Journal of Agricultural and Resource Economics 26(2):431–444

The Effect of *E. Coli* O157:H7 on Beef Prices

Andrew M. McKenzie and Michael R. Thomsen

Using an event study, we examine the impact of recalls for *E. Coli* O157:H7 on wholesale and farm-level beef prices. Prices for boneless beef, a high-volume product primarily used for processing into ground beef, react negatively to recalls, suggesting incentives exist for packing firms to adopt measures that reduce the risk of contamination. However, there is no reaction in live cattle prices and very little reaction in boxed beef prices to recall events. This suggests short-run price responses found at the wholesale level for boneless beef do not transmit back to the farm level.

Key words: beef prices, *Escherichia Coli* O157:H7, event studies, food safety, product recalls

Introduction

A significant fall in the demand for red meat has been identified by empirical research over the last 20 years. A large body of literature has attributed this shift in demand to nonprice consumer preference factors (e.g., Braschler; Chavas; Moschini and Meilke 1984, 1989; Eales and Unnevehr). In particular, health concerns relating to cholesterol have been recognized as a nonprice factor linked to reduction in red meat consumption over the long term (Capps and Schmitz; Kinnucan et al.). In contrast, Robenstein and Thurman, using meat futures price data, were unable to detect any influence on short-run demand with respect to cholesterol news stories contained in *Wall Street Journal* articles between 1971 and 1990.

In addition to dietary health concerns, food safety issues surrounding the beef industry have drawn recent attention in the literature (Flake and Patterson; Lusk and Schroeder). The relative safety of beef products has been brought into question by an increase of illnesses linked to foodborne bacterial contaminants tainting ground beef. It would be reasonable to assume that highly visible media coverage of incidents, such as the Jack in the Box restaurant case[1] or a large U.S. Department of Agriculture (USDA) recall, could precipitate an immediate drop in the demand for beef.

Flake and Patterson attempted to take into account the joint effects of cholesterol concerns and food safety issues within the beef industry. The effect of food safety information was quantified by constructing a safety information index comprised of Associated Press articles filed on *E. Coli* and *Salmonella* contamination in U.S. beef and press articles relating to the bovine spongiform encephalopathy (BSE) scare in the United Kingdom. Flake and Patterson found that information relating to both cholesterol levels and bacterial contaminants had a significant negative impact on beef demand.

The authors are assistant professors, both in the Department of Agricultural Economics and Agribusiness, University of Arkansas. Senior authorship is unassigned. The authors are indebted to two anonymous referees for helpful comments.
Review coordinated by Russell Tronstad.

[1] This contamination incident occurred in 1993, and resulted in several deaths. The outbreak was traced to undercooked hamburgers sold through the restaurant chain.

Lusk and Schroeder analyzed the effect of food safety concerns on short-run price movements for beef and pork. USDA Food Safety and Inspection Service (FSIS) recall announcements were used as a source of new information about potentially hazardous products resulting from food safety violations in the meat industry. In a similar vein to Robenstein and Thurman's study, they analyzed the effect of meat recalls on daily futures prices for cattle and hogs. Recalls were found to have only a marginally negative impact on nearby cattle futures prices and no effect on hog futures prices. Lusk and Schroeder concluded meat recalls had little effect on the short-run demand for beef and pork.

The aforementioned studies address two different types of health concerns. The first relates to dietary health risks that contribute, over the long term, to chronic cardiovascular disease. The second type relates to foodborne pathogens which can result in immediate illness and, in some cases, death. Attribution theory suggests consumers respond differently to different types of information depending on whether other causal factors are present (Mizerski; Bemmels). In particular, Kelley points out that the role of a given cause in producing an effect is discounted if other plausible causes are present. With this in mind, a food safety recall would induce a potentially larger consumer reaction than would dietary health concerns, which represent only one of several risk factors associated with cardiovascular disease.

Structural demand studies using low-frequency data (annual or quarterly) have noted significant responses to one or both types of information (Capps and Schmitz; Kinnucan et al.; Flake and Patterson). Studies using high-frequency data such as daily futures prices have found no evidence to link either press coverage of dietary health concerns (Robenstein and Thurman) or meat recalls for foodborne pathogens (Lusk and Schroeder) to a decline in short-run demand for meats. Based on these findings, one might conclude adverse health and food safety information only affects the demand for red meat in the long run. Both Robenstein and Thurman, and Lusk and Schroeder argue that changes in red meat demand take place gradually and hence are not reflected in daily futures price changes, which would be sensitive to short-run demand shifts.

In our analysis we attempt to build on these earlier studies by focusing on the effects of food safety information at the wholesale and farm levels. Specifically, we analyze the effect of class 1 USDA Food Safety and Inspection Service (FSIS) recalls for beef contaminated by *E. Coli* O157:H7.

There are two reasons we would expect unfavorable information about *E. Coli* contamination to be reflected in wholesale beef prices, and especially prices for ground beef. First, *E. Coli* O157:H7 bacterial contamination is a greater risk factor in ground beef products than it is in other table cuts of beef.[2] As such, we believe wholesale prices of beef destined for ground beef are better candidates to pick up any short-run changes in meat demand brought about by *E. Coli* O157:H7 recall announcements than other meat cuts. In contrast, the effect of *E. Coli* O157:H7 on live cattle prices is likely small because live animals yield many different cuts of meat in addition to those used in the processing of ground beef.

