Impacts of meat product recalls on consumer demand in the US

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Abstract. We empirically test the impact of meat product recall events on consumer demand (beef, pork, poultry, and other consumption goods) in the United States. Beef, pork, and poultry recall indices are constructed from both the Food Safety Inspection Service's meat recall events and from newspaper reports over the period 1982-1998. Following previous product recall studies, recall indices are incorporated as shift variables in the consumer's demand functions. Estimating an absolute price version of the Rotterdam demand model, findings indicate that Food Safety Inspection Service's meat recall events significantly impact demand and newspaper reports do not. Moreover, although elasticities related to recall events are significant they are small in magnitude relative to price and income effects. Any favorable effects on the demands of meat substitutes for a recall are offset by a more general negative effect on meat demand. The general negative effect indicates a shift out of meat to non-meat consumption goods.

Key Words: product quality, consumer demand, food safety

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I. INTRODUCTION

Foodborne contaminants causing human illness are extremely costly to society with estimates exceeding billions of US dollars annually (Roberts, 1989; USDA, 2001). Recalls of contaminated meat products contribute directly to industry cost and have dramatically increased during the last two decades. Product recalls directly impact the industrial sector and may also adversely impact consumer demand for recalled products. Meat recall events suggest lower quality products and/or lax quality control, inducing consumers to substitute out of meat products being recalled into other meat or nonmeat products.

The purpose of this study is to empirically investigate impacts of meat product recalls on US consumer demand. Both Jarrell and Peltzman (1985) and Reilly and Hoffer (1983) emphasize the need to better understand the impact of product recalls on consumer demand. Recalls have potential shortcomings as a proxy for product quality in a consumer demand function. Nevertheless, product recalls are a primary source of information regarding meat quality problems and are consistent data series over time. Since 1982, meat product recalls have been recorded in a database collected by the United States Department of Agriculture (USDA) - Food Safety Inspection Service (FSIS).

Previous studies linking recall events to consumer behavior have been limited, focusing on the impact of drug or automobile product recalls on consumer demand and on the wealth of shareholders of firms. Hoffer and Wynne (1976) used a single equation regression model to link recalls to market shares in the US subcompact automobile market. Crafton, Hoffer, and Reilly (1981) applied paired difference tests to ascertain the significance of automobile recalls on demand. Recalls were found to adversely influence sales of automobiles. Reilly and Hoffer (1983) also applied paired difference tests and found that recalls adversely affected the demand for automobiles being recalled, while benefiting substitutes of other manufactures. In each of these studies, product recalls were treated as shift variables in consumer demand. Subsequently, several studies have examined impacts of product recalls on shareholders. Jarrell and Peltzman (1985) found that for drug and automobile recalls the shareholders and not the producers bear the largest losses. Moreover, owners of competing firms suffered substantial spillover effects from recalls of rival products. Thomsen and McKenzie (2001) reported that shareholder losses arise in meat and poultry recalls involving serous food safety hazards, but not when recalls involve less severe hazards.

Previous studies linking aggregate meat demand to contaminants are limited. The principle studies relate to meat safety in Great Britain and have focused on outbreaks of bovine spongiform encephalopathy (BSE). Burton and Young (1996) constructed a media index from journal articles and popular press to reflect consumer information about BSE. To test the impact of BSE on beef and other meats, the food safety index was included as a shift variable in meat demand functions. Statistically significant effects were found in the allocation of consumer expenditure among meat types, which included both short and long run impacts reducing beef market share. Burton, Young, and Cromb (1999) provided additional evidence that supported the robustness of these findings.

In contrast to the Burton and Young (1996) study, we do not focus exclusively on consumer perceived risk to outbreaks of a single, selected contaminant. Instead, we follow Crafton, Hoffer, and Reilly (1981) and argue that consumers perceive product recalls as a proxy for low quality and react accordingly.[1] Consequently, the basic hypotheses tested are about consumer response to recall events from a bundle of contaminants based on the comprehensive list reported by FSIS.[2] If statistically significant inferences can be drawn from examining the effects of recall events on meat demand, then this suggests consumers use recall information to gain knowledge of product quality. If so, this has important implications for food policy. Laws and regulations changing FSIS inspection methods, pathogen identification, and reporting procedures of recall events may affect consumer decisions by altering the amount of information consumers are exposed to. Furthermore, food laws and regulation and market forces could jointly create incentives for improving product quality.

To test impacts of recall events on US meat demand, we identify several hypotheses within the framework of a theoretically consistent consumer demand model. The consumer's choice set is specified to include beef, pork, poultry, and other consumption goods. Price and quantity series are US national-level, quarterly data from 1982 to 1998. Following Hoffer and Wynne (1976), Crafton, Hoffer, and Reilly (1981), Reilly and Hoffer (1983), and Burton and Young (1996) recall indices are included in an empirical demand model as exogenous shifters. For the first hypothesis, we test if actual product recall events have had a significant impact on consumer demand for meat. To do this beef, pork, and poultry recall indices are constructed from FSIS meat product recalls over the period 1982 -1998. The answer is unequivocally, yes. Second, we test if media information covering meat recall events have had a significant impact on consumer demand. Media indices are constructed from the number of recall events reported by US newspapers from 1982 to1998. For media indices based on newspaper reports the answer is no. Third, we assess the direction and magnitude of own- and cross-effects due to FSIS recall events for each meat type on other substitute meat and non-meat products. Interestingly, meat product recalls tend to induce a reallocation of expenditure both within the meats group and across meat and non-meat groups.

