FOOD SAFETY AND THE DEMAND FOR MEAT PRODUCTS

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ABSTRACT. *This paper estimates the impact of Escherichia coli (E. coli) O157:H7 contaminated ground beef recall events on the demand for ground beef and poultry products. While past literature has mainly analyzed media indices, singular events, or aggregate household data to measure the impact of food safety information, the present study measures the impact using confirmed multiple food safety events and disaggregated household data. The results of a random-effects Tobit model estimation suggest that E. coli O157:H7 contaminated ground beef recall events negatively impact household demand for ground beef products and positively impact household demand for poultry products in the weeks immediately following the recalls.*

I. INTRODUCTION

Unsafe contaminated food products sicken millions of individuals and lead to significant losses in life and productivity. The Centers for Disease Control and Prevention [CDC] recently estimated that foodborne disease is the cause of approximately 48 million illnesses, 128,000 hospitalizations, and 3,000 deaths annually within the United States (Scallan, et al. 2011a and 2011b). In fiscal terms, this translates to an estimated annual cost of 152 billion dollars covering medical expenditures, lost productivity, and quality-of-life losses (Scharff 2010). The majority of such disease is associated with the consumption of animal products - namely, meat, poultry, eggs, milk, and shellfish (CDC 2005). And currently, the most common bacterial foodborne pathogens are *Campylobacter*, *Salmonella*, and *Escherichia coli* [*E. coli*] *O157.H7* (CDC 2005).

Assuming consumers prefer to minimize health risks, concerns of bacterial contamination and foodborne disease have the strong potential to influence demand for animal products. For example, concerns of *E. coli* O157*:H7* beef contamination can potentially depress the demand for beef products, while simultaneously increasing the demand for close substitutes assumed to be safer by the consumer. As a result, any information regarding changes in consumer behavior in response to food safety risks is of valuable interest to both producers and regulators of the industry in order to determine the welfare benefits (losses) associated with increased (decreased) food safety measures.

Indeed, over the past several decades, an extensive and growing body of literature investigating the impact of food safety information on the demand for food products has emerged. Many of these studies have measured the impact of food safety information with the use of media indices – indices constructed based on the number of published newspaper articles pertaining to food safety and product contamination over a specified time frame (Smith, et al. 1988; Burton and Young 1996; Dahlgran and Fairchild 2002; Piggott and Marsh 2004; Coffey, et al. 2011). Alternatively, other studies have investigated changes in consumer demand before and after a single food safety shock, such as a major publicized contamination event (Brown 1969; Foster and Just 1989; Shimshack, Ward and Beatty 2007). Generally, both types of studies – those using media indices and those examining a single food safety event – have concluded that food safety information has a statistically significant effect on consumer demand, though the effect is often marginal and short-term.

The objective of this paper is to further investigate the effect of food safety information on the demand for meat products. But rather than estimate the effect of a time-continuous media index or a single food safety event, this study estimates the effect of multiple food safety events varying over time and space – specifically, recalls of *E. coli O157:H7* contaminated ground beef products. Using disaggregated household demographic and purchasing data, this study effectively takes advantage of the temporal and geographic variability of *E. coli O157:H7* contaminated ground beef recalls in order to accurately measure the impact of food safety information on the demand for ground beef products. Moreover, the use of both disaggregated household purchasing data and multiple food safety event data facilitates statistical analyses that have not previously been employed in the context of food safety.

II. Background

Within the United States, the two federal authorities responsible for food safety are the Department of Agriculture's Food Safety and Inspection Service [FSIS] and the Department of Health and Human Services' Food and Drug Administration [FDA]. The FSIS inspects and regulates meat, poultry, and processed egg products, while the FDA inspects and regulates all other food products. In order to ensure that the nation's meat and poultry products are safe, wholesome, and accurately labeled, the FSIS coordinates and oversees the recalls of meat products that may cause increased health risks.[1]

Health risks are usually discovered one of three ways: the manufacturer or distributer discovers the presence of a contaminant through testing; an FSIS field inspector discovers the presence of a contaminant through testing; or a consumer illness prompts an investigation and the source of illness is traced back to a specific product and manufacturer. As soon as the threat is discovered and the manufacturer decides to recall the contaminated meat or poultry product, the FSIS determines the severity of the threat posed by the contaminated product and assigns the recall one of three classifications: Class I, II, or III. Class I represents a health hazard situation in which there is reasonable probability that consuming the product will cause health problems or death; Class II represents a potential health hazard situation in which there is a remote probability of adverse health consequences from the consumption of the product; and Class III represents a situation in which consuming the product will not cause adverse health consequences. A product recall due to *E. coli O157:H7* contamination is always classified as Class I as consumption can lead to severe and bloody diarrhea; and in three to five percent of

[1]Note that the initial decision to recall is that of the manufacturer or distributor. However, if a manufacturer or distributor refuses to recall a contaminated product, FSIS has the legal authority to detain and seize the contaminated product in question.

cases, consumption can even lead to temporary anemia, profuse bleeding, and kidney failure (CDC 2005).

Once the recall is assigned a severity classification, the FSIS issues a press release to vendors and media outlets in the areas where the product was distributed. As an example, the text of a 2007 press release announcing the recall of *E. coli O157:H7* contaminated ground beef products is included in Appendix A. The press release includes the date of the FSIS recall announcement, a description of the product recalled, the contaminant involved, the number of pounds recalled, the distribution of the contaminated product, information on how the contaminant was discovered, and the severity classification. In addition, the press release also includes information as to whether the contaminated product was available for retail purchase, or distributed to restaurants and institutional facilities (schools, prisons, nursing homes, etc.).

Following the press release, vendors of the contaminated product are instructed to remove the product from the market so that it is no longer available for purchase or consumption. Likewise, consumers are instructed to check any products they may have purchased before the recall announcement and determine whether their products match the description of the contaminated product. If the description is a match, consumers are strongly encouraged to discard the product or return the product for a refund. If a consumer has already consumed the product, the consumer is instructed to closely monitor his or her health and seek any necessary medical attention.

The present study focuses on the years 2007 and 2008. During this time, there were a total of 112 meat product recalls overseen by the FSIS; 38 of which were the result of *E. coli O157:H7* ground beef contamination. Details of these recalls are summarized in Table 1. Of the 38 ground beef products recalled due to *E. coli O157:H7* contamination, 23 were available for retail consumer purchase. Details of these recalls are summarized in Tables 2 and 3. As this study is primarily concerned with household purchases of retail goods in response to recalls, retail recalls as opposed to recalls of restaurant and institutional products are, henceforth, the focus of the current paper.[2] The largest recall during this period – 21.7 million pounds of *E. coli O157:H7* contaminated ground beef products – occurred on September 25, 2007. At the time, it was the second largest meat recall in the history of the United States, and the manufacturer – once the largest manufacturer of frozen hamburgers – subsequently filed for bankruptcy and ceased operations.