[2] Other cuts of beef pose less of a health risk even though they may be contaminated with the deadly O157:H7 strain. The contamination only occurs on exposed surfaces of the meat, and cooking subjects these surfaces to temperatures high enough to destroy the bacteria. In ground beef, however, the contaminant is mixed throughout the meat and an adequate internal temperature must be reached in order to eliminate the risk of illness.

Second, the extensive literature concerning price transmission among farm, wholesale, and retail markets for livestock and red meat (for recent examples, see Goodwin and Holt; Bessler and Akleman) may also help explain why food safety information has little noticeable short-run impact on livestock futures prices. Goodwin and Holt document the primary conclusions from this body of research and suggest the following factors may contribute to this lack of short-run response: (*a*) the perceived existence of asymmetrical price adjustments, (*b*) a direction of causality flowing from the farm to the wholesale and retail levels, and (*c*) the unresponsiveness of farm-level markets to price shocks initiated at either the retail or the wholesale level. It thus seems plausible that a price shock at the wholesale or retail level reflecting a change in the short-run demand for red meat would not necessarily be simultaneously transmitted to farm-level prices via a change in the effective derived demand. This could explain earlier findings indicating farm-level demand is insensitive to safety and health information.

The effect of *E. Coli* O157:H7 recalls on wholesale and farm beef prices are analyzed within a standard event study framework. Event studies have been used in two recent investigations examining the effect of food recalls on company stock prices (Salin and Hooker; Thomsen and McKenzie). Salin and Hooker report mixed evidence of security price movements in the wake of recalls, while Thomsen and McKenzie find significant and negative stock price reactions to recalls involving serious health hazards. The methods used here follow closely those of Thomsen and McKenzie, i.e., we analyze the effect of *E. Coli* recalls in the aggregate and not on a case-by-case basis.

In this study, we analyze impacts at the farm level by using daily live cattle futures and cash prices. Responses at the wholesale level are analyzed using the daily Chicago Mercantile Exchange (CME) weighted average cash settlement price for its boneless beef futures contract and the boxed beef cutout prices for heavy choice taken from the USDA's National Carlot Meat Report. Of these four series (live cattle futures prices, live cattle cash prices, boneless beef prices, and boxed beef prices), we would expect boneless beef prices to be most responsive to *E. Coli* recalls.

In the following section, we provide some background on the recall process and a description of the data. We then outline the event study methods used to examine the effect of recall announcements on meat prices. In the final three sections of the article, the results, discussion, and concluding comments are presented. The discussion section addresses the policy implications of the study.

Meat Recalls and Data Considerations

Recalls of meat and poultry products are carried out under the supervision of the USDA/FSIS. FSIS has the responsibility to ensure meat, poultry, and egg products are unadulterated, labeled accurately, and safe for human consumption. Recalls are initiated voluntarily by firms either under their own initiative or at the request of FSIS.

When a company determines a recall is necessary, FSIS must be notified of the recall action within 24 hours (American Meat Institute Foundation). FSIS determines the severity of the threat posed by the affected product and assigns one of three recall classifications (USDA/FSIS). Class 1 recalls are the most severe and involve cases where there is a reasonable probability that consuming the product will cause serious adverse health consequences or death. Class 2 recalls account for potential hazards where adverse health consequences are a remote probability and are reversible. Class 3 recalls involve

Table 1. FSIS Recalls for *E. Coli* O157:H7, October 1994–October 2000

Description	1994–96	1997	1998	1999	2000	Total
All FSIS Recalls for *E. Coli* O157:H7:						
No. of Recalls	8	6	13	10	18	55
Total (lbs.)	1,772,844	25,613,978	2,058,325	728,311	1,548,290	31,721,748
Mean (lbs.)	221,606	4,268,996	158,333	72,831	86,016	576,759
Std. Dev. (lbs.)	214,216	10,157,552	220,886	93,491	112,898	3,358,341
Recalls Included in 18-Day Clean Windows:[a]						
No. of Recalls	7	4	4	6	4	25
Total (lbs.)	1,177,495	25,170,222	1,010,615	394,602	110,460	27,863,394
Mean (lbs.)	168,214	6,292,556	252,654	65,767	27,615	1,114,536
Std. Dev. (lbs.)	164,103	12,471,881	233,261	85,298	17,442	4,978,362

[a] A recall is considered to be in a "clean" window if no other recall is announced within the next 18 days.

situations where consumption of the product is not likely to cause any adverse health consequences. For example, a class 3 recall might concern a misbranding incident not involving undeclared allergens. During the recall process, FSIS notifies the public or appropriate state and local authorities of the hazard and monitors the effectiveness of the recall. A recall is terminated after FSIS determines all reasonable efforts have been made to recover the product in question.

One factor to consider when analyzing recall events relates to the precise date at which market agents become aware of the contamination incident. As noted above, a company may begin initiating a recall and make contact with customers in the distribution channel up to 24 hours before notifying FSIS and before FSIS has had time to assess the incident and issue a formal recall announcement. Also, in some cases the market may become aware that health authorities have linked an outbreak before it can be traced to a specific company's product. This issue has implications for our research design, which we address in the next section.

