_{pb}	−0.245	−0.174	−0.118	−0.243	−0.240	−0.223
η_{pp}	−0.737	−0.692	−0.699	−0.701	−0.688	−0.687
η_{pc}	−0.260	−0.232	−0.188	−0.320	−0.305	−0.297
η_{cb}	0.286	0.117	0.160	0.341	0.294	0.299
η_{cp}	−0.095	−0.136	−0.115	−0.167	−0.168	−0.166
η_{cc}	−0.384	−0.341	−0.439	−0.328	−0.334	−0.350
Expenditure						
η_{bM}	1.109	1.143	1.171	1.105	1.105	1.115
η_{pM}	1.243	1.098	1.005	1.264	1.233	1.206
η_{cM}	0.192	0.361	0.394	0.154	0.208	0.217
Hicksian Price						
ε_{bb}	−0.323	−0.302	−0.323	−0.342	−0.330	−0.335
ε_{bp}	0.205	0.207	0.211	0.214	0.207	0.209
ε_{bc}	0.119	0.095	0.112	0.129	0.123	0.126
ε_{pb}	0.384	0.386	0.393	0.401	0.388	0.391
ε_{pp}	−0.376	−0.373	−0.407	−0.334	−0.330	−0.337
ε_{pc}	−0.008	−0.013	0.014	−0.066	−0.058	−0.055
ε_{cb}	0.365	0.286	0.342	0.395	0.376	0.385
ε_{cp}	−0.036	−0.029	0.003	−0.118	−0.103	−0.098
ε_{cc}	−0.329	−0.257	−0.345	−0.277	−0.273	−0.287
			Food Safety			
Direct Effect						
$\omega_{b,bf}$	–	–	–	−1.44E-02	−1.56E-02	−1.58E-02
$\omega_{b,pk}$	–	–	–	−1.34E-03	2.72E-04	−1.98E-04
$\omega_{b,py}$	–	–	–	−1.89E-05	1.58E-03	1.62E-03
$\omega_{p,bf}$	–	–	–	−4.30E-02	−4.27E-02	−4.22E-02
$\omega_{p,pk}$	–	–	–	−1.31E-02	−1.11E-02	−1.10E-02
$\omega_{p,py}$	–	–	–	2.04E-02	2.13E-02	2.14E-02
$\omega_{c,bf}$	–	–	–	−2.88E-03	−4.57E-03	−4.64E-03
$\omega_{c,pk}$	–	–	–	1.79E-03	1.97E-03	1.55E-03
$\omega_{c,py}$	–	–	–	−2.50E-02	−2.24E-02	−2.24E-02
Total Effect						
$\psi_{b,bf}$	–	–	–	1.33E-03	1.13E-03	1.08E-03
$\psi_{b,pk}$	–	–	–	−9.22E-03	−9.08E-03	−9.09E-03
$\psi_{b,py}$	–	–	–	8.53E-03	8.69E-03	8.84E-03
$\psi_{p,bf}$	–	–	–	1.64E-03	2.14E-03	1.95E-03
$\psi_{p,pk}$	–	–	–	−5.51E-03	−5.91E-03	−5.48E-03
$\psi_{p,py}$	–	–	–	3.60E-03	3.10E-03	2.93E-03
$\psi_{c,bf}$	–	–	–	−3.51E-04	−9.52E-05	−1.51E-04
$\psi_{c,pk}$	–	–	–	1.54E-02	1.44E-02	1.42E-02
$\psi_{c,py}$	–	–	–	−2.04E-02	−1.95E-02	−1.91E-02
P_{NSD}	88.73	100.00	98.59	98.59	98.59	98.59

Notes: η_{ij} and ε_{ij} represent the Marshallian and Hicksian price elasticities of demand for the *i*th good with respect to the *j*th price, and η_{iM} is expenditure elasticities for the *i*th good, where $i, j =$ b for beef, p for pork, and c for poultry. $\omega_{i,k}$ measures the percentage change in the pre-committed quantity of the *i*th good in response to a 1% increase in the *k*th food safety variable, where $k = bf$ for beef, pk for pork, and py for poultry food safety, respectively. $\psi_{i,k}$ measures the percentage change in the total quantity demanded of the *i*th good in response to a 1% increase in the *k*th food safety variable. P_{NSD} is the percentage of observations that satisfy the curvature requirements of negative semidefiniteness of the Slutsky matrix. Estimates shown are the sample means of the elasticities computed at every data point using predicted expenditure shares.

expenditure elasticities appear to be quite robust across specification choices concerning autocorrelation and whether food safety variables are incorporated.