II. MEAT PRODUCT RECALLS

Recalls are voluntary removal by firms of a product from trade and consumer channels with the purpose of protecting human health and well being. Recalls of meat products in the U.S. are regulated by the Federal Meat Inspection Act[3] and the Poultry Products Inspection Act.[4] USDA-FSIS has responsibility for ensuring that meat and poultry are safe, wholesome, and accurately labeled. FSIS inspects and regulates all raw beef, pork, lamb, chicken, and turkey sold in interstate and foreign commerce. State agencies oversee state-inspected firms or retail establishments. In the event FSIS recalls occur, FSIS issues a press release and a Recall Notification Report is posted at its web site and distributed to health and inspector programs nationwide.[5]

To construct measures of meat product recalls, the number of FSIS reported recall events are linearly aggregated quarterly for beef, pork, and poultry.[6] FSIS meat recalls averaged 2.2 per quarter for beef, 2.0 for pork, and 1.6 for poultry from 1982 to 1998 (Table 1). During the last three-quarters of 1998 beef had from 4 to 8 recalls each quarter and a total of 18 for the year. In contrast, pork and poultry each had 4 or fewer recalls during each quarter of 1998. Product recalls during 1998 for pork and poultry totaled 10 and 9, respectively. Beef experienced its highest number of recalls in 1987 at 20. Figure 1 shows the number of recall events for beef, pork, and poultry cumulated annually.

Beef, pork, and poultry each show an upward trend in the number of recall events over time.

Table 2 summarizes FSIS recalls by meat product and type of recall over 1982-1998. Beef has had more recalls due to bacteria contamination than any of the other meat species with 68 recalls compared to 44 for pork and 27 for chicken and turkey combined. Perhaps even more interesting is that the first *E. coli* O157:H7 FSIS recall recorded since 1982 (beef's most common bacterial contamination problem) did not occur until 1988. Thus, detection of *E. coli's* presence has been much more common in recent years than during the early and mid-1980s. Beef and pork also tend to have more frequent extraneous material contamination of products compared to competing meats. Overall, beef had the highest number of total recalls over this time frame with 151 followed by 138 for pork, 64 for chicken, and 42 for turkey.[7]

The second measure of product recalls considered is based on media reports. Following earlier studies (e.g., Burton and Young, 1996), media measures (MEDIA) are constructed based on the number of articles from the popular press covering meat recalls. Data were obtained by searching the top fifty English language newspapers in circulation from 1982 to 1998 using Lexis-Nexis. Key words searched were *product recalls* and *meat recalls*. The search was narrowed to collect specific beef, pork, and poultry information by defining additional terms that included *beef* and *hamburger*, *pork* and *ham*, and *chicken*, *turkey*, and *poultry*, respectively. Each article was then individually examined for relevancy and those not related to meat recalls and from newspapers outside the US were discarded.[8] The data were not weighted otherwise. Like the FSIS recalls, the number of newspaper articles covering recalls were linearly aggregated for separate beef, pork, and poultry MEDIA measures. Figure 2 shows the beef, pork, and poultry media numbers cumulated annually. In 1997 the MEDIA numbers changed dramatically with a sharp increase in newspaper articles. Beef peaked at 350 articles, pork at 202, and poultry at 42. Many of these articles are related to a massive beef recall contaminated with *E. coli*. Two other important events that emerged just prior to 1997 included a BSE outbreak in Europe and the USDA 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.

Figure 3 shows the composite (beef, pork, and poultry) annual number of both recalls and newspaper articles from 1982 to 1998. From 1982 up to 1996 the FSIS and MEDIA measures are similar in magnitude. Regressing FSIS recall events on MEDIA numbers over this period demonstrates that FSIS recall events were positively and significantly related to newspaper reports. That is, MEDIA=5.00 (1.04)+0.54 (2.78) FSIS with t-values in parentheses and R^2 =.37. In 1997 there were 593 newspaper articles on meat recalls and only 25 FSIS recall events, depicting a striking change in the relationship between the FSIS and media measures. For completeness, both the FSIS and MEDIA indices are tested and reported in the demand model.

III. MODEL SPECIFICATION

Let x denote an N-vector of commodities consumed with an N-vector of prices p. We define z to be a K-vector of demand shift variables, say product recall information.

Assuming the personal cost of acquiring recall information is zero, then the consumer's maximization problem is

$$\max_{x}\left\{u(x, z)\ s.t.\ \mathrm{x} \geq 0,\ \mathrm{p}'\mathrm{x} = m\right\} \tag{1}$$

where u is utility and m denotes expenditure. The system of demand functions generated from this specification is given by $x_n = x_n(p, m, z)$ for $n=1,\ldots,N$. The consumer's decision problem is to optimally allocate expenditure m among the N-vector of goods x subject to a given level of z.

The marginal effects of recall information on the recalled product and its substitutes have important quality implications. Define $z_1, \ldots, z_{N-1}$ to be a set of recall indices respectively for meat goods $x_1, \ldots, x_{N-1}$ and let x_N be all other consumption goods. A priori expectations are that increases in recalls of the kth good, z_k, will shift down the demand for the recalled good x_k, or $\partial x_k / \partial z_k \leq 0$. This negative own-effect reflects consumer's perception that recall events signal lower quality products. Alternatively, spillover or cross-effects reflect the impact of recalls z_k on substitute goods. If $\partial x_i / \partial z_k < (>) 0$ then there is a negative (positive) spillover effect of the kth recalled product on the ith good. If $\partial x_i / \partial z_k = 0$ no spillover effect exists. Here, we have no a priori expectations about cross-effects within the meats group. Aside from substitution among goods within the meats group, it is possible that meat recalls induce a general negative effect, or $\partial x_i / \partial z_k \leq 0$ for $i=1,\ldots,N-1$, substituting expenditures out of the meats group into nonmeat goods, or $\partial x_N / \partial z_k \geq 0$.