Data were obtained from FSIS on recall activity over a six-year period. Recalls for *E. Coli* O157:H7 are summarized in table 1. The first recall in our sample occurred in October 1994, and the last occurred in October 2000. In total, the data include 55 recalls for *E. Coli* contamination. All but two of these recalls involved ground beef or ground beef patties. The two exceptions involved salami. Each of these recalls warranted the most serious class 1 designation. The recalls varied in size, with several involving less than 1,000 pounds. The largest occurred in August 1997, and involved 25 million pounds of product. Most of the *E. Coli* recalls occurred during 1998 and 1999 (in the wake of the large 1997 recall) and during the summer of 2000. During the sample period, ground beef contaminated with *E. Coli* was one of the most common microbiological contaminant sources resulting in recall, second only to *Listeria monocytogenes*.

The daily price series are described as follows. For farm prices, we use the Texas-Oklahoma live cattle cash price and settlement prices for nearby live cattle futures contracts. In compiling the live cattle futures prices, contracts maturing in the same month as an *E. Coli* recall are excluded. For example, suppose a recall occurred on December 10. In this case, the February contract is used rather than the December contract as the nearest contract to maturity. This approach circumvents the possibility of picking up any spurious relationships due to excess noise and volatility in the futures price series.

Increased levels of volatility observed in the daily prices of maturing futures contracts are associated with the convergence process of futures and cash prices during the month of contract maturity and hence should not be attributed to exogenous events such as meat recalls.

For wholesale prices, we use the CME 90% lean boneless beef price index. This index constitutes a weighted average of cash prices taken from the USDA National Carlot Meat Report, otherwise known as the "Blue Sheet," and is used as the cash settlement index for the CME's 90% boneless beef futures contract.[3] Finally, the USDA's boxed beef cutout price for heavy choice carcasses is used as a wholesale price series for beef table cuts. This data series was also obtained from the National Carlot Meat Report.

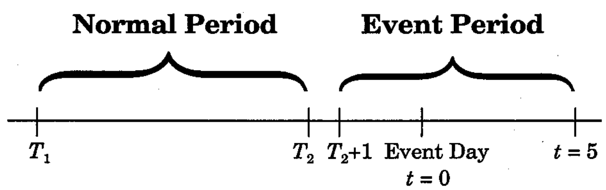
One data problem relates to the issue of clustered events. Recalls for *E. Coli* O157:H7 occur as needed. Thus there may be more than one recall within a very short period of time. In this event study, the possibility exists that the impact on price of a single event cannot be isolated from the impact of successive recalls. Such an occurrence also creates statistical complications, as the test statistics used in this study require independence between events. To account for this problem, we exclude recalls occurring within 18 days of one another. The 18-day period corresponds to the length of the combined estimation and event windows used in the study (as described in the following section). After excluding events occurring within 18 days of one another, the final sample consists of 25 events that could be used to analyze short-run responses for each price series.

Methodology

To quantify the impact of *E. Coli* recalls, we use a standard mean return model to analyze price reactions for each of our four series over the days surrounding recall events (Brown and Warner). Specifically, the model focuses on returns defined as daily percentage changes in the price of a commodity or financial instrument. First, normal returns—those that would be expected to occur in the absence of a product recall—are estimated for each price series over a period of time prior to the recall announcement. Second, abnormal returns—the difference between the observed return on a price series at a given date and its predicted normal return—are estimated for days of an event period surrounding the recall. Finally, these abnormal returns are aggregated over intervals of the event period and averaged across events to obtain an overall measure of the impact of a product recall on a price series.

While the notation and some test statistics that follow are similar to those of Thomsen and McKenzie, the approach differs. First, we use a mean return model, rather than a market model, to examine normal returns behavior. A market model is better suited to examining movements in stock prices as opposed to commodity prices. The primary problem is the absence of an acceptable market index which could be used in conjunction with commodity prices to control for the effects of broader market forces. Second, we conduct a sensitivity analysis of results with respect to the choice of normal period as part of the research design. This is especially important, as the normal period used here is much shorter than the normal period used in Thomsen and McKenzie's market model study.

[3] CME's 90% boneless beef futures prices were also collected and analyzed. However, the market has been extremely thin since its inception in 1997. Hence, results are presented only with respect to the cash settlement index described in the main body of the text.



Normal Periods and Event Periods Used in the Study

Normal Periods:	Event Periods:
$t = T_1 = -12$ to $t = T_2 = -5$	$t = T_2 + 1 = -4$ to $t = 5$
$t = T_1 = -10$ to $t = T_2 = -3$	$t = T_2 + 1 = -2$ to $t = 5$
$t = T_1 = -8$ to $t = T_2 = -1$	$t = T_2 + 1 = 0$ to $t = 5$

Figure 1. Timeline for normal and event periods

Let the subscript i refer to the ith recall event. The event day, the day on which USDA announces a recall for *E. Coli* contamination, is defined as $t = 0$. Our analysis is based on observed prices over a period of 18 days surrounding each event (days $t = -12$ through $t = 5$). Normal periods used for the study are defined as the following (T_1, T_2) intervals in event time: (-12, -5), (-10, -3), and (-8, -1), where T_1 is the first day and T_2 is the last day of the normal period. As illustrated in figure 1, event periods corresponding to each of the normal periods include days $t = T_2 + 1$ to $t = 5$.