Direct Effects

The estimated direct economic effects of the food safety variables are noticeably small in comparison to price and expenditure effects.[27] The own-direct elasticity on beef indicates that there would be a 0.144% decline in the pre-committed quantity of beef in response to a 10% increase in the beef food safety index. Based on the average $\tilde{c}_{b,t}$ of 16.616 pounds per person, this elasticity implies that only a decline of 0.024 pounds per person would occur as a result of a 10% increase in the beef food safety index. The own-direct elasticity on poultry indicates that there would be a 0.250% decline in the pre-committed quantity of poultry in response to a 10% increase in the poultry food safety index. Based on the average $\tilde{c}_{c,t}$ of 15.434 pounds per person, this direct effect for poultry represents a decline of 0.039 pounds per person would occur as a result of a 10% increase in the poultry food safety index. This is larger than the own-direct effect for beef (about 1.7 times) implying that the pre-committed quantities of poultry are more susceptible to food safety events than beef pre-committed quantities. Pork demand has the smallest own-direct elasticity, a 0.13% decline in the pre-committed quantity of pork would occur in response to a 10% increase in the pork food safety index. Interestingly, the direct-cross elasticities from beef food safety (−0.043) and poultry food safety (0.020) on pork demand not only have alternative impacts (differ in sign), but they are also larger in magnitude than the direct own-effect on pork demand (−0.013). These different direct own- and cross-commodity impacts from food safety information, highlight the virtue of measuring separately food safety impacts and allowing for cross-commodity effects.

A final important finding concerning the estimated own-direct food safety elasticities relates to their variation over the sample period. While the reported averages are small, there are periods where significantly larger negative shocks occur relative to the reported averages. These larger shocks are short-lived and coincide with periods of large increases in the food safety indices. Examples of these extremes are in 1996(2) when the own-direct food safety elasticity for beef ($\omega_{b,bf}$) is −0.112 (7.7 times larger than the average), in 1999(2) when the own-direct food safety elasticity for pork ($\omega_{p,pk}$) is −0.086 (6.6 times larger than the average), and in 1997(4) when the own-direct food safety elasticity for poultry is −0.082 ($\omega_{c,py}$) (3.3 times larger than the average). The magnitude of these extreme own-direct effects exemplify the *relatively* large quarterly shocks that can occur. Nonetheless, these extremes remain small compared to price and expenditure effects. In each case these extremes revert back to the small and mildly negative trending estimated effects over the sample, with apparently no lagged effects on demand.

Total Effects

While the direct effects provide an estimate of a "pure" food safety effect, the total effect accounts for both direct and indirect food safety effects. A comparison of the direct and total own-effect elasticities in table 4 reveals that in some cases, more specifically for beef, there are important indirect effects. The indirect effect is made up of two components, the supernumerary and re-allocation effects as described in equation (12). The re-allocation elasticities are globally positive for beef and pork, and alternating in sign (but small) for poultry food safety with averages of 0.201 for beef, 0.039 for pork, and −0.005 for poultry. The relative magnitudes of these reallocation elasticities are important with beef overshadowing pork and poultry, helping to identify differences in the observed direct and total own-effects. The supernumerary expenditure effects further influence the indirect elasticity. The averages of these effects over the sample are 1.046 for beef, 0.633 for pork, and −0.09 for poultry. The elastic beef supernumerary effect multiplies and magnifies the positive and dominant beef reallocation effect, whereas the inelastic pork and poultry dampen the less prominent reallocation elasticities for pork and poultry. Consequently, the beef indirect effect dominates the lesser pork and negligible poultry indirect effects (meaning that pork and poultry events that lead to decreases in their respective pre-committed

---

[27] The statistical significance of each of the direct food safety elasticities can be inferred from the coefficient estimates that measure the separate effects (i.e, the ϕ_{k0}'s, π_{k0}'s, and κ_{k0}'s). McCloskey argues that an insightful analysis should extend beyond statistical significance and include some discussion of the magnitude of the estimated economic effects—the focus of much of the remainder of this section.

consumption levels effectively induce a reallocation of supernumerary expenditure to beef).