Two familiar specification issues arise in modeling consumer demand systems, which restrict parameter coefficients of exogenous shift variables such as product recalls. First, as is well known, differentiating the budget constraint with respect to z_k yields

$$\sum_{j=1}^{N} p_j \frac{\partial x_j}{\partial z_k} = 0 \tag{2}$$

Otherwise stated, given total expenditure is constant, any increase(s) in demand from a change in z_k must be balanced by demand decrease(s) in other goods. Second, exogenous variables may be introduced into demand models in various static or dynamic functional specifications (Pollack and Wales, 1981; Brown and Lee, 1993). In either specification issue, incorrect restrictions on parameters can lead to estimates that will be biased and inconsistent (Judge et al., 1988). Next, we address both issues in specifying the empirical model and discuss their relevance in estimating meat recall effects.

Empirical model

The two most common approaches to estimating demand systems that incorporate demand shifters are the Rotterdam model (Theil, 1965) and almost ideal demand system (Deaton and Muellbauer, 1990). For this study we estimate meat demand systems using the absolute price version of the Rotterdam model. The Rotterdam model, which is derived from consumer demand theory, is a valid discrete approximation in variable space and is linear in parameters. Barnett (1979) and Mountain (1988) demonstrated that it is appropriate for aggregate and individual consumer analysis, respectively. It also allows theoretically correct specification of exogenous demand shifters in a consumer demand system with or without imposing functional restrictions on shift variables (Brown and Lee, 1993).

The ith equation of the absolute price version of the Rotterdam model is given by

$$w_i d\ln x_i = a_{i0} + \sum_{j=1}^{3} a_{ij} D_{ij} + \sum_{k=1}^{K}\sum_{l=0}^{L} e_{ikl}(d\ln z_{kl}) + b_i(d\ln \overline{q}) + \sum_{j=1}^{n}(c_{ij} d\ln p_j) + v_i \qquad (3)$$

where w_i is the ith budget share, D_{ij} are quarterly binary variables for seasonality, z_{kl} represents the kth exogenous demand shifter with lag length l=0,1,…,L, $d\ln\overline{q}$ is the Divisia volume index, a_{ij}, b_i, c_{ij}, and e_{ikl} are parameters to be estimated, and v_i is the random error term. In equation (3) $d\ln p_j$, for example, is the standard first difference operator on ln p_j. The intercept term a_0 in the Rotterdam model represents a linear time trend.

General demand restrictions, which are derived from economic theory, were imposed using parameter constraints. Adding up conditions are given by:

$$\sum_{i=1}^{N} c_{ij} = 0, \sum_{i=1}^{N} b_i = 1, \sum_{i=1}^{N} e_{ikl} = 0, \text{and } \sum_{i=1}^{N} a_{ij} = 0 \qquad (4)$$

Homogeneity and symmetry restrictions were imposed by:

$$\sum_{j=1}^{N} c_{ij} = 0 \text{ and } c_{ij} = c_{ji} \qquad (5)$$

Price and income elasticities are

$$\varepsilon_{ij} = c_{ij}/\mathrm{w_i} \text{ and } \eta_i = \beta_i / \mathrm{w_i} \qquad (6)$$

and demand shifter elasticities are calculated as

$$\phi_{ik\ell} = \frac{\sum_{l=0}^{\ell} e_{ikl}}{w_i} \quad . \qquad (7)$$

In (7), for example, $\phi_{ik0}(\ell = 0)$ yields a current period elasticity estimate. In the event z_{kl} achieves an equilibrium value over time, then $z_{k0} = z_{k1} =, ..., = z_{kL} = z_k$ and $\phi_{ikL}(\ell = L)$ yields a long-run elasticity estimate.

The empirical demand system is specified from a set of commodities that include beef, pork, poultry, and other consumption goods. Estimating a three-good demand system would have restricted the weighted sum of meat recall elasticities across the beef, pork, and poultry equations to zero, requiring at least one to be positive. Estimating a four-good system by including the other consumption goods variable provides the flexibility for the meat recall elasticities across beef, pork, and poultry to be negative or positive as determined by the information set of the model itself. In addition, it offers insight into the substitution among both meat and non-meat goods.

The linear time trend is included for structural changes not captured by the recall variables. Other studies have examined structural change (Moschini, Moro, and Green, 1994) and exogenous shifts due to health information (Brown and Schrader, 1990; Capps and Schmitz, 1991; Kinnucan et al., 1997), female participation in the labor force (McGuirk et al., 1995; Kalwij, Alessie, and Fontein, 1998) and advertising (Brester and Schroeder, 1995; Kinnucan et al., 1997; and Coulibaly and Brorsen, 1999). Our approach is similar to Piggott et al. (1996) and Burton and Young (1996), who employed time trends to proxy structural changes in meat demand outside of the demand shifters of interest.[9]