As previously emphasized, the greatest advantage of using multiple recall events to measure the impact of food safety information is the temporal and geographic variability. That is, temporal variability allows for the analysis of multiple recall events over time, and geographic variability allows for the analysis of a regional recall on the impacted region as compared with the rest of the nation. Of the 17 retail *E. coli O157:H7* contaminated ground beef products recalled in 2007, only five were distributed nationwide, and of the six retail *E. coli O157:H7* contaminated ground beef products recalled in 2008, only one was distributed nationwide. The remaining recalled products were distributed to regions identified by the FSIS, and the size of the affected regions ranged from a single city or county to several states. Specifically, the average regional recall impacted five states, while the most expansive regional recall impacted twelve. Further details regarding the recalls and the geographic and temporal variability are presented in Tables 3, 4, and 5.

III. LITERATURE

Past studies investigating the impact of food safety information on consumer demand can usually be classified into one or more of three groups: studies that use continuous-time food

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[2] When all 38 recalls of *E. coli O157:H7* contaminated ground beef products were considered, the final results proved to be insignificant and uninteresting.

safety media indices, studies that analyze the impact of a single food safety event, and studies that use data aggregated across consumers and across time. The present paper deviates from the established literature by analyzing disaggregated household panel data so as to examine the impact of multiple food safety events that vary both temporally and geographically.

Historically, analysis of food safety media indices and aggregate consumer demand has been the most popular strategy in investigating the impact of food safety information. Smith, van Ravenswaay, and Thompson (1988) considered the effect of media publicity following the 1982 heptachlor contamination of fresh milk in Oahu, Hawaii. Using aggregate monthly data on milk purchases, they concluded food safety information had a statistically significant negative effect on milk purchases. Similarly, Burton and Young (1996) found that publicity of *Bovine Spongiform Encephalopathy* [BSE] in Great Britain had a significant effect on consumer expenditure among meats, with the market share for beef declining by 4.5 percent by the end of 1993. Dahlgran and Fairchild (2002) concluded that adverse publicity regarding *Salmonella* indeed depressed demand for poultry, though the magnitude of the effect was small, less than one percent, with consumers reverting back to previous consumption behavior in several weeks. Lastly, Piggott and Marsh (2004), using multiple meat-specific media indices for beef, pork, and poultry, analyzed the impact of food safety information on the demand for beef, pork, and poultry. They found that the average demand response was small, though statistically significant, in the short-run and there was no lagged effect in the long-run.

Most recently, however, Coffey, Schroeder, and Marsh (2011) analyzed disaggregated household panel data collected by the National Purchase Diary Group to determine the impact of food safety media indices. Similar to the methods of Piggott and Marsh, Coffey, et al. created several meat-specific media indices to estimate the effect of media on 12 different conventional beef, pork, poultry, and fish products. Ultimately, they found the food safety media index elasticities to be small, and for the most part, not statistically significant. The one exception was the elasticity of pork chops with respect to the pork food safety index.

The use of continuous-time media indices, however, limits analyses in that it does not necessarily capture the effect of actual food safety events on consumer demand. For one, the use of media indices often implicitly assumes that consumers nationwide are equally affected by the same media information, thereby effectively diminishing any impact of a localized food safety event on local consumers. Secondly, consumers may perceive media reports to be a source of biased information regarding food quality, whereas actual food safety events may be perceived as a source of unbiased information. If so, media indices could potentially understate any impact on consumer demand. Lastly, as Marsh, Schroeder, and Mintert (2004) acknowledged, there are likely diminishing returns to multiple media reports on a single event; therefore, media indices would again underestimate any impact of food safety information on consumer demand.

Alternatively, other studies have analyzed the impact of a single food safety event on consumer demand. Foster and Just (1989) measured the consumer welfare loss due to nondisclosure of information following the 1982 heptachlor contaminated milk crisis in Hawaii using the same aggregate consumption data as Smith, van Ravenswaay, and Thompson. In doing so, they first demonstrated using a dummy variable approach that the crisis had a sizable and statistically significant negative impact on milk consumption. Shimshack, Ward, and Beatty (2007) examined responses to a national FDA advisory urging at-risk consumers (i.e., households with young children, nursing mothers, and pregnant women) to limit store-bought fish consumption due to possible methyl-mercury exposure. Analyzing disaggregated household panel data and employing both parametric and non-parametric methods, they found that some targeted consumers significantly reduced canned fish purchases as a result of the advisory. They also found evidence of unintended spillover effects of decreased fish consumption among households that were not targeted by the advisory. Nonetheless, studies such as these, which focus on a single unique food safety event, may not accurately represent the impact of recurrent food safety events, such as recalls, which may occur several times within a few years.

Therefore, to address these shortcomings, Marsh, Schroeder, and Mintert (2004) analyzed the impact of meat product recalls on consumer demand. In doing so, the authors argued that consumers perceive recall events as an unbiased proxy for low quality. Furthermore, they conducted the same analysis with media indices instead of recalls to determine any differences in strategy. Their results indicated that recall events indeed significantly impacted aggregate demand for meat products, while media reports did not. Similarly, Tonsor, Mintert, and Schroeder (2010) also examined the impact of recalls on aggregate quarterly demand for meat products. They concluded that a 10 percent increase in beef recalls reduced aggregate beef demand by 0.2 percent and increased poultry demand by 0.2 percent in the long run.

Lastly, it must be noted that the majority of the mentioned studies used data aggregated across consumers and across time. However, aggregation of data across households reduces the amount of information available from demand analysis by ignoring variability in purchasing behavior among households. For example, any income measure included in a demand analysis using linearly aggregated data implicitly assumes that income is evenly distributed across households. If this unrealistic assumption is not met, the aggregate demand function will not represent the individual household function and parameter estimates will likely be biased (Mittelhammer, et al. 1996). Additionally, aggregation of data across time, e.g., months or quarters, further reduces the informativeness of demand analysis by ignoring or diminishing any short-run impact that may occur in the weeks immediately following the recall. Thus, to improve upon and contribute to the existing literature, this paper analyzes disaggregated household data and multiple beef product recalls that vary over time and space.

IV. ECONOMIC FRAMEWORK

Fundamental to the present analysis is the assumption that consumers derive value from food safety because it signals a lower degree of health risk. Yet perfect information regarding the safety of a given food product is rarely available. Were it available, the safety of the food product would be no different than other quality attributes, such as taste, appearance, source, etc. And a consumer would make a purchase decision based on their preferences, income, and price of the product. However, consumers often face imperfect information; that is, they are mostly uncertain regarding the safety of available food products. Thus, consumers make their choice of purchase based on their expected preferences given their knowledge and perception of the risk of contamination and risk of contracting disease. As more food safety information and resources become available through increased media and recall advisories, consumers can make more informed decisions by purchasing foods they deem to be less risky and weighing the risk against the price of the given product.