The total own-pork and -poultry food safety elasticities (table 4, column 4) are globally non-positive with averages of –0.0055 ($\psi_{p,pk}$) and –0.020 ($\psi_{c,py}$), respectively. These small differences in magnitude between the direct and total own-effects reflect the small indirect effects for pork and poultry food safety. In comparison, the total own-beef food safety elasticity alternates in sign over the sample with an average of 0.0013 ($\psi_{1,bf}$). This alternating in sign can be attributed to large positive indirect effects for beef that in some quarters more than offset the negative direct effect.[28] Further inspection of this total own-beef food safety elasticity reveals a median value of 0.0007 over the period 1982(1)–1995(4) and a median of –0.0027 over the period 1996(1)–1999(3). Reflecting back on figure 1 reveals, prior to 1996, a smaller number of food safety events for beef (with notable exceptions in 1990(2) and 1993(1)) relative to poultry. In these circumstances the outcome was a reallocation of supernumerary expenditure to beef, which explains why the small negative own-direct effects were dominated by the positive own-indirect effects for beef. After 1996, corresponding with the beginning of the proliferation of the number of food safety articles for beef, the larger negative own-direct effect tended to more consistently outweigh the counteracting positive own-indirect effect as characterized by the median value of –0.0027 over the period 1996(1)–1999(3).

A characterization of the total cross-effect elasticities is that most infer substitution away from the meat tied to food safety events toward other meats. The total cross-effects that were positive included poultry food safety on beef demand (0.0085) and pork demand (0.0036), pork food safety on poultry demand (0.0154) (the largest of the total cross-commodity effects), and beef food safety on pork demand (0.0016). Total cross-effects that were negative, inferring adverse spillover effects to other meats from food safety events, included pork food safety on beef demand (–0.0092) and beef food safety on poultry demand (–0.0004) (the smallest in magnitude of the total cross-effects). Comparing the magnitude of these total cross-effects to the total-own effects reveals that although none are as prominent as the total own-effect on poultry (–0.0204), the total cross-effect from pork food safety on poultry demand (0.0154) and total cross food safety elasticities from pork food safety (–0.0092) and poultry food safety (0.0085) on beef demand are all larger than the total-own effects on pork and beef. This comparison further highlights the importance of allowing for cross-commodity effects.

Demand Response Simulations

To further illustrate the magnitude of the impacts of food safety concerns on demand, separate simulations for each of the own-demand responses were carried out using the preferred estimated demand model.[29] The own-demand response to food safety concerns was quantified by comparing the own-predicted average quarterly demand and simulated average quarterly demand for different years within the sample period. The reported simulated demands (the average of quarterly predicted own-demand within a given year) were calculated by holding each own-food safety index constant, in separate simulations, at the average quarterly values for the initial year of the sample (1982), respectively. The results of this simulation shown in table 5 reveal the decline in average quarterly beef demand would have been 2.21% less between the period 1982 and 1998, if food safety concerns for beef had remained at 1982 levels. Furthermore, the increases in pork and poultry demand would have been 0.99 and 6.88% more, respectively, between the period 1982 and 1998 if food safety concerns for pork and poultry had remained at 1982 levels. These simulated results further illustrate the economic importance of food safety concerns as being modest on average over the study period, with the own-effects for poultry more prominent than beef and pork (negligible).

One other characteristic of the estimated demand response to food safety further illustrated in the simulations is the finding that in specific periods the demand response can be significantly larger than the reported averages over the sample. These instances coincide with significant changes in the food safety indices. For example, the difference in

---

[28] The median of this total own-beef food safety elasticity was 0.0006 and reflects that fact that there is a large positive outlier in 1996(2), which coincided with a spike in the beef food safety index of 1,283 (the maximum value for this index over the sample).