The daily returns measure is calculated as:

(1) $$R_{it} = \ln(P_{it}/P_{it-1})100,$$

where P_{it} is the observed daily price (settlement price in the case of the live cattle futures series). Normal returns for the price series surrounding each recall, $\bar{R}_i$, are calculated as the arithmetic mean of R_{it} computed over the eight-day normal period (days $t = T_1$ to T_2). Abnormal returns are then calculated for the ith recall on each day in event time as the difference between actual returns and normal returns:

(2) $$AR_{it} = R_{it} - \bar{R}_i.$$

These abnormal returns are then averaged across the N recall events in the sample to obtain the mean abnormal return for each day in event time:

(3) $$AR_t = \frac{1}{N} \sum_{i=1}^{N} AR_{it}.$$

To determine the total reaction of a price series to an *E. Coli* recall, we aggregate abnormal returns over time into a cumulative abnormal returns (CAR) measure:

(4) $$CAR(\tau_1, \tau_2) = \sum_{t=\tau_1}^{\tau_2} AR_t.$$

$CAR(\tau_1, \tau_2)$ reflects the total impact of an event over any given τ_1 to τ_2 interval, where $T_2 + 1 \le \tau_1 \le \tau_2 \le 5$. Thus, $CAR(\tau_1, \tau_2)$ accounts for the possibility the impact of a recall may occur over more than one day, and this measure is particularly useful in the context of meat recalls because it can account for the possibility of information leakage prior to the official announcement date. If *E. Coli* recalls have a negative impact on the price series, then $CAR(\tau_1, \tau_2)$ will be negative. Formally, the hypotheses we test can be stated as follows:

$$H_0\colon CAR_{\tau_1,\tau_2} \geq 0 \quad \text{and} \quad H_A\colon CAR_{\tau_1,\tau_2} < 0.$$

The following parametric test statistic, Z_p, can be used to examine these hypotheses (Brown and Warner):

$$Z_p = \frac{CAR(\tau_1, \tau_2)}{\left(\sum_{t=\tau_1}^{\tau_2} s_t^2\right)^{1/2}}, \tag{5}$$

where

$$s_t^2 = \frac{\sum_{t=T_1}^{T_2} (AR_t - AR)^2}{7} \quad \text{and} \quad AR = \frac{1}{8}\sum_{t=T_1}^{T_2} AR_t.$$

Under the null hypothesis, Z_p follows a unit normal distribution as the number of events becomes large. Note when $\tau_1 = \tau_2 = t$, $CAR(\tau_1, \tau_2) = AR_t$. Hence, this statistic can also be used to determine the significance of the AR_t measures defined in equation (3).

Given the relatively small number of recalls for *E. Coli* O157:H7 and the large sample properties of the test statistics, it is important to examine alternative approaches for making inferences about the magnitude of abnormal returns. To make the results more robust, we also use two distribution-free, nonparametric test statistics. The first is a generalized sign test. This test is based on a comparison of the proportion of positive abnormal returns during a subset of the event period to the proportion of abnormal returns from the normal period, a period presumed to be unaffected by the event. The second test is a generalization of Corrado's rank test, which is based on the ranking of abnormal returns during the event period relative to the rankings over the combined estimation and event periods. Cowan provides an empirical examination of the properties of these statistics.

Let N_w^+ be the number of events with positive cumulative abnormal returns over one or more days of the event period, i.e., $CAR(\tau_1, \tau_2) = \Sigma_{t=\tau_1}^{\tau_2} AR_{it} > 0$, and let $p_{it} = 1$ if $AR_{it} > 0$, and $p_{it} = 0$ otherwise. The generalized sign test, Z_g, is given as follows:

$$Z_g = \frac{N_w^+ - Np}{(Np(1-p))^{1/2}}, \tag{6}$$

where

$$p = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{8}\sum_{t=T_1}^{T_2} p_{it}.$$

Corrado proposed a rank statistic to test the significance of abnormal returns on the event day. Like the generalized sign test, this statistic does not require symmetry among cross-sectional abnormal returns distributions for correct specification. The rank statistic used here is an extension of the statistic proposed by Corrado and can be used to examine multiple days of the event period (Campbell and Wasley; Cowan). Let k_{it} represent the rank of abnormal return AR_{it} over the combined normal and event periods. For example, in the case of the (−12, −5) normal period, each k_{it} would satisfy $1 \le k_{it} \le 18$. A value of $k_{it} = 1$ would correspond to the smallest abnormal return; a value of $k_{it} = 18$ would correspond to the largest, and the expected rank, $E(k)$, would be 9.5. The multi-period Corrado rank statistic, Z_r, is represented by:

(7) $$Z_r = \frac{(\tau_2 - \tau_1 + 1)^{1/2}\left(k(\tau_1, \tau_2) - E(k)\right)}{\left(\sum_{t=T_1}^{5} \left(k_t - E(k)\right)^2 / (6 - T_1)\right)^{1/2}}.$$

In equation (7), $k(\tau_1, \tau_2)$ is the mean of k_{it} computed over the N events and the one or more days for which $CAR(\tau_1, \tau_2)$ is calculated; k_t is the average rank over the N events on day t of the combined normal and event periods.[4]

Results

Table 2 reports average abnormal return estimates for the four price series based on the normal period of $t = -12$ to $t = -5$.[5] Table 3 presents cumulative average abnormal returns and test statistics for several intervals of the event period. Reported computations in table 3 are based on the (−12, −5) and the (−10, −3) normal periods.