In the context of the current paper, consider a consumer who must choose how much to purchase among the following vector of goods $\boldsymbol{y}$, where y_{GB} represents ground beef, y_{NRS} represents a viable 'no-risk' substitute, and $\boldsymbol{y_x}$ represents all other goods. The consumer derives utility, $U(y_{\text{GB}}, y_{\text{NRS}}, \boldsymbol{y_x}, s)$, directly from the consumption of goods, $\boldsymbol{y}$, and his or her health, s. For simplicity purposes and without loss of generality, health, in turn, is defined as a function of the consumption quantity, y_{GB}, and quality, q_{GB}, of ground beef: $s(y_{\text{GB}}, q_{\text{GB}})$. At this stage, several assumptions are necessary regarding this utility function. Namely, the quantity of goods and the consumer's utility are positively correlated: $U_{y_i} > 0$; health and utility are positively correlated: $U_s > 0$; health and the quality of 'risky' goods are positively correlated: $s_{q_{\mathrm{GB}}} > 0$; and lastly, the consumer's utility function is concave.

The quality of the ground beef, q_{GB}, is determined by whether the product is contaminated with *E. coli O157:H7* bacteria. Of course, this information is not known to the consumer, but the consumer believes that quality is distributed according to the following cumulative distribution function conditional on his or her perception of contamination risk, r_{GB}: $F(q_{\mathrm{GB}}|r_{\mathrm{GB}})$. Thus, the consumer's expected utility maximization problem can be expressed as

$$\max_{\boldsymbol{y}} \int \dots \int U\big(y_{\mathrm{GB}},\ y_{\mathrm{NRS}}\ , \boldsymbol{y_x}, s(y_{\mathrm{GB}}, q_{\mathrm{GB}})\big)\, F(q_{\mathrm{GB}}|r_{\mathrm{GB}})$$

$$\text{subject to } I \geq p_{\mathrm{GB}} y_{\mathrm{GB}} + p_{\mathrm{NRS}} y_{\mathrm{NRS}} + \boldsymbol{p_x}' \boldsymbol{y_x} \qquad (1)$$

where $\boldsymbol{p}$ is a vector of prices corresponding to the vector of goods $\boldsymbol{y}$, and I represents the disposable income of the consumer. Solving the maximization problem yields the following Marhsallian demands for ground beef and the no-risk substitute:

$$y_{\mathrm{GB}}(\boldsymbol{p}, I, r_{\mathrm{GB}})$$

$$y_{\mathrm{NRS}}(\boldsymbol{p}, I, r_{\mathrm{GB}}). \qquad (2)$$

As a result of heightened awareness following recall events and the severity of the health consequences, recalls of ground beef products as a result of *E. coli O157:H7* contamination likely negatively influence consumer perception of ground beef quality (Marsh, et al. 2004). That is, consumers likely perceive the risk of contamination, r_{GB}, to be greater following recall events. Consequently, as consumer perception of food safety declines, the likelihood of purchasing the potentially contaminated food product also declines (Foster and Just 1989). Applying this logic to the present theoretical model, one would expect that following a recall, if the perceived risk of ground beef contamination, r_{GB}, increased, then the demand for the ground beef would subsequently decrease; otherwise stated:

$$\frac{\partial y_{\text{GB}}(\boldsymbol{p},I,r_{\text{GB}})}{\partial r_{\text{GB}}} < 0. \tag{3}$$

Conversely, it follows that an increase in the perceived risk of ground beef contamination, r_{GB}, would also lead to a subsequent increase in the demand for a no-risk substitute; otherwise stated:

$$\frac{\partial y_{\text{NRS}}(\boldsymbol{p},I,r_{\text{GB}})}{\partial r_{\text{GB}}} > 0. \tag{4}$$

Thus, empirically estimating demand functions for ground beef and a viable substitute proves to be an informative exercise in order to determine whether these predicted relationships hold in reality. Alternatively stated, an empirical analysis will test whether consumer demand for ground beef decreases following *E. coli O157:H7* contaminated ground beef recalls and whether consumer demand for a viable substitute increases.

V. Data

The primary dataset used in this analysis is the Nielsen Homescan panel - a nationwide panel of households that provide a detailed account of their retail food purchases. Households participating in the panel are provided a handheld scanner to scan the Universal Product Code [UPC] on their purchases and upload all information on a weekly basis to Nielsen Company through a landline phone or the Internet. The panel is selected to be geographically and demographically representative of the United States based on 30 different targets including location, income, race, etc. Furthermore, in order for the data of any particular household to be included in the final Nielsen Homescan dataset, the household must participate in the survey at least 10 months of a given year.

The data of household purchases include a detailed product description, date of purchase, total quantity, and total expenditure for every item purchased. Households also provide demographic data including county of residence, household composition, household size, income, education, occupation, age, and race. While Nielsen requires panelists to update their retail purchases weekly, demographic information is only updated at the beginning of each year that the household chooses to participate.

As previously stated, the years of interest are 2007 and 2008, and a biweekly periodicity was selected to reflect both the standard pay period and the average household's tendency to purchase most meat and poultry products twice a month (Moen and Capps 1988). The products chosen for analysis are ground beef and poultry (chicken and turkey), specifically packaged fresh and frozen ground beef and poultry products. Poultry was chosen as a viable substitute for ground beef based on frequency of household purchases and price.[3] Lastly, processed meat products (e.g. deli meats, frozen dinners, etc.) were not considered as it is not possible to determine the extent of processing.

The full dataset contains retail food purchase data for 74,674 households participating in the survey for some part of 2007 and 2008. However, as stated earlier, households are not required to participate for the full 12 months of a given year. While the data indicate how many months the household chose to participate within a year (10, 11, or 12), the data do not identify which months those are. Therefore, households that did not participate for a full 12 months in either 2007 or 2008 are not included in the empirical analysis; only households that participated for the

[3] Pork and non-ground beef products were also initially considered as viable substitutes. However, from the dataset comprised of 64,672 households participating in the years 2007 and 2008 and purchasing a total of 441,183 packaged meat products (ground beef, non-ground beef, poultry, and pork), there were only 26,470 packaged pork purchases and 12,444 packaged non-ground beef purchases. That is, pork purchases comprised only six percent of total packaged meat purchases and non-ground beef comprised only 2.82 percent. Thus, pork and non-ground beef products were ultimately not chosen as viable substitutes for ground beef.

entirety of 2007 or 2008 or both are included. Upon removing these households, the dataset contains the retail food purchase behavior of 64,672 households. Similarly, household demographic variables, such as state of residence, are only updated at the beginning of each calendar year. Thus, while it is possible to identify households that moved across state lines at some point between 2007 and 2008, it is not possible to identify when exactly the move occurred. As exposure to recalls based on geographic location is fundamental to the present analysis, the 223 households that moved between states in 2007 are also removed from the final dataset. The households under analysis are reduced further by only analyzing the consumption patterns of households that purchased both packaged ground beef and packaged poultry at least once over the two year period. By only analyzing the consumption patterns of these households, there is a greater chance of observing a change in consumption behavior during periods of *E. coli O157:H7* contaminated ground beef recalls as these are the households that were most likely affected by the recalls. Thus, the final dataset for analysis contains the retail food purchase behavior of 25,108 households. Summary statistics of selected characteristics of participating households are presented in Table 6. Ultimately, the households selected for this analysis had an average number of persons per household of 2.70, slightly higher than 2.41, the average number of persons per household for the entire Nielsen panel, and 2.62, the national average household size estimated by the Census Bureau. Households also had a median annual income range of 50,000 to 59,999 dollars, consistent with both the entire Nielsen panel and Census Bureau figures. And lastly, 31.61 percent of selected households included an individual under the age of 18, more than 25.21 percent, the figure from the entire Nielsen panel, but slightly less than 33.9, the national percentage estimated by the Census.