[29] We wish to acknowledge the suggestion by an anonymous referee to perform these simulations to further illustrate the economic significance of these results.

Table 5. Simulated Average Quarterly Own-Demand Response to Food Safety Concerns for Beef, Pork, and Poultry Demand

	Beef Demand			Pork Demand			Poultry Demand		
Year	Fitted (a)	Simulated[a] (b)	Δ (a)–(b)	Fitted (a)	Simulated[b] (b)	Δ (a)–(b)	Fitted (a)	Simulated[c] (b)	Δ (a)–(b)
				lbs/per person					
1982	19.28	19.28	0.00	12.28	12.28	0.00	14.98	14.98	0.00
1990	16.95	16.87	0.08	12.39	12.45	−0.06	19.87	20.30	−0.42
1998	16.72	17.14	−0.43	12.78	12.90	−0.12	22.84	23.87	−1.03
Differences									
				lbs/per person					
Δ (1990–1982)	−2.33	−2.41	0.08	0.10	0.17	−0.06	4.90	5.32	−0.42
Δ (1998–1982)	−2.56	−2.13	−0.43	0.50	0.62	−0.12	7.86	8.89	−1.03
				Percent Change					
Δ (1990–1982)	−12.08	−12.50	0.41	0.85	1.35	−0.50	32.71	35.52	−2.81
Δ (1998–1982)	−13.28	−11.06	−2.21	4.03	5.03	−0.99	52.52	59.39	−6.88

[a] Fitted values with the beef food safety index (bfa) constant at 1982 average level.

[b] Fitted values with the pork food safety index (pka) constant at 1982 average level.

[c] Fitted values with the poultry food safety index (pya) constant at 1982 average level.

predicted and simulated own-demand response to poultry food safety was as much as −1.64 pounds per person (or a 6.9% decline) in 1997(4) coinciding with the maximum of the poultry food safety index in that quarter. The average difference in own-demand response over the sample was only −0.41 pounds person per quarter. Similarly for beef, the difference in own-demand response to beef food safety was as much as −0.94 pounds per person (or a 5.9% decline) in 1997(1) coinciding with the large increase in the beef food safety index for several periods around that time. The average difference in own-demand response over the sample was only −0.08 pounds person per quarter. Overall, these significant deviations suggest the reported average effects should not be misconstrued as meaning that the immediate response to a particular event might not be economically significant. Rather the results indicate the demand response can be significantly larger than the reported average effects when a large increase in the food safety index occurs, but this more economically significant effect is not sustained past the large increase in food safety information.

Conclusion

This article develops an economic and empirical framework to investigate whether food safety information surrounding beef, pork, and poultry has impacted meat consumption in the United States over the last several decades. Pre-committed levels of meat consumption were determined to exist with consumers requiring approximately 15.2 pounds of beef, 7.3 pounds of pork, and 10.4 pounds per quarter that are impacted by seasonal factors, time trends, and by food safety information. Hypothesis tests reveal coefficients measuring the own- and cross-commodity effect from food safety variables are jointly statistically significant from zero. The impact of the food safety information on demand was determined to be limited to a contemporaneous effect.

The direct own-demand response food safety elasticities on pre-committed quantities (negative) indicate publicized food safety information is detrimental toward demand. The direct cross-demand response food safety elasticities reveal substitution and spillover adverse effects on to other meats pre-committed quantities. A comparison of the direct- and total-effect elasticities reveals important indirect effects from asymmetric changes in supernumerary expenditures. There is a large indirect effect on beef relative to pork and poultry, meaning that beef, pork, and poultry events that lead to decreases in their respective pre-committed consumption levels effectively induce a reallocation of supernumerary expenditure towards beef. The magnitude of the re-allocation effects imply that on average the negative own-direct effect from beef safety is more than offset, and results in, a small positive own-total effect. In contrast, because of the relatively small reallocation effects for pork and poultry, the negative own-direct and total effects from pork and poultry are very similar.