Wholesale Meat Series

As observed from table 2, the abnormal returns measures for the boneless beef price series are negative and statistically significant on the fourth day prior to the event, the event day (day 0), and one day following the event. Hence, there is evidence confirming boneless beef prices are adversely affected on the announcement date itself and that recall announcements do contain information which is compounded by the marketplace.

One explanation for the negative abnormal returns prior to the event day is leakage of information. Many studies have examined the reactions of commodity price series to information contained in government reports (e.g., Miller; Colling and Irwin; Garcia et al.; Grunewald, McNulty, and Biere; Schroeder, Blair, and Mintert). Most conclude there is insignificant price response to information anticipated in the reports, suggesting market participants are effective at exchanging information prior to the formal release date. These findings are consistent with the pre-event price movements observed here. As noted earlier, it is possible for news of an impending recall to reach the marketplace prior to the formal announcement date by FSIS. Based on our results, market participants trade on information about an outbreak or potential contamination incident several days before a public announcement by FSIS. However, the full extent of information associated with a contamination incident is not revealed until the recall announcement. The negative and significant abnormal return on the event day (table 2) implies new information is provided to the market by recall announcements themselves.

---

[4] The term $(6 - T_1)$ in the denominator of equation (7) is the total number of periods in the combined normal and event periods. It reflects the sum of the eight-day normal period $(T_2 - T_1 + 1)$, the number of days in the event window prior to and including the event day $(0 - T_2)$, and the five post-event days included in the event window.

[5] Abnormal returns results for additional normal periods, days −10 to −3 and days −8 to −1 are not reported. In general, results for these windows are consistent with those reported. For the boneless beef price series, the abnormal return on day $t = 0$ is negative and significant for each normal period.

Table 2. Abnormal Returns and Test Statistics for the $t = -12$ to $t = -5$ Normal Period

	Boneless Beef		Boxed Beef		Live Cattle Cash Price		Live Cattle Futures	
Event Day	Abnormal Returns	Z_p Test Statistic	Abnormal Returns	Z_p Test Statistic	Abnormal Returns	Z_p Test Statistic	Abnormal Returns	Z_p Test Statistic
-4	-0.769	-1.726**	-0.139	-1.507*	0.002	0.010	0.074	0.363
-3	-0.074	-0.166	-0.096	-1.045	0.050	0.200	0.050	0.245
-2	-0.383	-0.861	-0.124	-1.344*	-0.029	-0.118	0.150	0.738
-1	-0.277	-0.622	0.178	1.934	0.102	0.408	0.008	0.040
0	-0.994	-2.233**	0.043	0.466	0.138	0.555	-0.109	-0.536
1	-0.715	-1.607*	-0.112	-1.219	0.407	1.631	0.327	1.604
2	-0.261	-0.586	0.001	0.008	-0.092	-0.367	-0.028	-0.139
3	0.090	0.201	-0.045	-0.490	0.052	0.208	0.035	0.173
4	-0.337	-0.756	-0.093	-1.013	0.115	0.462	-0.155	-0.762
5	0.400	0.898	-0.136	-1.483*	-0.064	-0.258	-0.232	-1.139

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels, respectively (both for a one-tailed test). Z_p is a standard normal parametric test statistic used to test hypotheses about the average abnormal return [refer to text equation (5)].

CAR estimates reported in table 3 reflect an aggregation over several days of the event period and can provide a better measure of the total impact of the recall if the market reaction is dissipated over several days. CAR estimates suggest virtually all of the price reaction has occurred by one day after the FSIS recall. For example, this result is illustrated by comparing intervals for days (0, 1) and days (0, 5). Overall, CAR results are consistent irrespective of the normal period considered. One notable exception is the time frame in which the price response occurs. Results based on the (-12, -5) normal period show more evidence of adverse price movement prior to the event day. This reflects the negative and significant abnormal return on day -4. With the exception of the (-12, -5) normal period, both the parametric and sign tests for boneless beef show significance at either the 5% or 10% level. Rank test statistics (not reported here) are weaker but approach significance for some intervals at the 12–13% level.[6]

Turning next to the boxed beef prices, table 2 shows the abnormal returns measures are much smaller in magnitude than was the case for the boneless beef series. Negative and marginally significant (at the 10% level) abnormal returns occurred on days -4, -2, and 5. However, these findings are only for the results based on the (-12, -5) normal period. Abnormal returns on the event day itself and on the day just prior to the event are positive for the normal periods reported. The cumulative average abnormal returns for boxed beef reported in table 3 indicate that for the (-12, -5) normal period, negative and at least marginally significant CAR measures are observed for the (-4, 5) and (0, 5) intervals. However, the sign and significance levels are sensitive to changes in the normal period. Rank statistics (not reported) are also insignificant. The only exception is for the (0, 5) interval for the (-12, -5) normal period, in which case the rank statistic is negative and significant at the 10% level. In summary, there is very little evidence of a decline in boxed beef prices due to *E. Coli* recall announcements.