Prices per pound of meat (ground beef and poultry) were calculated by dividing total expenditure (dollars) by total quantity (pounds). However, upon initial review of the data, possible outliers or reporting errors were observed. First, the dataset contained extremely low price per pound observations, possibly due to store discounts or household use of coupons. Therefore, any observation with a price per pound equal to zero dollars was removed from the dataset.[4] Second, the dataset contained extremely high price per pound observations, possibly indicating either the purchase of a highly specialized meat or a recording error. Therefore, for both beef and poultry, the upper 0.01 percent of price observations was also discarded from the dataset.[5] Thus, the cut-off price for ground beef became 13.96 dollars per pound and for poultry, 14.88 dollars per pound.

A further issue with prices inherent in disaggregated demand analysis is the availability of price information for substitutes faced by the household. That is, if a household chose not to purchase a product, the price they faced for that product was not recorded. Therefore, missing prices for households without positive purchases of either ground beef or poultry in a given two-week period needed to be imputed.[6] To impute the missing prices for both ground beef and poultry, the following equation was used to estimate a household-specific fixed effect, $\beta_{i,h}$, for household h and good i:

$$p_{i,h,t}/\bar{p}_{i,t} = \beta_{i,h} + \varepsilon_{i,h,t}. \quad (5)$$

Explicitly, prices from observed purchases were divided by the national average price for the corresponding two-week period, t, and the results, in turn, were averaged over each household to determine the estimated household fixed-effect, $\hat{\beta}_{i,h}$. The resulting parameter estimates, $\hat{\beta}_{i,h}$,

[4] Zero prices comprised 0.31 percent of ground beef observations and 0.21 percent of poultry observations.
[5] Final regression results that included price outliers were greatly skewed. Conversely, trimming outliers further, for example, by discarding the upper 0.02 percent of price observations, did not significantly affect the results.
[6] Explicitly, 86.55 percent of ground beef prices and 86.49 percent of poultry prices were missing and thus imputed.

along with the national average retail price data, were then used to impute the missing prices as follows:

$$\hat{p}_{i,h,t} = \hat{\beta}_{i,h} \cdot \bar{p}_{i,t}. \tag{6}$$

Table 7 summarizes the descriptive statistics of the observed price data and the completed price data where the unobserved prices have been replaced by imputed prices, $\hat{p}_{i,h,t}$, using Equation 6.

VI. EMPIRICAL ESTIMATION

Together, the disaggregated household Nielsen panel and FSIS recall data allow for a unique panel estimation of the impact of food safety information on the quantities of beef and poultry demanded. Since a large fraction of the quantity demanded observations are zero-valued for any given biweekly period, a classical linear panel regression is not appropriate as it fails to account for the qualitative difference between zero-valued observations and continuous positive observations (Greene 2008). Thus, to adequately address the censored nature of the data, a nonlinear panel model is necessary to estimate the demand for beef and poultry; specifically, a Tobit panel model is necessary. The general formulation of which can be expressed as

$$Y^*_{h,t} = \boldsymbol{X}'_{h,t}\boldsymbol{\beta} + \varepsilon_{h,t}$$

$$Y_{h,t} = \begin{cases} Y^*_{h,t} = \boldsymbol{X}'_{h,t}\boldsymbol{\beta} + \varepsilon_{h,t} & \text{if } Y^*_{h,t} > 0 \\ 0 & \text{if } Y^*_{h,t} \leq 0 \end{cases} \tag{7}$$

where $Y^*_{h,t}$ is the latent variable, $Y_{h,t}$ is the observed counterpart, $\boldsymbol{X}_{h,t}$ is a vector of explanatory variables, $\boldsymbol{\beta}$ is a vector of parameters to be estimated, and $\varepsilon_{h,t}$ is the error term.

Initially, one might consider estimating a fixed-effects Tobit model so as not to make any unrealistic assumptions regarding unobservable household effects. However, nonlinear fixed-effects maximum likelihood estimation yields inconsistent results due to the incidental parameters problem, and there is no simple differencing or conditioning method that can provide a consistent estimator. Thus, to avoid the incidental parameters problem, a random-effects Tobit estimation model is used with the error term taking the form

$$\varepsilon_{h,t} = v_h + u_{h,t} \tag{8}$$

where v_h is an unobservable household effect, and $u_{h,t}$ is an independent random disturbance with a normal distribution. Alternatively stated, it is necessary to assume that v_h is distributed independently of the regressors, $\boldsymbol{X}_{h,t}$: $v_h \sim [v, \sigma_v^2]$.

Specific to the central analysis, the household demand for ground beef and poultry is estimated using the following random-effects Tobit model specification:

$$y_{i,h,t} = \alpha + \beta p_{i,h,t} + \gamma p_{j,h,t} + \boldsymbol{\delta}'\boldsymbol{I}_{h,t} + \boldsymbol{\zeta}'\boldsymbol{N}_{h,t} + \boldsymbol{\theta}'\boldsymbol{Q}_t + \kappa R_{h,t} + \varepsilon_{i,h,t} \tag{9}$$

Here, the dependent variable, $y_{i,h,t}$, is the quantity in pounds of the i-th good, either ground beef or poultry, purchased by household h in biweekly period t. The independent variables representing prices, $p_{i,h,t}$ and $p_{j,h,t}$, are the retail prices per pound of the i-th good and j-th substitute faced by household h in biweekly period t, where i and j represent either ground beef or poultry. The impact of $p_{i,h,t}$ on the quantity demanded of good i is expected to be negative. That is, as price decreases, it is expected that the quantity purchased increases. Conversely, the impact of $p_{j,h,t}$ on the quantity demanded of good i is expected to be positive, indicating that ground beef and poultry are substitute goods.

Household income is not reported by Nielsen as a continuous variable. Thus, $\boldsymbol{I}_{h,t}$ is a vector of dummy variables indicating the approximate income level of household h in biweekly period t; the income dummy variables and corresponding household income ranges are summarized in Table 8. Similarly, $\boldsymbol{N}_{h,t}$ is a vector of dummy variables indicating the size of household h in time t. Household sizes range from one to nine individuals, and households with more than nine individuals are capped at nine. The impact of household income and household size on the consumption of ground beef and poultry is expected to be positive, and increase as household income and household size increases. As mentioned earlier, demographic variables, such as household income and household size, are only updated at the beginning of every year that the household chooses to participate in the survey. Lastly, $\boldsymbol{Q}_t$ is a vector of variables indicating the quarter of the year and is included to account for any seasonal trends in the demand for ground beef or poultry.