Although taking account of own- and cross-commodity effects was found to be *statistically* important, the estimated average demand response to food safety events over the study period were found to be *economically* small, especially in comparison to price effects, and to previous estimates of other health issues concerning consumption of meat such as health information. Poultry demand appears to be more responsive to food safety concerns compared to beef and pork demand. Finding adverse affects from food safety events on demand is consistent with the event study results of Thomsen and McKenzie that found losses to share holders in processing firms reflecting anticipation of this adverse effect. It remains the topic of future research to compare whether their estimates of the magnitudes of the losses to share holders (between 1.5 and 3%) resemble the estimated adverse demand response in this research. These results are also consistent with the findings of Dahlgran and Fairchild that adverse publicity concerning *salmonella* in chicken depressed demand but the magnitude and duration of this impact was small and short-lived.

For policy-makers and others in the U.S. meat industry concerned with assessing the impacts of food safety events on consumption, this research provides some useful input to priority settings in relation to the importance of factors that may affect demand for meat. Adverse publicity concerning food safety concerns do have *statistically* important own- and cross-commodity impacts on demand for meat in the United States but the average impact of these effects have been *economically* small over the last several decades. This average small impact on demand can be attributed to the average amount of adverse food safety information being small and there was no evidence of cumulative effects (no lagged effects on demand). There are several instances, however, where the demand response has been significantly larger than the reported averages corresponding with periods where large increase in food safety concerns occurred. The presence of periods of significantly larger demand responses can be attributed to food safety information being highly skewed temporally with shocks that are significantly larger than the average over the sample. Therefore, food safety information can be characterized as having a minor long-run impact on demand accompanied with important shocks to demand corresponding with significant food safety events. This can be contrasted with the effects of health information, which have been found to have a much larger impact on demand. This emphasizes important differences in how consumers respond to food safety and health information. The timeliness of conveying adverse effects of food safety or health information to the public, as well as the timing of unanticipated outbreaks or impacts, appears to be important determinants characterizing the differences in the demand response.

Finally, despite the encouraging results with these new data that capture food safety concerns *separately* for each meat type we must temper any conclusion drawn by the fact that the results are also conditioned on the joint hypothesis of functional form and other aspects of model specification choices. The robustness of these results, and in turn any definitive conclusions, is subject to even further scrutiny across alternative model specification choices and more refined data concerning measuring food safety concerns which remain the topic of further investigation. Natural extensions concerning model specification might include employing alternative functional forms, for example, such as the Rotterdam model (Theil) or the CBS or NBR models (Lee, Brown, and Seale), to investigate the further robustness of the results to functional form choices. Natural extensions concerning food safety indices might include more refined data on measuring food safety concerns such as taking into account other media information or using cross-sectional or panel data.

[Received April 2001;
accepted June 2003.]

References

Alston, J.M., J.A. Chalfant, and N.E. Piggott. "Incorporating Demand Shifters in the Almost Ideal Demand System." *Economic Letters* 70(2001):73–78.

Alston, J.M., and J.A. Chalfant. "Can We Take the Con Out of Meat Demand Studies?" *Western Journal of Agricultural Economics* 16(1991a):36–48.

——. "Unstable Models From Incorrect Forms." *American Journal of Agricultural Economics* 71(1991b):1171–81.

Barten, A.P. "The Systems of Consumer Demand Functions Approach: A Review." *Econometrica* 45(1977):23–51.

Berndt, E.R., and N.E. Savin. "Evaluation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances." *Econometrica* 32(1975):937–57.

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

Bockstael, N.E., and K.E. McConnell. "Public Goods as Characteristics of Non-Market Commodities." *Economic Journal* 103(1993):1244–57.

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

Brester, G.W., and T.C. Schroeder. "The Impacts of Brand and Generic Advertising on Meat Demand." *American Journal of Agricultural Economics* 77(1995):969–79.

Brown, J.D. "Effect of a Health Hazard Scare on Consumer Demand." *American Journal of Agricultural Economics* 51(1969):676–78.

Burton, M., and T. Young. "The Impact of BSE on the Demand for Beef and Other Meats in Great Britian." *Applied Economics* 28(1996):687–93.

Burton, M., T. Young, and R. Cromb. "Meat Consumer's Long-Term response to Perceived Risks Associated with BSE in Great Britain." *Cahiers, d'Economie-et-Sociologie-Rurales* 50 (1999):7–19.