[6] These intervals are (0, 1) for the (-10, -3) normal period, and intervals (-4, 0), (-4, 5), and (0, 1) for the (-12, -5) normal period.

Table 3. Cumulative Abnormal Returns (CAR) and Test Statistics

		Boneless Beef			Boxed Beef		
Normal Period	Interval (τ_1, τ_2)	CAR	Parametric Test (Z_p)	Sign Test (Z_g)	CAR	Parametric Test (Z_p)	Sign Test (Z_g)
(-10, -3)	(-2, 0)	-1.40	-1.67**	-1.47*	0.26	2.03	-0.60
(-10, -3)	(-2, 5)	-1.79	-1.31*	-1.47*	0.15	0.70	0.20
(-10, -3)	(0, 1)	-1.54	-2.25**	-1.88**	0.04	0.38	0.20
(-10, -3)	(0, 5)	-1.31	-1.10	-1.47*	-0.02	-0.09	-0.60
(-12, -5)	(-4, 0)	-2.50	-2.51**	0.40	-0.14	-0.67	-0.05
(-12, -5)	(-4, 5)	-3.32	-2.36**	-1.21	-0.52	-1.80**	-0.45
(-12, -5)	(-2, 0)	-1.65	-2.15**	-0.40	0.10	0.61	0.75
(-12, -5)	(-2, 5)	-2.48	-1.97**	-0.81	-0.29	-1.11	-0.05
(-12, -5)	(0, 1)	-1.71	-2.71**	-0.81	-0.07	-0.53	-0.85
(-12, -5)	(0, 5)	-1.82	-1.67**	-0.81	-0.34	-1.52*	-1.65**

Notes: Single and double asterisks (*) denote significance at the 10% and 5% levels, respectively (both for a one-tailed test). Z_p is a parametric test statistic and Z_g is a nonparametric sign test, both used to test hypotheses about the cumulative average abnormal return [refer to text equations (5) and (6), respectively].

Live Cattle Price Series

The day 0 abnormal return reported in table 2 is negative for the nearby live cattle futures series but is not significantly different from zero. Although not reported, there is some evidence of statistically significant price drops on the fourth and fifth days following the event when abnormal returns were calculated for the (-10, -3) and (-8, -1) normal periods. As observed from the CAR measures for the nearby live cattle futures series in table 3, regardless of the test statistic used, we fail to reject the null hypothesis that $CAR \geq 0$. Indeed, many of the estimated CAR measures are positive over the intervals reported. There is little if any evidence to indicate nearby live cattle futures prices respond in a systematic manner to *E. Coli* recalls.

An examination of the results from the live cattle cash price series leads to similar conclusions. From table 2, many of the abnormal returns, including the event day, are positive but insignificant. CAR measures in table 3 provide no evidence of adverse price responses in live cattle cash prices. Again, the CAR measures are positive in sign, and some would be significant if a two-tailed test were used instead of a one-tailed test.

Both abnormal and cumulative abnormal return measures suggest live cattle prices are not affected by *E. Coli* recalls, or the effects are minor enough to be immeasurable using the methods employed here. One plausible explanation is that a negative shock at the retail or wholesale level may affect farm-level prices only gradually and after several periods.[7] The methods used here are ill suited to an examination of this type of price reaction.

To summarize, our results suggest *E. Coli* recalls are reflected in adverse boneless beef price movements but do not have a large impact on the price of other wholesale beef products. Results consistently show a significant drop in the boneless beef price occurs on the day of the recall. These findings are robust to changes in the normal period and

[7] We credit an anonymous reviewer for this explanation.

Table 3. Extended

		Live Cattle Cash Price			Live Cattle Futures		
Normal Period	Interval (τ_1, τ_2)	CAR	Parametric Test (Z_p)	Sign Test (Z_g)	CAR	Parametric Test (Z_p)	Sign Test (Z_g)
(-10, -3)	(-2, 0)	0.18	0.97	0.72	-0.15	-1.03	-0.89
(-10, -3)	(-2, 5)	0.63	2.38	0.72	0.13	0.65	0.71
(-10, -3)	(0, 1)	0.58	1.80	0.31	0.06	0.26	0.71
(-10, -3)	(0, 5)	0.20	0.47	0.21	-0.10	-0.35	-0.36
(-12, -5)	(-4, 0)	0.61	0.87	-0.62	-0.40	-0.86	0.04
(-12, -5)	(-4, 5)	0.14	0.55	1.03	-0.16	-0.96	-0.76
(-12, -5)	(-2, 0)	0.54	1.54	1.03	0.12	0.51	0.84
(-12, -5)	(-2, 5)	0.45	1.04	0.21	0.04	0.14	-0.36
(-12, -5)	(0, 1)	0.54	0.89	-0.62	-0.46	-1.14	-0.36
(-12, -5)	(0, 5)	0.68	0.86	-0.05	0.12	0.19	1.29

persist even as the normal period used approaches the event day. In one respect, this finding is consistent with results presented in Thomsen and McKenzie's study of stock market reactions to recalls. They found equity prices of affected companies dropped because companies responsible could be readily linked to the recall.

Similarly, of the price series examined here, boneless beef prices are most easily linked to ground beef contaminated by *E. Coli*. While the results show some evidence of adverse boxed beef price movements, the evidence is much weaker because the boxed beef results depend heavily on features like the normal period chosen. Finally, the estimates of abnormal and cumulative abnormal returns in the live cattle futures and cash prices show little if any response to recalls.