The proxy for food safety information, and the variable of greatest interest, is the dummy variable representing recalls of *E. coli O157:H7* contaminated ground beef, $R_{h,t}$. $R_{h,t}$ is equal to one if a recall occurred during biweekly period t in the geographic region of household h, and is equal to zero otherwise. Note that the geographic region of a recall is defined as the region specified by FSIS in the corresponding press release. As expressed by Equation 3, an *E. coli O157:H7* contaminated ground beef recall is expected to decrease the quantity of ground beef demanded. Conversely, according to Equation 4, if consumers consider poultry to be a safe alternative to ground beef, the quantity of poultry demanded is expected to increase.

VII. RESULTS

The results of both the ground beef and poultry random-effects Tobit model regressions are summarized in Table 9. For both regressions, the data revealed statistically significant parameter estimates corresponding with the prices of ground beef and poultry. Furthermore, the signs associated with these parameters were consistent with expectations, confirming standard demand theory and price substitution effects between ground beef and poultry.

Household size and income also had a statistically significant impact on household consumption of ground beef and poultry. All household size coefficients were statistically significant at the one percent level, with the coefficients increasing as household size increased. Similarly, household income coefficients were all significant at the one, five, and ten percent level and generally increasing as household income increased. These results are once again consistent with economic theory and expectations.

The parameter of greatest interest, the parameter corresponding with *E. coli O157:H7* contaminated ground beef recalls, was negative and significant at the one percent level when estimating the demand for ground beef, and positive and significant at the one percent level when estimating the demand for poultry. The results are thus consistent with expectations that negative perceptions of food safety following ground beef recalls depress the demand for ground beef (Equation 3) and that consumers consider poultry to be a safe viable substitute for ground beef (Equation 4). That is, recalls of ground beef increased the demand for poultry, indicating that poultry is likely considered by consumers to be a safer, preferred alternative to ground beef.

Ultimately, the results indicate that consumers do, in fact, react to food safety information, though the impact is small in magnitude relative to price, income, and household size effects. Using the estimated coefficients to calculate marginal effects, a household of median size and income, that is, a household of two individuals with an income between 50,000 and 59,999 dollars is 0.352 percent less likely to purchase ground beef products and 0.319 percent more likely to purchases poultry products immediately following a recall. Alternatively, if the median household were to purchase ground beef following a recall, the results indicate that the household would purchase 0.007 pounds less or 0.002 percent less given that the average quantity of packaged ground beef purchased by the median household is 3.21 pounds.[7] The marginal effects of ground beef recalls on ground beef purchases for all household sizes and

[7] Using the delta method, all marginal effects statistics were significant at the one percent level.

incomes are presented in Tables 10 and 11, and the marginal effects of ground beef recalls on poultry purchases are presented in Tables 12 and 13. Overall, the results intuitively suggest that ground beef recalls have a greater impact on the qualitative decision of whether or not to purchase ground beef or poultry rather than the quantitative decision of how much to purchase (given that the household has already decided to buy). Furthermore, the marginal effects vary only slightly among different household types, signifying that all households, regardless of size or income, are affected by ground beef recalls to a certain extent.

Lastly, given that *E. coli O157:H7* contaminated ground beef recalls significantly impact consumer purchases of ground beef and poultry, albeit marginally, an informative sensitivity exercise is to determine the duration of the effect – the length of time that the consumer was influenced by the recall event when making purchase decisions. Therefore, Equation 9 is re-estimated with $R_{h,t}$ equal to one if a recall occurred within the previous four weeks (biweekly periods t or $t-1$) rather than just the previous two weeks (biweekly period t), and is equal to zero otherwise. The exercise is again repeated with $R_{h,t}$ equal to one if a recall occurred within the previous six weeks (biweekly periods t, $t-1$, and $t-2$) and equal to zero otherwise. The results of these estimations, presented in Table 14, reveal that consumers are influenced by *E. coli O157:H7* contaminated ground beef recalls within the first four weeks following the recall with the effect diminishing from one biweekly period to the next before reverting back to previous consumption behavior. Such short-term behavior modification with respect to food safety information is consistent with the findings of previous empirical analyses (e.g., Dahlgran and Fairchild 2002; Piggott and Marsh 2004), and indicates that consumers either have a short attention span with regards to food safety events or that they believe the relative safety of ground beef products improves within that time.

VIII. CONCLUSION

The objective of this study was to investigate the impact of food safety information on the demand for meat products. Using disaggregated household purchase data and *E. coli O157:H7* contaminated ground beef recalls as a proxy for food safety information, the results reveal that recall events have a statistically significant negative impact on ground beef consumption and a positive impact on poultry consumption, though the impacts are small relative to price and income effects and disappear within a few weeks time.

Existing literature investigating the impact of food safety information on consumer demand has relied heavily upon analyses of media indices, singular events, or aggregate data. Generally, these studies have found statistically significant evidence of own-effects on the demand for the contaminated product involved (Smith, et al. 1988; Foster and Just 1989; Burton and Young 1996; Dahlgran and Fairchild 2002; Marsh, et al. 2004; Piggott and Marsh 2004; Shimshack, et al. 2007; Tonsor, et al. 2010), and some have even found evidence of cross-effects on the demand for other products (Burton and Young 1996; Marsh, et al. 2004; Piggott and Marsh 2004; Tonsor, et al. 2010). However, analyses of media indices and singular events do not necessarily capture the impact of actualized recurrent food safety events, and analyses of data that have been aggregated across households and across time often ignore household heterogeneity, localized impacts of regional events, and any immediate short-run effects. With the use of disaggregated household data, the current study overcomes these hurdles by exploiting the temporal and geographic variability of *E. coli O157:H7* contaminated ground beef recall events. Though the final results are mainly consistent with much of the existing literature, they do differ in several critical ways. First, using household locational data, the present study addresses the regional nature of most recall events by identifying and analyzing the purchases of households experiencing a recall in their geographic region in any given biweekly time period. Second, in direct contrast with studies that have aggregated data across months or quarters,[8] the chosen biweekly periodicity allows for the analysis of immediate short-run impacts. This distinction is of particular importance given that the results reveal that the impact of recall events on ground beef and poultry consumption does not last for more than four weeks. Third, as opposed to studies analyzing aggregate consumption data, the present study considers possible heterogeneity of household responses and calculates the marginal effects of recalls by household size and income. Ultimately, the results reveal that all households were significantly affected by recall events, independent of household size and income. Fourth, and lastly, given the use of nonlinear panel model estimation, the present study was able to determine that recall events have a greater impact on the initial household decision of whether or not to purchase ground beef rather than the subsequent quantitative decision of how much to purchase.