IV. DATA

The data set was restricted to the 1982 to 1998 period because FSIS data for food recall events were only available starting in 1982. The beef, pork, chicken, and turkey quantity variables represent quarterly per capita disappearance expressed in retail weight (pounds). Following Eales, Hyde, and Schrader (1998) and Piggott (1997), chicken and turkey were aggregated to form a single poultry variable. The beef, pork, and poultry price variables are estimates of quarterly average retail prices (cents per pound). The poultry price was constructed by summing together, in each quarter, total expenditure on chicken and turkey divided by per capita poultry consumption. Quantity and price series are reported by the Livestock Marketing Information Center (LMIC) and the United States Department of Agriculture - Economic Research Service (USDA-ERS). The price of other consumption goods is calculated from the Consumer Price Index (CPI), per capita personal consumption expenditures (deflated by the personal consumption expenditure implicit price deflator), and weighted price indexes for beef, pork, and poultry (see, for example, Brester and Schroeder, 1995). Personal consumption expenditure and its associated implicit price deflator, which are used to calculate per capita real consumption expenditures, come from the National Accounts data published by the United States Department of Commerce - Bureau of Economic Analysis. The CPI for all urban consumers, used to adjust for inflation over time, represents the US city average price of all items, as reported by the United States Department of Commerce - Bureau of Labor Statistics (BLS).

Summary statistics of data used in estimation of the beef demand model are contained in Table 1. Per capita beef consumption was the largest of the three meat groups, averaging 17.8 lbs./capita/quarter, with poultry second, averaging 15.6 lbs./capita/quarter, followed by pork with an average consumption of 12.8 lbs./capita/quarter. Over time, per capita beef consumption declined, whereas per capita poultry consumption increased steadily. Pork consumption was more stable than either beef or poultry consumption, generally oscillating between 12 and 14 lbs./capita/quarter over the 17-year period. Retail beef price had the highest average among competing meats at 335.36 cents/lb. expressed in 1998 US dollars. Pork price had the next highest average at 249.15 cents/lb. and poultry price averaged 110.77 cents/lb.

V. MODEL ESTIMATION AND DISCUSSION

The empirical analysis is completed in several steps. In the first step, demand models are estimated that included price (beef, pork, poultry, and all other goods) and expenditure variables along with either FSIS or MEDIA recall indices. Models are estimated for lag lengths (L=0,1,2,3 quarters) on unrestricted shift variables with likelihood ratio test statistics calculated for each lag length. The second step involved specifying and estimating a final model in which restrictions are imposed on the number of recall lags to provide a more parsimonious model.

Following typical demand system estimation procedures, one equation is deleted from the system during the estimation process to avoid singularity in the covariance matrix. For this study the poultry demand equation is dropped during estimation of demand models. The models are estimated using iterative seemingly unrelated regression with autocorrelation corrections (Berndt and Savin, 1975; Piggott et al, 1996). The aforementioned symmetry, adding up, and homogeneity conditions are imposed to make the models consistent with economic theory.

Results

Table 3 contains results of likelihood ratio (LR) tests for the demand model with FSIS recall variables. Sequences of tests were completed to determine the appropriate lag lengths of the recall variables and order of autocorrelation (Judge et al., 1988). The results indicate that lags *L*=0,2 are significant at the 0.05 level. Further the null of no autocorrelation is rejected for each lag length L. First order autocorrelation is exhibited for recall lags *L*=2,3, second order autocorrelation is present for *L*=0,1, and third order autocorrelation exists when no recall variables are included in the demand model. In all, the LR tests support a model with lag length up to *L*=2 for the FSIS recall variables and first order autocorrelation. [10]

Table 4 contains results of LR tests for the demand model with MEDIA recall variables, but no FSIS recall variables. Again, LR tests are completed to determine the appropriate lag lengths of the recall variables and order of autocorrelation. The results indicate that MEDIA variables are not significant at either the 0.05 or the 0.10 level for *L*=0,1,2,3. Further the null of no autocorrelation is rejected for each lag length L. Second order autocorrelation is present for *L*=0,1,2,3 and third order autocorrelation exists when no MEDIA recall variables are included in the demand model. In contrast to the FSIS models, the MEDIA models not only lack significance but also exhibit more severe autocorrelation for *L*=2,3.

Based on the above findings, the final demand model specification incorporated individual FSIS indices for beef, pork, and poultry recall events. This is advantageous from an economic perspective, as incorporating individual indices offers the opportunity to examine own- and cross-effects of recall events on meat demand. The final demand model incorporated unrestricted second-order (*L*=2 quarters) lag specification on the recall indices and first-order [*AR*(1)] autocorrelation correction. An alternative could have been to impose a polynomial lag structure on recall indices to potentially attain a more parsimonious demand model specification. However, for the present study, we chose to retain the unrestricted specification to more freely interpret the impacts across recall types and over time.[11]

The price, expenditure, seasonality, trend, and autocorrelation parameter estimates, as well as regression statistics from estimation of the four-good Rotterdam model are reported in Table 5. Goodness of fit is measured with the R-square, which yielded 82.6%, 88.4%, 89.4%, and 99.8% for beef, pork, poultry, and other goods respectively. Curvature restrictions for the price variables in the Rotterdam model are satisfied in that the matrix of price coefficients is negative semidefinite. Own price coefficients are statistically significant at the 0.05 level except for poultry. Expenditure coefficients for beef and other goods are statistically significant at the 0.05 level. The coefficients for the dummy variables capturing seasonality and trend variables are predominantly different from zero.