Policy Implications

As noted in our introduction, the deadly *E. Coli* O157:H7 strain poses the greatest risk in ground beef. Hence, the finding that a recall leads to short-run price reductions for boneless beef, a product primarily used for further processing into ground beef, is expected. Other beef cuts, where *E. Coli* O157:H7 is not as problematic, are the highest value components of live cattle and boxed beef prices. Computations based on research by May et al. indicate these other cuts (excluding bone, fat trim, and cuts and trimmings destined for ground beef) account for roughly 80% of carcass value. Our results are consistent with this breakdown of carcass value and imply recalls have a much smaller impact on overall cattle and wholesale beef prices.

Adverse price movements for a high-volume product like boneless beef[8] suggest packers have incentives to adopt measures designed to reduce the risk of *E. Coli* contamination. Current industry developments reveal firms are acting on these incentives by adopting such measures. Examples include the use of steam pasteurization for carcasses, chemical rinses, and organic acid rinses in slaughter and fabrication plants.

[8] Computations based on the May et al. study show beef cuts primarily destined for ground beef average around 20.5% of carcass weight and around 18.7% of carcass value. In terms of carcass value, these averages are 12.2% for lean trimmings, 3.4% for special trim, and 3% for shank meat.

Further, market participants and regulatory agencies can play a role in transmitting these incentives back to producers. The observation that prices respond prior to recall announcement dates indicates market participants are quick to react to any news of a contamination incident. However, the full movement in prices is not observed until the announcement itself, suggesting public information generated by regulatory activity plays an important role and enhances the effectiveness by which markets can transmit signals or incentives to firms. Recent efforts to enhance the information content and availability of recall announcements can be justified on the grounds of facilitating market activity in addition to generating better public awareness of health hazards.[9]

The natural habitat of *E. Coli* O157:H7 is the digestive tract of the bovine animal. For this reason, the farm level may become an important point of intervention in controlling this pathogen, and research is now examining feeding practices which may affect the bacterium (Buchko et al.; Harmon et al.). The failure of our analysis to find discernable movements in live cattle prices may imply that incentives to reduce *E. Coli* are lower or nonexistent at the farm level.

However, to say market incentives do not exist at the farm level, and hence food safety regulations at this level would be less effective, is premature. Additional investigation is needed to examine longer-term price movements, which may more accurately reflect market incentives. Such extended analysis should seek to answer the question: If adverse cattle price movements are observed longer term, do these translate as adequate incentives for atomistic producers? And if not, what vehicles might be used to facilitate better coordination between packers and feeding operations?

Concluding Comments

Earlier research examining the effects of health and safety information, consisting largely of demand systems estimated from low-frequency data, has found demand does react negatively to adverse information such as the link between cholesterol consumption and cardiovascular disease. Recent research using daily farm-level data has not found significant price reactions to dietary health concerns (Robenstein and Thurman) or to food safety information (Lusk and Schroeder). Similar to these two studies, we use high-frequency data. However, unlike these studies, we do find evidence of a significant and negative price response to unfavorable product safety information.

We believe there are three primary factors contributing to our results.

- First, in this study we examined a health risk, *E. Coli* O157:H7, known to result in very serious short-term consequences. Hence it is more likely a problem of this immediacy will manifest itself in a short-run price response than will a problem involving longer-term health risks like a diet high in cholesterol.

- Second, we examined prices for boneless beef, a product for which *E. Coli* contamination is of great concern. The specificity of this series may explain why adverse price movements were documented, whereas Lusk and Schroeder, using livestock futures prices, found little response to adverse safety information contained in

[9] In recent years, steps have been taken to improve the information content of recall announcements. In 1998, FSIS began issuing Recall Notification Reports which provide additional background on brands implicated in recalls and areas where recalled products were distributed. The issuance of press releases has also become a matter of policy in all recall cases.

recalls. However, our conclusions regarding the impact of *E. Coli* recalls on live cattle prices are similar to their findings on the response of livestock futures prices to all meat recalls.

- Third, recent research relating to price transmission in the beef sector has found price shocks are transmitted in only one direction, from the farm level to the wholesale and retail markets (e.g., Goodwin and Holt; Bessler and Akleman). Our results are consistent with the finding of no feedback from retail to farm prices. What price responses we do find occur at the wholesale level and do not appear to significantly affect live cattle prices.

[*Received July 2000; final revision received October 2001.*]

References

American Meat Institute Foundation. *Crisis Management Handbook.* Mt. Morris IL: Watt Book Services, 1998.

Bemmels, B. "Attribution Theory and Discipline Arbitrations." *Industrial and Labor Relations Rev.* 44 (April 1991):548–62.

Bessler, D. A., and D. G. Akleman. "Farm Prices, Retail Prices, and Directed Graphs: Results for Pork and Beef." *Amer. J. Agr. Econ.* 80,5(1998):1144–49.

Braschler, C. "The Changing Demand Structure for Pork and Beef in the 1970's: Implications for the 1980's." *S. J. Agr. Econ.* 15(December 1983):105–10.

Brown S. J., and J. B. Warner. "Using Daily Stock Returns: The Case of Event Studies." *J. Finan. Econ.* 14(March 1985):3–31.