The dramatic increase in the number of meat products recalled over the past few decades highlights the need for a complete understanding of consumer behavior in response to recalls. The present results indicate that despite the removal of *E. coli O157:H7* contaminated products from retail locations, consumers respond to recall events by purchasing less ground beef products and more poultry products in the weeks immediately following. This observation suggests that consumers use recall events to gauge product quality, and that they believe recall events signal lower quality, riskier products. In turn, this translates to lost sales for all ground beef producers, not just the firm liable for the contaminated product. Thus, greater consumer education and awareness with regards to the safety and quality of the products that remain on the market following a recall may lessen the magnitude of the impact and benefit the industry

[8] Exceptions include Dahlgran and Fairchild (2002) and Shimshack, Ward and Beatty (2007).

as a whole. Additionally, a reduction in recalls through increased protection against bacterial contamination may have the potential to further benefit both consumers and producers.

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X. TABLES

Table 1 – Summary Statistics of FSIS *E. coli O157:H7* Ground Beef Recalls: 2007 & 2008*

	2007	2008	Total
No. of Recalls	22	16	38
No. of Nationwide Recalls	5	2	7
Mean Recall Quantity (Lbs.)	1,528,075	547,386	1,131,856
Standard Error (Lbs.)	1,003,177	409,101	630,064
Maximum Recall Quantity (Lbs.)	21,700,000	5,300,000	21,700,000
Minimum Recall Quantity (Lbs.)	50	345	50
Total No. of Pounds Recalled (Lbs.)	33,617,651	7,116,018	40,746,819
Total No. of Pounds Recovered (Lbs.)	19,965,736	2,701,999	22,667,735

* Recall quantity data were not available for two recalls in 2008.

Table 2 – Summary Statistics of FSIS *E. coli O157:H7* Ground Beef *Retail* Recalls: 2007 & 2008*

	2007	2008	Total
No. of Recalls	17	6	23
No. of Nationwide Recalls	5	1	6
Mean Recall Quantity(Lbs.)	1,969,320	1,682,363	1,914,661
Standard Error (Lbs.)	1,286,760	1,245,758	1,057,011
Maximum Recall Quantity (Lbs.)	21,700,000	5,300,000	21,700,000
Minimum Recall Quantity (Lbs.)	102	780	102
Total No. of Pounds Recalled (Lbs.)	33,478,436	6,729,450	40,207,886
Total No. of Pounds Recovered (Lbs.)	19,876,725	2,591,756	22,468,481

* Recall quantity data were not available for two recalls in 2008.

Table 3 – FSIS *E. coli O157:H7* Ground Beef *Retail* Recalls: 2007 & 2008

Date of Announcement	Recall Quantity	Distribution
Jan. 29, 2007	4,240	Independence County, AR
Mar. 02, 2007	16,743	ID, OR, UT, WA
Apr. 20, 2007	259,230	PA, VA, WV
Apr. 20, 2007	107,943	AZ, CA, ID, OR, WA
May 10, 2007	117,500	AZ, IL, IA, MI, MN, OH, VA, WI
Jun. 03, 2007	5,700,000	CA, CO, ID, MT, NV, NM, OR, UT, WA, WY
Jun. 08, 2007	40,440	AL, AR, CO, KS, KY, LA, MO, MS, NM, OK, TN, TX
Jul. 21, 2007	26,669	MI
Jul. 25, 2007	5,920	CO, NE
Sep. 05, 2007	884	CT, ME, MA, NH, RI, VT
Sep. 25, 2007	21,700,000	Nationwide
Oct. 06, 2007	845,000	Nationwide
Oct. 13, 2007	173,554	Nationwide
Nov. 01, 2007	3,300,000	Nationwide
Nov. 03, 2007	1,084,284	Nationwide
Nov. 24, 2007	95,927	IN, KY, MD, OH, TN, VA, WI
Dec. 17, 2007	102	Afton, TN
May 08, 2008	68,670	HI
May 16, 2008	N/A	FL, GA, IL, IN, IA, MA, MI, MO, NE, PA, WI
Jun. 25, 2008	N/A	AL, GA, MI, OH, SC, Knoxville, TN
Jun. 30, 2008	5,300,000	CO, IL, MI, NY, PA, TX
Aug. 08, 2008	1,360,000	Nationwide
Aug. 11, 2008	780	Fresno, CA

Table 4 – FSIS Retail *E. coli O157:H7* Recalls by State: 2007 & 2008*

	2007	2008	Total
Alabama	1	1	2
Alaska	0	0	0
Arizona	2	0	2
Arkansas	1	0	1
California	2	0	2
Colorado	3	1	4
Connecticut	1	0	1
Delaware	0	0	0
District of Columbia	0	0	0
Florida	0	1	1
Georgia	0	2	2
Hawaii	0	1	1
Idaho	3	0	3
Illinois	1	2	3
Indiana	1	1	2
Iowa	1	1	2
Kansas	1	0	1
Kentucky	2	0	2
Louisiana	1	0	1
Maine	1	0	1
Maryland	1	0	1
Massachusetts	1	1	2
Michigan	2	3	5
Minnesota	1	0	1
Mississippi	1	0	1
Missouri	1	1	2
Montana	1	0	1
Nebraska	1	1	2
Nevada	1	0	1
New Hampshire	1	0	1
New Jersey	0	0	0
New Mexico	2	0	2
New York	0	1	1
North Carolina	0	0	0
North Dakota	0	0	0
Ohio	2	1	3
Oklahoma	1	0	1
Oregon	3	0	3
Pennsylvania	1	2	3
Rhode Island	1	0	1
South Carolina	0	1	1
South Dakota	0	0	0
Tennessee	2	0	2
Texas	1	1	2
Utah	2	0	2
Vermont	1	0	1
Virginia	3	0	3
Washington	3	0	3
West Virginia	1	0	1
Wisconsin	2	1	3
Wyoming	1	0	1

* Excludes nationwide and county-specific recalls.

Table 5 – FSIS Recalls *E. coli O157:H7* Recalls by Month: 2007 & 2008

	2007	2008
January	1	0
February	0	0
March	1	0
April	2	0
May	1	2
June	2	2
July	2	0
August	0	2
September	2	0
October	2	0
November	3	0
December	1	0
Total:	17	6

Table 6 – Medians of Selected Consumer Demographic Information from Nielsen Homescan Panel Data

	Census†	Full Panel Dataset	Households Surveyed for Entirety of 2007 or 2008 or Both	Stationary Households Purchasing Packaged Beef and Poultry at Least Once
Median Household Size	–	2	2	2
Mean Household Size	2007: 2.61 2008: 2.62	2.41*	2.38*	2.70*
Median Household Income	2007: $50,740 2008: $52,029	$50,000-59,999	$50,000-59,999	$50,000-$59,999
Households with Children	2007: 34.4% 2008: 33.9%	25.21%	23.77%	31.61%
No. of Households	–	74,674	64,672	25,108

† Source: U.S. Census Bureau, 2007 and 2008 American Community Survey
* Mean household size may be biased downwards because the number of reported individuals per household is capped at nine. However, households of nine or more members only account for 0.19 percent of households.