Capps, O, Jr., and J.D. Schmitz. "A Recognition of Health and Nutrition Factors in Food Demand Analysis." *Western Journal of Agricultural Economics* 16(1991):21–35.

Carson, R., N.E. Flores, and W.M. Hanemann. "Sequencing and Valuing Public Goods." *Journal of Environmental Economics and Management* 36(1998):314–23.

Chalfant, J.A., and J.M. Alston. "Accounting for Changes in Taste." *Journal of Political Economy* 96(1998):391–410.

Chavas, J.P. "Structural Change in the Demand for Meat." *American Journal of Agricultural Economics* 65(1983):148–53.

Centers for Disease Control and Prevention (CDC). Available at http://www.cdc.gov/ncidod/diseases/foodborn/foodborn.htm, December 1999.

Crafton, S.E., G.E. Hoffer, and R.J. Reilly. "Testing the Impact of Recalls on the Demand for Automobiles." *Economic Inquiry* 19(1981):694–703.

Dahlgran, R.A. "Complete Flexibility Systems and the Stationarity of U.S. Meat Demand." *Western Journal of Agricultural Economics* 12(1987):152–63.

Dahlgran, R.A., and D.G. Fairchild. "The Demand Impacts of Chicken Contamination Publicity—A Case Study." *Agribusiness* 18(1987):459–74.

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

Eales, J.S., and L.J. Unnevehr. "Demand for Beef and Chicken Products: Separability and Structural Change." *American Journal of Agricultural Economics* 70(1988):521–32.

——. "Simultaneity and Structural Change in U.S. Meat Demand." *American Journal of Agricultural Economics* 75(1993):259–68.

Flake, O.L., and P.M. Patterson. "Health, Food Safety, and Meat Demand." Contributed paper, American Agricultural Economics Association annual meetings, Nashville, TN. August 1999.

Food Safety Inspection Service (FSIS). *Meat and Poultry Product Recalls: OPHS Database and Recall Notification Reports*. Available at http://www.fsis.usda.gov/OA/news/yrecalls.htm#RNR.

Foster, W., and R.E. Just. "Measuring Welfare Effects of Product Contamination with Consumer Uncertainty." *Journal of Environmental Economics and Management* 17(1989):266–83.

Gao, X.M., and J.S. Shonkwiler. "Characterizing Taste Change in a Model of U.S. Meat Demand: Correcting for Spurious Regression and Measurement Errors." *Review of Agricultural Economics* 15(1993):313–24.

Gao, X.M., and T. Spreen. "A Microeconometric Analysis of the United-States Meat Demand." *Canadian Journal of Agricultural Economics* 42(1994):397–412.

Green, R., and J.M. Alston. "Elasticities in AIDS Models." *American Journal of Agricultural Economics* 72(1990):442–45.

Hayes, D., J. Shogren, S. Shin, and J. Kliebenstein. "Valuing Food Safety in Experimental Auction Markets." *American Journal of Agricultural Economics* 77(1995):40–53.

Holt, M.T., and B.K. Goodwin. "Generalized Habit Formulation in an Inverse Almost Ideal Demand System: An Application to Meat Expenditures in the U.S." *Empirical Economics* 22(1997):293–320.

Hooker, N.H., and J.A. Caswell. "Regulatory Targets and Regimes for Food Safety: A Comparison of North American and European Approaches." In J.A. Caswell, ed. *Economics of Reducing Health Risk From Food*. Storrs CT: Food Marketing Policy Center, 1995, pp. 3–17.

Johnson, F.R. "Economic Cost of Misinforming about Risk: The EDB Scare and the Media." *Risk Analysis* 8(1988):261–69.

Jensen, H.H., and J.R. Schroeter. "Television Advertising and Beef Demand: An Econometric Analysis of "Split-Cable" Household Panel

Scanner Data." *Canadian Journal of Agricultural Economics* 40(1992):271–94.

Kinnucan, H.W., H. Xiao, C.-J. Hsia, and J.D. Jackson. "Effects of Health Information and Generic Advertising on U.S. Meat Demand." *American Journal of Agricultural Economics* 79(1997):13–23.