Buchko, S. J., R. A. Holley, W. O. Olson, V. P. J. Gannon, and D. M. Veira. "The Effect of Fasting and Diet on Fecal Shedding of *Escherichea Coli* O157:H7 by Cattle." *Can. J. Animal Sci.* 80(December 2000):741–44.

Campbell, C. J., and C. E. Wasley. "Measuring Security Price Performance Using Daily NASDAQ Returns." *J. Finan. Econ.* 33(February 1993):73–92.

Capps, O., Jr., and J. D. Schmitz. "A Recognition of Health and Nutrition Factors in Food Demand Analysis." *West. J. Agr. Econ.* 16(July 1991):21–35.

Chavas, J.-P. "Structural Change in the Demand for Meat." *Amer. J. Agr. Econ.* 65(February 1983): 148–53.

Colling, P. L., and S. H. Irwin. "The Reaction of Live Hog Futures Prices to USDA Hogs and Pigs Reports." *Amer. J. Agr. Econ.* 72(February 1990):84–94.

Corrado, C. J. "A Nonparametric Test for Abnormal Security-Price Performance in Event Studies." *J. Finan. Econ.* 23(August 1989):385–95.

Cowan, A. R. "Nonparametric Event Study Tests." *Rev. Quantitative Fin. and Accounting* 2(December 1992):343–58.

Eales, J. S., and L. J. Unnevehr. "Demand for Beef and Chicken Products: Separability and Structural Change." *Amer. J. Agr. Econ.* 70(August 1988):521–32.

Flake, O. L., and P. M. Patterson. "Health, Food Safety, and Meat Demand." Selected paper presented at annual meetings of the Amer. Agr. Econ. Assoc., Nashville TN, August 1999.

Garcia, P., S. H. Irwin, R. M. Leuthold, and L. Yang. "The Value of Information in Commodity Futures Markets." *J. Econ. Behavior and Organization* 32(April 1997):559–70.

Goodwin, B. K., and M. T. Holt. "Price Transmission and Asymmetric Adjustment in the U.S. Beef Sector." *Amer. J. Agr. Econ.* 81(August 1999):630–37.

Grunewald, O., M. S. McNulty, and A. W. Biere. "Live Cattle Futures Response to Cattle on Feed Reports." *Amer. J. Agr. Econ.* 75(February 1993):131–37.

Harmon, B. G., C. A. Brown, S. Tkalcic, P. O. E. Mueller, A. Parks, A. V. Jain, T. Zhao, and M. P. Doyle. "Fecal Shedding and Rumen Growth of *Escherichia Coli* O157:H7 in Fasted Calves." *J. Food Protection* 62(June 1999):574–79.

Kelley, H. "Process of Causal Attribution." *Amer. Psychologist* 28(February 1973):107–28.

Kinnucan, H. W., H. Xiao, C. Hsia, and J. D. Jackson. "Effects of Health Information and Generic Advertising on U.S. Meat Demand." *Amer. J. Agr. Econ.* 79(February 1997):13–23.

Lusk, J. L., and T. C. Schroeder. "Effects of Meat Recalls on Futures Market Prices." Paper presented at the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management, Chicago IL, 17–18 April 2000.

May, S. G., W. L. Mies, J. W. Edwards, F. L. Williams, J. W. Wise, J. J. Harris, J. W. Savell, and H. R. Cross. "Effect of Frame Size, Muscle Score, and External Fatness on Live and Carcass Value of Beef Cattle." *J. Animal Sci.* 70(November 1992):3311–16.

Miller, S. "The Response of Futures Prices to New Market Information: The Case of Live Hogs." *S. J. Agr. Econ.* 11(July 1979):67–70.

Mizerski, R. W. "An Attribution Explanation of the Disproportionate Influence of Unfavorable Information." *J. Consumer Res.* 9(December 1982):301–10.

Moschini, G., and K. D. Meilke. "Parameter Stability and the U.S. Demand for Beef." *West. J. Agr. Econ.* 9(December 1984):271–82.

———. "Modeling the Pattern of Structural Change in U.S. Meat Demand." *Amer. J. Agr. Econ.* 71(May 1989):253–61.

Robenstein, R. G., and W. N. Thurman. "Health Risk and the Demand for Red Meat: Evidence from Futures Markets." *Rev. Agr. Econ.* 18(October 1996):629–41.

Salin, V., and N. H. Hooker. "Stock Market Reaction to Food Recalls." *Rev. Agr. Econ.* 23(Spring/Summer 2001):33–46.

Schroeder, T., J. Blair, and J. Mintert. "Abnormal Returns in Livestock Futures Prices Around USDA Inventory Report Releases." *N. Cent. J. Agr. Econ.* 12(July 1990):293–304.

Thomsen, M. R., and A. M. McKenzie. "Market Incentives for Safe Foods: An Examination of Shareholder Losses from Meat and Poultry Recalls." *Amer. J. Agr. Econ.* 82(August 2001):526–38.

U.S. Department of Agriculture, Food Safety and Inspection Service. "Improving Recalls at the Food Safety and Inspection Service." Report of the Recall Policy Working Group, FSIS, Washington DC. Online. Available at http://www.fsis.usda.gov/OA/programs/recallwg.htm. [Retrieved December 5, 1999.]