Table 7 – Summary Statistics of Observed and Imputed Meat Prices

	No. of Observations	Mean	Standard Deviation
Ground Beef			
Observed Prices Per Pound	146,815	2.68	1.04
Complete Prices Per Pound	1,091,246	2.69	1.01
Poultry			
Observed Prices Per Pound	147,436	2.21	0.95
Complete Prices Per Pound	1,091,246	2.24	0.87

Table 8 – Household Income Ranges and Corresponding Dummy Variables

Dummy Variable	Household Income
Income1	Under $20,000
Income2	$20,000 - $29,999
Income3	$30,000 - $39,999
Income4	$40,000 - $49,999
Income5	$50,000 - $59,999
Income6	$60,000 - $69,999
Income7	$70,000 - $99,999
Income8	$100,000+

Table 9 – Random-Effects Tobit Estimation Results for Demand of Ground Beef and Poultry

	Beef		Poultry	
	Coefficient	**Standard Error**	**Coefficient**	**Standard Error**
Price/Lb. Beef	-0.395	0.004***	0.038	0.005***
Price/Lb. Poultry	0.033	0.004***	-0.578	0.006***
Recall	-0.016	0.005***	0.018	0.006***
HHSize2	0.113	0.012***	0.099	0.015***
HHSize3	0.175	0.014***	0.190	0.017***
HHSize4	0.244	0.015***	0.259	0.018***
HHSize5	0.295	0.018***	0.358	0.022***
HHSize6	0.348	0.024***	0.342	0.030***
HHSize7	0.352	0.036***	0.466	0.045***
HHSize8	0.424	0.056***	0.449	0.071***
HHSize9	0.582	0.074***	0.759	0.093***
Income2	0.040	0.014***	0.034	0.017*
Income3	0.041	0.014***	0.074	0.018***
Income4	0.035	0.015**	0.096	0.019***
Income5	0.036	0.015**	0.126	0.019***
Income6	0.056	0.016***	0.124	0.020***
Income7	0.054	0.015***	0.154	0.019***
Income8	0.041	0.017**	0.162	0.021***
Quarter2	0.083	0.004***	-0.009	0.005
Quarter3	0.083	0.004***	-0.017	0.006***
Quarter4	-0.019	0.005***	-0.101	0.006***
Constant	1.254	0.019***	1.590	0.024***
Observations	1,091,246		1,091,246	
Households	25,108		25,108	
Log Likelihood	-2,077,807.9		-2,333,782	

*, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

Table 10 – Marginal Effect on the Decision to Purchase Ground Beef ($y_{GB} > 0$) by Household Size and Income*

		Household Size								
		1	2	3	4	5	6	7	8	9+
Household Income	Under $20,000	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0033 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0032 (0.0010)	-0.0028 (0.0009)
	$20,000-$29,999	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0034 (0.0010)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0031 (0.0009)	-0.0031 (0.0009)	-0.0028 (0.0009)
	$30,000-$39,999	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0034 (0.0010)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0032 (0.0010)	-0.0032 (0.0010)	-0.0029 (0.0009)
	$40,000-$49,999	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0035 (0.0010)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0030 (0.0009)
	$50,000-$59,999	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0035 (0.0011)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0032 (0.0010)	-0.0030 (0.0009)	-0.0028 (0.0009)
	$60,000-$69,999	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0035 (0.0011)	-0.0034 (0.0010)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0031 (0.0009)	-0.0030 (0.0009)
	$70,000-$99,999	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0035 (0.0011)	-0.0034 (0.0010)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0009)	-0.0031 (0.0009)	-0.0031 (0.0009)
	$100,000+	-0.0036 (0.0011)	-0.0035 (0.0011)	-0.0035 (0.0011)	-0.0035 (0.0010)	-0.0034 (0.0010)	-0.0033 (0.0010)	-0.0033 (0.0010)	-0.0032 (0.0010)	-0.0031 (0.0010)

*Using the delta method, all statistics were significant at the one percent level.

Table 11 – Marginal Effect on Ground Beef Quantity Purchased by Household Size and Income (Lbs.)*

		Household Size								
		1	2	3	4	5	6	7	8	9+
Household Income	Under $20,000	-0.0066 (0.0020)	-0.0070 (0.0021)	-0.0072 (0.0022)	-0.0074 (0.0023)	-0.0078 (0.0024)	-0.0078 (0.0024)	-0.0080 (0.0024)	-0.0080 (0.0024)	-0.0089 (0.0027)
	$20,000-$29,999	-0.0066 (0.0020)	-0.0070 (0.0021)	-0.0072 (0.0022)	-0.0074 (0.0022)	-0.0077 (0.0023)	-0.0078 (0.0024)	-0.0080 (0.0024)	-0.0083 (0.0025)	-0.0088 (0.0027)
	$30,000-$39,999	-0.0065 (0.0020)	-0.0069 (0.0021)	-0.0072 (0.0022)	-0.0075 (0.0023)	-0.0076 (0.0023)	-0.0079 (0.0024)	-0.0080 (0.0024)	-0.0080 (0.0024)	-0.0088 (0.0026)
	$40,000-$49,999	-0.0064 (0.0019)	-0.0069 (0.0021)	-0.0071 (0.0022)	-0.0073 (0.0022)	-0.0076 (0.0023)	-0.0078 (0.0024)	-0.0078 (0.0024)	-0.0080 (0.0024)	-0.0084 (0.0025)
	$50,000-$59,999	-0.0064 (0.0019)	-0.0068 (0.0021)	-0.0071 (0.0021)	-0.0073 (0.0022)	-0.0075 (0.0023)	-0.0078 (0.0024)	-0.0079 (0.0024)	-0.0083 (0.0025)	-0.0089 (0.0027)
	$60,000-$69,999	-0.0064 (0.0019)	-0.0068 (0.0021)	-0.0070 (0.0021)	-0.0073 (0.0022)	-0.0075 (0.0023)	-0.0077 (0.0023)	-0.0080 (0.0024)	-0.0081 (0.0025)	-0.0085 (0.0026)
	$70,000-$99,999	-0.0063 (0.0019)	-0.0067 (0.0020)	-0.0070 (0.0021)	-0.0072 (0.0022)	-0.0074 (0.0022)	-0.0076 (0.0023)	-0.0079 (0.0024)	-0.0081 (0.0024)	-0.0083 (0.0025)
	$100,000+	-0.0064 (0.0019)	-0.0066 (0.0020)	-0.0068 (0.0021)	-0.0070 (0.0021)	-0.0071 (0.0022)	-0.0075 (0.0023)	-0.0076 (0.0023)	-0.0078 (0.0024)	-0.0081 (0.0025)

*Using the delta method, all statistics were significant at the one percent level.