The parameter estimates for the current and lagged recall indices are reported in Table 6. Recall events are predominately negative for the beef and pork equations, but not for the poultry or other goods equations. Statistically significant negative effects are observed for both the beef and pork demand equations, according to individual t-values. Recall events are positive for poultry except for the current period own-effect, which is negative. For the poultry equation the own-effect is the only significant impact around the 0.10 level. For the other consumption goods equation only beef recalls lagged one period are negative, but not significant at 0.10 level. Further, there are positive and significant recall effects at the 0.05 level on the other goods equation across the current and second lagged periods.

Discussion

The persistent presence of autocorrelation in the demand models indicates a potential misspecification problem(s). Although each model was corrected for autocorrelation, it is clear that alternative functional specifications and shift variables should be considered in future research. Misspecification of consumer demand functions may reflect a host of factors, including inappropriate functional form, ignored dynamics, or omitted variables (Deaton and Muellbauer). Following the latter reasoning, for sake of discussion, one explanation is that other exogenous factors are being ignored. These could include other food safety shocks. For example, media information regarding Bovine Spongiform Encephalopathy outbreaks in Europe is readily available to US consumers. This information could potentially influence consumers, but is not included in the FSIS product recall information.

The lack of statistical significance for the MEDIA indices can be rationalized several ways. Perhaps most importantly relates to the sharp increase in newspaper articles in 1997 and 1998. If increases in recall media reports do correlate with perceived decrease in quality, then substantial downward shifts in meat demand should be expected in 1997 and 1998 relative to previous periods. However, for beef this is not the case. In fact, in 1998 beef demand stabilized and since 1999 the first upward shifts in demand for beef that have been detected within the last two decades (Schroeder, Marsh, and Mintert, 2000). Secondly, Crafton, Hoffer, and Reilly (1981) conjecture that the media does not report unbiased information. Alternatively, consumers may well perceive a product recall as providing unbiased information. Finally, results suggest there are likely diminishing returns to multiple media reports on a single recall event. This indicates that the diminishing value of newspaper reports to the consumer should be explored in empirical analysis focusing on media indices.

Price and expenditure elasticities at the mean are reported in Table 7. The estimated compensated own-price elasticities are -0.784, -0.495, -0.082, and –0.015 for beef, pork, poultry and other goods, respectively. For example, this indicates a 1% increase in beef price causes a 0.784% decline in per capita beef consumption. The compensated cross-price elasticities are positive suggesting substitutes, except for beef and poultry. Expenditure elasticity estimates are 0.590 for beef, 0.285 for pork, -0.354 for poultry, and 1.019 for other goods. This implies across the meat types that beef is the most sensitive to changes in total expenditures, followed by poultry and then pork. These results indicate that beef and pork are normal goods, whereas poultry is an inferior good. Overall the estimated price and expenditure are mostly consistent with prior expectations and results of previous studies (e.g., Brester and Schroeder, 1995).

Table 8 reports the current-period FSIS recall elasicities. Meat product recalls have negative own-effects on retail beef, pork, and poultry demand. The own-elasticities are -0.00052, -0.0010, and -0.0014 for beef, pork, and poultry recalls, respectively. Only poultry own-effects are significant at the 0.10 level. Meat recalls also have spillover or cross-effects. For example, increases in beef recalls have a negative and significant impact on pork and a positive impact on poultry demand. Similarly, increases in pork recalls had a negative and significant impact on beef and a positive impact on poultry consumption.[12] Increases in poultry recalls had a negative impact on beef and pork consumption. Beef, pork, and poultry recalls each had positive and significant spillover effects on other consumption goods.

Table 9 reports the long-run FSIS recall elasticities. Only the own-effect of poultry recalls changes sign relative to the current-period elasticities in Table 8. It changes from negative to positive and is insignificant. Except for the poultry own-effect, the long-run effects are larger in magnitude than the current-period effects. Relative to price and income effects, long-run effects are small in magnitude.

Overall, consumers appear to perceive current and lagged meat recall information as a decrease in product quality for beef and pork. In contrast, only current period poultry recalls appear to significantly shift down poultry demand. Moreover there are significant spillover effects within the meats group. Coinciding with a perceived drop in quality for meat products, we also detect a general negative effect on meat demand. That is, consumers often prefer other consumption goods when meat recalls occur.[13]

VI. CONCLUSIONS AND IMPLICATIONS

This study assessed the impacts of meat product recall events on US consumer demand. Both FSIS meat recall events and a measure of media (newspaper articles) reporting meat recalls were examined. Statistical evidence suggested individual FSIS recall indices for beef, pork, and poultry aggregated quarterly significantly affected demand for recalled meat products. In contrast, MEDIA recall indices were not statistically significant. Moreover, autocorrelation was persistent in all the empirical demand models indicating misspecification. Although each model was corrected for autocorrelation, it is clear that alternative shift variables should be considered in future research.

Our results provide important insight into the impact of meat product recall events on US consumer demand. Food recall events explained a significant, but not large, portion of consumer demand relative to price and income effects. From 1982-1998, beef and pork product recall events had a negative impact on demand for beef and pork, but not poultry. Meat recall information significantly impacted demand for beef and pork in current and lagged periods, but wore off after two quarters. Only current period poultry recalls had a negative and significant impact on demand for poultry. Similar to the findings of Jarrell and Peltzman (1985) any favorable effects on the demands for substitutes for a recalled product were offset by a more general negative effect on demand. The general effect indicated a shift out of meat to other consumption goods.