Lee, J., M.G. Brown, and J.L. Seale "Model Choice in Consumer Analysis: Taiwan, 1970–89." *American Journal of Agricultural Economics* 76(1994):504–12.

Lusk, J.L., and T.C. Schroeder. "Effects of Meat Recalls on Futures Market Prices." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL, April 2000.

Madden, P. "A Generalization of the Hicksian q Substitutes and Complements with Application to Demand Rationing." *Econometrica* 59(1991):1497–1508.

McCloskey, D.N. "The Loss Function Has Been Mislaid—The Rhetoric of Significance Tests." *American Economic Review* 75(1985):201–5.

McGuirk, A., P. Driscoll, J. Alwang, and H. Huang. "System Misspecification Testing and Structural Change in Demand for Meats." *Journal of Agricultural and Resource Economics* 20(1995):1–21.

McKenzie, A.M., and M.R. Thomsen. "The Effect of E. Coli 0157:H7 on Beef Prices." *Journal of Agricultural and Resource Economics* 26(2001):431–44.

Mojduszka, E.M., and J.A. Caswell. "A Test of Nutritional Signaling in Food Markets Prior to Implementation of Mandatory Labeling." *American Journal of Agricultural Economics* 82(2000):298–309.

Moschini, G., and K.D. Meilke. "Parameter Stability and the U.S. Demand for Beef." *Western Journal of Agricultural Economics* 9(1984):271–82.

——. "Modeling the Pattern of Structural Change in U.S. Meat Demand." *American Journal of Agricultural Economics* 71(1989):253–61.

Moschini, G., D. Moro, and R.D. Green. "Maintaining and Testing Separability in Demand Systems." *American Journal of Agricultural Economics* 71(1994):61–73.

Piggott, N.E. "The Nested PIGLOG Model: An Application to U.S. Food Demand." *American Journal of Agricultural Economics* 84(2003):1–15.

Piggott, N.E., J.A. Chalfant, J.M. Alston, and G.R. Griffith. "Demand Response to Advertising in the Australian Meat Industry." *American Journal of Agricultural Economics* 78(1996):268–79.

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

Robenstein, R.G., and W.N. Thurman. "Health Risk and the Demand for Red Meat: Evidence from Futures Markets." *Review of Agricultural Economics* 18(1996):629–41.

Smith, M.E., E.O. van Ravenswaay, and S.R. Thompson. "Sales Loss Determination in Food Contamination Incidents: An Application to Milk Bans in Hawaii." *American Journal of Agricultural Economics* 70(1988):513–20.

Theil, H. "The Information Approach to Demand Analysis." *Econometrica* 33(1965):67–87.

Thomsen, M.R., and A.M. McKenzie. "Market Incentives for Safe Foods: An Examination of Shareholder Losses From Meat and Poultry Recalls." *American Journal of Agricultural Economics* 82(2001):526–38.

Thurman, W.N. "The Poultry Market: Demand Stability and Industry Structure." *American Journal of Agricultural Economics* 69(1987):30–37.

U.S. Department of Agriculture. Economic Research Service. *Red Meats Yearbook*. Statistical Bulletin No. 921, Washington DC, 1995.

——. Economic Research Service. *Poultry Yearbook*. Statistical Bulletin No. 916, Washington DC, 1995.

U.S. Department of Environmental Protection Agency. Office of Scinece and Technology. *Economic Analysis of Proposed Effluent Limitations Guidelines and Standards for the Meat and Poultry Products Industry*. EPA-821-B-01-006, Washington DC, 2002.

van Ravenswaay, E.O., and J.P. Hoehn. "The Impact of Health Risk Information on Food Demand: A Case Study of Alar and Apples." In J.A. Caswell ed. *Economics of Food Safety*. New York: Elsevier, 1991.

Ward, R.W., and C. Lambert. "Generic Promotion of Beef: Measuring the Impact of the U.S. Beef Checkoff." *Journal of Agricultural Economics* 44(1993):456–65.

Wohlgenant, M.K. "Estimating Cross Elasticities of Demand for Beef." *Western Journal of Agricultural Economics* 10(1985):322–29.