Table 12 – Marginal Effect on the Decision to Purchase Poultry ($y_{PLTRY} > 0$) by Household Size and Income*

		Household Size								
		1	2	3	4	5	6	7	8	9+
Household Income	Under $20,000	0.0032 (0.0011)	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0029 (0.0010)	0.0029 (0.0010)	0.0030 (0.0010)
	$20,000-$29,999	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0028 (0.0009)	0.0029 (0.0010)	0.0028 (0.0009)
	$30,000-$39,999	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0027 (0.0009)
	$40,000-$49,999	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0029 (0.0010)	0.0027 (0.0009)
	$50,000-$59,999	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0029 (0.0010)	0.0029 (0.0010)	0.0026 (0.0009)
	$60,000-$69,999	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0029 (0.0010)	0.0029 (0.0010)	0.0029 (0.0010)
	$70,000-$99,999	0.0032 (0.0011)	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0031 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0027 (0.0009)
	$100,000+	0.0032 (0.0011)	0.0032 (0.0011)	0.0032 (0.0011)	0.0032 (0.0011)	0.0031 (0.0010)	0.0031 (0.0010)	0.0030 (0.0010)	0.0030 (0.0010)	0.0029 (0.0010)

*Using the delta method, all statistics were significant at the one percent level.

Table 13 – Marginal Effect on Poultry Quantity Purchased by Household Size and Income (Lbs.)*

		Household Size								
		1	2	3	4	5	6	7	8	9+
Household Income	Under $20,000	0.0077 (0.0026)	0.0080 (0.0027)	0.0081 (0.0027)	0.0083 (0.0028)	0.0087 (0.0029)	0.0087 (0.0029)	0.0091 (0.0030)	0.0092 (0.0031)	0.0090 (0.0030)
	$20,000-$29,999	0.0076 (0.0025)	0.0079 (0.0026)	0.0082 (0.0027)	0.0084 (0.0028)	0.0087 (0.0029)	0.0086 (0.0029)	0.0092 (0.0031)	0.0091 (0.0030)	0.0095 (0.0032)
	$30,000-$39,999	0.0076 (0.0025)	0.0080 (0.0027)	0.0082 (0.0027)	0.0083 (0.0028)	0.0086 (0.0029)	0.0085 (0.0028)	0.0090 (0.0030)	0.0089 (0.0030)	0.0099 (0.0033)
	$40,000-$49,999	0.0074 (0.0025)	0.0079 (0.0026)	0.0082 (0.0027)	0.0083 (0.0028)	0.0086 (0.0029)	0.0087 (0.0029)	0.0090 (0.0030)	0.0092 (0.0031)	0.0099 (0.0033)
	$50,000-$59,999	0.0076 (0.0025)	0.0079 (0.0026)	0.0081 (0.0027)	0.0082 (0.0027)	0.0086 (0.0029)	0.0086 (0.0029)	0.0091 (0.0030)	0.0093 (0.0031)	0.0102 (0.0034)
	$60,000-$69,999	0.0075 (0.0025)	0.0076 (0.0026)	0.0081 (0.0027)	0.0081 (0.0027)	0.0084 (0.0028)	0.0085 (0.0028)	0.0091 (0.0030)	0.0089 (0.0030)	0.0093 (0.0031)
	$70,000-$99,999	0.0075 (0.0025)	0.0078 (0.0026)	0.0080 (0.0027)	0.0081 (0.0027)	0.0084 (0.0028)	0.0085 (0.0028)	0.0088 (0.0029)	0.0085 (0.0028)	0.0098 (0.0033)
	$100,000+	0.0076 (0.0025)	0.0077 (0.0026)	0.0079 (0.0026)	0.0080 (0.0027)	0.0083 (0.0028)	0.0084 (0.0028)	0.0087 (0.0029)	0.0087 (0.0029)	0.0090 (0.0030)

*Using the delta method, all statistics were significant at the one percent level.

Table 14 – Random-Effects Tobit Estimation Results for Recall Coefficients Given Varying Effect Durations

Duration of the Recall Effect	Beef		Poultry	
	Coefficient	Standard Error	Coefficient	Standard Error
Two Weeks	-0.016	0.005***	0.018	0.006***
Four Weeks	-0.007	0.004*	0.011	0.005**
Six Weeks	-0.001	0.004	0.001	0.005

Coefficient results for the other variables are suppressed for the purposes of clarity and comparison.
*, **, and *** indicate significance at the 10, 5, and 1 percent level, respectively.

APPENDIX A: RECALL PRESS RELEASE EXAMPLE

Texas Firm Recalls Ground Beef Products Due to Possible *E. coli* O157:H7 Contamination

Recall Release	**CLASS I RECALL**
FSIS-RC-027-2007	**HEALTH RISK: HIGH**

Congressional and Public Affairs
(202) 720-9113
Amanda Eamich

WASHINGTON, June 8, 2007 - Tyson Fresh Meats, Inc., a Sherman, Texas, establishment, is voluntarily recalling approximately 40,440 pounds of ground beef products due to possible contamination with *E. coli* O157:H7, the U.S. Department of Agriculture's Food Safety and Inspection Service announced today.

The products subject to recall include:

- 1.5-pound trays of "ANGUS STEAK BURGER ALL NATURAL, 85/15, 6- 1/4 POUND PATTIES."
- 1.33-pound trays of "ANGUS STEAK BURGER ALL NATURAL, 85/15, EXTRA THICK, 4- 1/3 POUND PATTIES."
- 2.25-pound trays of "73/27 ALL NATURAL GROUND BEEF, CARNE MOLIDA DE RES."
- 5.5-pound trays of "73/27 ALL NATURAL GROUND BEEF, CARNE MOLIDA DE RES."

Each label bears the establishment number "Est. 244S" inside the USDA mark of inspection as well as a "Use or Freeze By" date of "JUN 13 07."

The problem was discovered through trim sampling done by the company. The ground beef products were produced on June 2, 2007 and were distributed to retail establishments in Alabama, Arkansas, Colorado, Kansas, Kentucky, Louisiana, Missouri, Mississippi, New Mexico, Oklahoma, Tennessee and Texas.

Consumers with questions about the recall should contact the Tyson Consumer Hotline at (800) 233-6332. Media with questions about the recall should contact company Director of Media Relations Gary Mickelson at (479) 290-6111.

E. coli O157:H7 is a potentially deadly bacterium that can cause bloody diarrhea and dehydration. The very young, seniors and persons with compromised immune systems are the most susceptible to foodborne illness.

Consumers with food safety questions can "Ask Karen," the FSIS virtual representative available 24 hours a day at

AskKaren.gov. The toll-free USDA Meat and Poultry Hotline 1-888-MPHotline (1-888-674-6854) is available in English and Spanish and can be reached from l0 a.m. to 4 p.m. (Eastern Time) Monday through Friday. Recorded food safety messages are available 24 hours a day.

#

www.fsis.usda.gov

Food Safety Questions? Ask Karen!
FSIS' automated response system can provide food safety information 24/7

Last Modified: June 8, 2007