Our results have implications for food policy. First, although the impact of meat product recalls on demand is economically small (except possibly in periods associated with a large number of recall events), firms in the meat industry risk losing out when consumers become concerned with meat quality issues. Second, meat product recall events have differing impacts on demand. Hence, it is prudent that industry considers a proactive program in order to minimize negative impacts on demand. Third, laws and regulations changing FSIS identification and reporting of recall events that alter the flow of information may affect consumer decisions regarding meat quality. Suggesting that policy changes on recalls affect consumer decisions is not necessarily unique. Reilly and Hoffer (1983) reached similar conclusions with respect to automobiles.

Food quality in the meat industry is complex in nature, involving a myriad of contaminants and other issues. It is also dynamic, evolving as new issues, regulations, and pathogens emerge. Although product recalls are a primary source of information regarding quality problems, their impact on aggregate demand provides insight into only one aspect among countless other important issues. Hence, to draw further inferences, alternative measures of food quality or safety ought to be carefully considered and their relation to consumer demand more rigorously examined.

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Table 1. Summary Statistics of Quarterly Data used to Estimate Beef Demand, 1982-98.

Variable	Average	Std. Dev.	Minimum	Maximum
Beef Consumption (lbs./capita)	17.8	1.38	15.9	20.8
Pork Consumption (lbs./capita)	12.8	0.69	11.6	14.5
Poultry Consumption (lbs./capita)	15.6	2.07	12.2	19.3
Retail Beef Price (cents/lb.) [a]	335.36	33.68	275.40	413.09
Retail Pork Price (cents/lb.) [a]	249.15	23.42	203.73	311.56
Retail Poultry Price (cents/lb.) [a]	110.77	10.68	96.72	136.45
Beef Expenditure Share (%) [b]	52.5	3.9	43.2	59.2
Pork Expenditure Share (%) [b]	28.1	1.6	25.1	32.0
Poultry Expenditure Share (%) [b]	19.5	2.8	14.0	24.7
Beef FSIS Recalls	2.22	2.07	0	11
Pork FSIS Recalls	2.02	1.95	0	8
Poultry FSIS Recalls	1.56	1.52	0	8

[a] Inflation-adjusted US dollars (deflated by CPI, 1998=100).
[b] Share of beef, pork, and poultry expenditures.

Table 2. Meat Product Food Safety Inspection Service Recalls, 1982 – 1998.

Recall Type:	Beef	Pork	Chicken	Turkey	Other Meat[a]	Processed Products[b]
Salmonel1a	15	6	1	0	1	2
Listeria	20	29	12	3	21	4
E. Coli O157:H7	26	2	0	0	0	0
Staphylococcus	1	3	0	0	0	0
Trichinae	0	3	0	0	0	0
Other Bacteria	6	1	4	7	1	3
Hepatitus A	0	1	1	0	0	0
Extraneous Matter[c]	38	46	29	23	18	10
Species Problem	23	4	1	0	11	0
Other Reasons[d]	22	43	16	9	16	10
Total Recalls	151	138	64	42	68	29

[a] Includes products such as hot dogs, luncheon meats, spreads, etc. that are not identified by species.
[b] Includes processed products such as soups, ravioli's, stews, etc. not identified specifically as containing meat or by meat species.
[c] Includes extraneous materials, drugs, chemicals, rodent and insect contamination, etc.
[d] Includes primarily product labeling, package damage, under-processing, odors, etc.

Table 3. Likelihood Ratio Tests of FSIS Recall Variables for Unrestricted Rotterdam Model.

	Hypothesis Test (H_u vs H_r) Alternative Lag Lengths of FSIS Variables						
	L=0 vs None	L=0 vs L=1	L=1 vs L=2	L=2 vs L=3	L=1 vs None	L=2 vs None	L=3 vs None
AR(0)	18.38	8.20	18.07	1.72	26.28	44.79	45.23
AR(1)	17.72	5.96	20.76	1.50	23.32	44.81	45.00
AR(2)	19.28	5.53	17.63	1.43	24.39	42.50	42.67
AR(3)	16.33	5.33	16.79	1.75	21.33	38.64	39.29
AR(4)	16.56	5.03	16.69	2.32	21.24	38.45	39.74
dof	9.00	9.00	9.00	9.00	18.00	27.00	36.00
critical 5%	16.92	16.92	16.92	16.92	28.87	40.11	50.71
critical 10%	14.68	14.68	14.68	14.68	25.99	36.74	47.12

Hypothesis Test (H_u vs H_r)	None	L=0	L=1	L=2	L=3	critical 5%	dof
AR(1) vs AR(0)	18.84	17.19	13.97	15.75	14.40	3.84	1
AR(2) vs AR(1)	5.05	6.38	5.60	2.34	2.11	3.84	1
AR(3) vs AR(2)	4.16	1.17	0.95	0.21	0.51	3.84	1
AR(4) vs AR(3)	0.00	0.34	0.06	0.08	0.64	3.84	1

Notes: H_u is unrestricted hypothesis; H_r is restricted hypothesis; L denotes the lag length of food safety variables included in each model; None denotes a model with no FSIS variables included; and dof denotes degrees of freedom. All likelihood ratio test statistics are calculated using the adjusted likelihood ratio test statistic for systems estimation LR[MT-.5(Nu+Nr)-.5M(M+1)]/(MT) where LR-unadjusted log-likelihood value, M-# equations, T-# observations, Nu-#parameters in unrestricted model, Nr-#parameters in restricted model (Moschini, Moro, and Green).

Table 4. Likelihood Ratio Tests of MEDIA Recall Variables for Unrestricted Rotterdam Model.

	Hypothesis Test (H_u vs H_r) Alternative Lag Lengths of MEDIA Variables						
	L=0 vs None	L=0 vs L=1	L=1 vs L=2	L=2 vs L=3	L=1 vs None	L=2 vs None	L=3 vs None
AR(0)	6.94	4.47	10.08	4.84	11.34	21.77	26.44
AR(1)	4.87	5.08	8.10	8.66	9.97	18.33	27.37
AR(2)	6.22	6.88	6.50	8.95	13.14	19.68	29.01
AR(3)	4.52	6.22	7.04	8.82	10.81	18.01	27.25
AR(4)	4.56	6.32	7.01	8.71	10.96	18.12	27.24
dof	9.00	9.00	9.00	9.00	18.00	27.00	36.00
critical 5%	16.92	16.92	16.92	16.92	28.87	40.11	50.71
critical 10%	14.68	14.68	14.68	14.68	25.99	36.74	47.12

Hypothesis Test (H_u vs H_r)	None	L=0	L=1	L=2	L=3	critical 5%	dof
AR(1) vs AR(0)	18.84	15.74	15.36	12.47	15.29	3.84	1.00
AR(2) vs AR(1)	5.05	6.08	7.47	5.47	5.42	3.84	1.00
AR(3) vs AR(2)	4.16	2.30	1.56	2.03	1.82	3.84	1.00
AR(4) vs AR(3)	0.00	0.08	0.21	0.22	0.17	3.84	1.00

Notes: H_u is unrestricted hypothesis; H_r is restricted hypothesis; L denotes the lag length of food safety variables included in each model; None denotes a model with no MEDIA variables included; and dof denotes degrees of freedom. All likelihood ratio test statistics are calculated using the adjusted likelihood ratio test statistic for systems estimation LR[MT-.5(Nu+Nr)-.5M(M+1)]/(MT) where LR-unadjusted log-likelihood value, M-# equations, T-# observations, Nu-#parameters in unrestricted model, Nr-#parameters in restricted model (Moschini, Moro, and Green).

Table 5. Price, Expenditure, Seasonality, and Trend Coefficient Estimates of Rotterdam Model (t-statistics reported below coefficient estimates).

	Demand Equation:			
Dependent Variable:	Beef	Pork	Poultry	Other Goods
Beef Price	-0.01074			
	-6.16			
Pork Price	0.00033	-0.00354		
	0.51	-7.12		
Poultry Price	-0.00029	0.00011	-0.00040	
	-0.49	0.36	-1.01	
Other Goods Price	0.01071	0.00310	0.00057	-0.01438
	5.95	3.90	0.80	-6.27
Expenditure	0.00809	0.00088	-0.00174	0.99277
	2.62	0.43	-1.09	253.26
Quarter 1 Dummy	0.00061	-0.00112	-0.00090	0.00141
	5.82	-16.07	-16.74	10.5
Quarter 2 Dummy	0.00128	-0.00075	-0.00011	-0.00041
	16.23	-14.69	-2.81	-4.09
Quarter 3 Dummy	0.00077	-0.00042	-0.00025	-0.00011
	6.91	-5.7	-4.31	-0.76
Intercept	-0.00081	0.00057	0.00035	-0.00012
	-11.92	13.15	10.17	-1.33
Adjusted R-square	0.826	0.884	0.894	0.998
Durbin-Watson	2.354	1.850	2.227	2.315

Autocorrelation coefficient with t-statistic in parenthesis is ρ= -0.38075 (-5.14).

Table 6. FSIS Recall Coefficient Estimates of Rotterdam Model (t-statistics reported below coefficient estimates).

	Demand Equation:			
Dependent Variable:	Beef	Pork	Poultry	Other Goods
Beef (L=0)	-7.14488E-06	-0.00001425	2.10779E-06	0.000019287
	-0.88	-2.68	0.52	1.88
Pork (L=0)	-0.00003988	-7.13313E-06	4.85415E-06	0.000042162
	-4.38	-1.19	1.05	3.6
Poultry (L=0)	-0.00001119	-7.41523E-06	-6.88445E-06	0.000025492
	-1.35	-1.36	-1.64	2.41
Beef (L=1)	9.84889E-06	-6.45509E-06	4.1499E-06	-7.54372E-06
	1.29	-1.31	1.08	-0.78
Pork (L=1)	-0.00001153	-4.47178E-06	4.58349E-06	0.000011418
	-1.21	-0.73	0.95	0.94
Poultry (L=1)	-5.60817E-06	-2.07399E-06	5.34711E-06	2.33511E-06
	-0.71	-0.4	1.34	0.24
Beef (L=2)	-0.00001555	-0.00001201	5.34416E-07	0.000027028
	-2.01	-2.36	0.14	2.76
Pork (L=2)	-0.00002094	-0.00001983	1.84027E-06	0.000038922
	-2.18	-3.14	0.38	3.18
Poultry (L=2)	-7.07265E-06	-0.00001765	3.15209E-06	0.000021569
	-0.89	-3.36	0.78	2.14

Table 7. Compensated Price and Expenditure Elasticities.

	Quantity of:			
With Respect to:	Beef	Pork	Poultry	Other Goods
Beef Price	-0.78418 -6.16	0.04540 0.51	-0.05871 -0.49	0.01099 5.95
Pork Price	0.02373 0.51	-0.49465 -7.12	0.02336 0.36	0.00319 3.90
Poultry Price	-0.02102 -0.49	0.01599 0.36	-0.08165 -1.01	0.00059 0.80
Other Goods Price	0.78146 5.95	0.43326 3.90	0.11700 0.80	-0.01476 -6.27
Expenditure	0.59020 2.62	0.28542 0.43	-0.35414 -1.09	1.01903 253.26

Elasticites are calculated at the mean values of the explanatory variables. Mean expenditure shares for beef, pork, poultry, and other goods are 0.0137, 0.00716, 0.00491, and 0.97423, respectively.

Table 8. Current-Period FSIS Recall Elasticities

	Quantity of:			
With Respect to:	Beef	Pork	Poultry	Other Goods
Beef Recalls	-0.000522 -0.88	-0.001989 -2.68	0.000430 0.52	0.000020 1.88
Pork Recalls	-0.002911 -4.38	-0.000996 -1.19	0.000990 1.05	0.000043 3.6
Poultry Recalls	-0.000817 -1.35	-0.001035 -1.36	-0.001404 -1.64	0.000026 2.41

Elasticites are calculated at the mean values of the explanatory variables. Mean expenditure shares for beef, pork, poultry, and other goods are 0.0137, 0.00716, 0.00491, and 0.97423, respectively.

Table 9. Long-Run FSIS Recall Elasticities.

	Quantity of:			
With Respect to:	Beef	Pork	Poultry	Other Goods
Beef Recalls	-0.000938 -0.70	-0.004567 -2.72	0.001385 0.73	0.000040 1.67
Pork Recalls	-0.005281 -3.53	-0.004389 -2.38	0.002299 1.09	0.000095 3.52
Poultry Recalls	-0.001742 -1.37	-0.003789 -2.37	0.000329 0.18	0.000051 2.23

Elasticites are calculated at the mean values of the explanatory variables. Mean expenditure shares for beef, pork, poultry, and other goods are 0.0137, 0.00716, 0.00491, and 0.97423, respectively. Asymptotic t-values are calculated as linear combinations of normal random variables (Theorem 4.9, Mittelhammer 1996).

Endnotes

[1] Swartz and Stand, as well as Smith, van Ravenswaay, and Thompson, suggest that perceived quality of remaining food supplies decline after a recall because consumers have imperfect information about the suspect portion of product supplies.

[2] Testing consumer response to a bundle of contaminants has justification. For example, Hayes et al. (1995) observed that individuals did not differentiate between specific pathogens and that the values elicited for reduction of risk from individual pathogens did not differ from values for reduction of the combined risk from five pathogens. These individuals appeared to possess general, rather than pathogen specific, preferences for food safety.

[3] See U.S. Code, Title 21, Chapter 12.

[4] See U.S. Code, Title 21, Chapter 10.

[5] See USDA-FSIS, Recall of Meat and Poultry Products, Directive 8080.1, Rev. 3, January 1, 2000 at www.fsis.usda.gov.

[6] Linear aggregation is consistent with the food safety indices used by Burton and Young (1996), Burton, Young, and Cromb (1999), and the health indices used by Kinnucan et al., Capps and Schmitz, and McGuirk et al.

[7] In the demand model estimation in this study the "Other Meat" and the "Processed Product" recall data are not included in the model since they were not identified by specific meat species. Moreover, the demand model estimation could have delineated recalls by class: serious food safety hazards (Class 1), potential health hazard (Class 2), or no adverse health consequences (Class 3). However, because we are focused on how consumers perceive product recalls as an indicator for low quality and not necessarily how consumers perceive risks to food safety scares, the recall data were not delineated by class.

[8] The search engine used was the academic version of Lexis-Nexis. It provides a relevancy index for key words by article and has various other options to analyze search results.

[9] Initial specifications of the model incorporated other demand shifters, including health index and female in the labor force variables. To focus on product recalls and avoid issues of jointly specifying recalls with other demand shifters, these variables were replaced with a time trend variable in our final analysis. Encouragingly the product recall effects remained robust in specifications with or without health index and female in the labor force variables (results available from the authors upon request).

[10] We also tested the impacts of the pounds of beef, pork, and poultry recalled on consumer demand instead of recall events. Current period and lagged recall variables (up to L=2 quarters) were significant at the 0.10 level, but not the 0.05 level. Qualitatively the results were similar in that the current period recall elasticities retained the same sign and the signs of long-run elasiticicities were identical except for the own-effects of beef and poultry.

[11] There are econometric reasons for not imposing functional restrictions on the lag structure of recall variables. In the event restrictions are incorrect the parameter estimates would be inconsistent (Judge et al., 1988).

[12] The magnitudes of the cross-effects relative to the own-effects for beef and pork recalls on demand for beef and pork can be explained. Upon closer inspection of the data, it is evident that beef and pork recalls often involved processed products that traditionally contain either beef or pork. Further, in the event that a recalled product included both beef and pork, then the recall event was allocated to both the beef recall index and the pork recall index.

[13] An important observation is that small elasticities do not necessarily imply irrelevant economic effects. Consider the total differential of the ith good scaled by x_i

$$\frac{dx_i}{x_i} = \sum \varepsilon_{ij} \frac{dx_i}{x_i} + \sum e_{ikl} \frac{dz_{kl}}{z_{kl}} + \eta_i \frac{dx_i}{m}$$

From Table 1 the average meat product recall in a given quarter is about 2. Thus, a couple additional recall events in a given quarter can comprise over a 100% change from the mean of the recall variable and induce a relevant economic effect.