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Ground Beef Recalls and Subsequent Food Safety Performance.

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The Findings and Conclusions in This Preliminary Presentation Have Not Been Formally Disseminated by the U. S. Department of Agriculture and Should Not Be Construed to Represent Any Agency Determination or Policy

ABSTRACT

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Economists (Shavell, 1984; Schmitz, 2000; Marino, 1997) argue that the costs of a product recall, including the direct and liability costs and the costs of a lost reputation for safety, encourage investment in safety. Economists, such as Thomsen and McKenzie (2001), have demonstrated that plants suffering recalls due failures in food safety incur substantial costs. However, little research has shown that plants either improve food safety performance or increase investment in food safety after a recall. This paper helps fill that void by first identifying the characteristics that distinguish plants with recalls from plants without recalls and distinguishing across plants with recalls for different reasons. Then, the paper evaluates changes in food safety performance from before the recall to afterward. Results show that plants with recalls have higher levels of *Salmonella* over time and not just at the time of a recall. Results also show that plants with recalls have higher levels of *Salmonella* during the event year and these levels diminish after the recalls.

Ground Beef Recalls and Subsequent Food Safety Performance.

The Food Safety Inspection Service (FSIS) of USDA recalled more than 370 million pounds of meat and poultry products and oversaw 918 recalls over 1998-2014. The associated products caused thousands of illnesses and some deaths. Painter et al. (2013) estimates that, overall, meat and poultry products caused 2.1 million illnesses leading to more than 12,200 hospitalizations and 418 deaths per year over 1998-2008.

Producers incur substantial costs if they are identified as the source of a recall. The Grocery Manufacturers Association estimates that the direct costs of product retrieval, destruction, reimbursements, etc. amounted to \$10-29 million per recall. These direct costs do not include the costs of a lost market value (Thompson and McKenzie, 2001; Pozo and Schroeder, 2014), litigation (Buzby and Frenzen, 1999), and price spillover effects to the broader market (Piggot and Marsh, 2004; Thompson, Shiptsova, and Hamm, 2006).

Economists (Shavell, 1984; Schmitz, 2000; Marino, 1997) argue that the costs of a product recall, including the direct and liability costs and the costs of a lost reputation for safety, encourage investment in safety. Golan et al. (2004) provide some anecdotal evidence of greater food safety investments after a food borne illness outbreak at *Jack-in-the-Box* restaurants. Other economists (Ollinger, Moore, and Chandran, 2004) provide some evidence of investment in food safety, but, to our knowledge, there have been no statistical studies examining the impact of a food product recalls on subsequent food safety investment and performance. The purpose of this paper is to fill that void by examining the performance of ground beef plants with Class 1

product recalls on *Salmonella* tests conducted by FSIS. Performance on *Salmonella* tests is a measure of plant food safety and is associated with food safety investment.

Following Shavell (1984), we hypothesize that plants with Class 1 product recalls underinvest in food safety and, therefore, have poorer performance on *Salmonella* tests than plants without recalls. We expect that plants with recalls then increase their food safety investment and improve their performance on tests for *Salmonella* after a recall. We use ground beef plants because they account for the largest share of meat or poultry recalls. We use Class 1 recalls because these recalls are prompted by the presence of an allergens, *E coli*: O157:H7 or another pathogen, glass, metal, or other contaminant in the product that gives a reasonable probability that consumption of the product will cause serious health outcomes.

The Recall Process

The recall process is initiated at FSIS after contaminants are detected in routine monitoring by government agencies or after consumer complaints and illnesses, reports from public health officials, and accounts from firms and others alert FSIS about potential foodborne contaminants. After receiving a report, FSIS conducts product testing and uses past records to determine when contaminated products entered the food supply. FSIS, then, issues a recall notice if it believes a recall is warranted. A manufacturer may or may not recall its products. **Regardless of the company's decision**, FSIS will issue a press release for a class I or class II recall and a recall notification report for a class III recall. Class I recalls are health hazards “where there is a reasonable probability that the use of the product will cause serious, adverse health consequences

or death.” Class II recalls are health hazards “where there is a remote probability of adverse health consequences from the use of the product.” Class III recalls are situations “where the use of the product will not cause adverse health consequences.”

FSIS cannot legally compel firms to recall products (Government Accountability Office (GAO) 2004; Roberts 2004b). However, Packman (1998) maintains that the agency has powers that are tantamount to mandatory recall authority. The press release issued by FSIS identifies the manufacturer, states the contamination, and indicates whether the manufacturer agreed to comply with FSIS’s recall recommendation. If the firm still refuses to a recall request, FSIS can invoke its authority to detain adulterated products, remove its inspectors from affected plants, and temporarily suspend a plant’s right to produce products that are eligible for interstate commerce. According to Lisa Volk of FSIS, there has only been one firm that refused to comply with a recall request in the past ten years, and that firm later agreed to recall its product after FSIS prepared a press release and a recall announcement became imminent (interview on July 23rd, 2008 with Lisa Volk).

If the firm agrees to conduct a recall, it stops production, removes products from inventory and commerce, notifies its consignees that they must do likewise, and conducts effectiveness checks with retailers and others. FSIS uses recall effectiveness information to decide whether to close a recall. Further details on recalls are available in *Recall of Meat and Poultry Products*, FSIS Directive 8080.1, Revision 6 (Washington, D.C.: October 26, 2010).

Table 1 shows the number and reasons for class I meat and poultry recalls from 1998 through 2014. The number of Class I recalls has hovered around 40 per year with a high of 74 in 2002 and low of 19 in 1998. Recalls for bacteria have trended down over time while recalls for allergens have risen.

Both Packman (1998) and Roberts (2004a) recognized that press releases issued by FSIS for recalls notifications can seriously tarnish a firm's reputation for food safety. Economists agree, e.g. Thompson and McKenzie (2001) and Pozo and Schroeder (2014), and have demonstrated the economic effects.

The Economic Framework of Meat and Poultry Recalls

Plants have an incentive to invest in food safety up to the point at which it is no longer profitable to do so. Efficient markets require perfect information Food safety, however, is characterized by asymmetric information between sellers and buyers in which buyers cannot accurately assess the food safety of the products they buy (Golan, et al. 2004) and can lead to reduced investment and, in the worst case, market breakdowns (Akerlof, 1970; Dulleck, Kerschbamer, and Sutter, 2011).

Conventional thought holds that food recalls reduce human exposure to health hazards by removing contaminated products from the marketplace or alerting consumers that have been exposed to these products so that they can seek medical attention. Roberts (2004a) points out that recalls also assign blame to the responsible firm so that firms can better be held liable for harm that their products cause. Economic theory (Shavell, 1984; Schmitz, 2000; Marino, 1997) indicates that stronger liability mechanisms improve the alignment of private and social incentives for costly measures that prevent product safety failures and that costs of safety failures internalized by firms encourage investment in safety.

Incentives for food safety may vary across plants. Many plants, particularly small ones, may never have a recall because they produce such small volumes that they can sicken only a

few people. Under other circumstances, a plant manager may think that the value of harm occurring through a recall may exceed the value of assets and, thus, have little incentive to make food safety investments. Shavell (1984) has shown that setting and enforcing safety standards can improve social outcomes in cases such as these, and, so, it is comforting to know that regulatory standards enforced by FSIS inspectors constitute an important component of food safety oversight in the meat and poultry industries.

An empirical model of the likelihood of a plant recall should include variables that account for plant size and other plant characteristics and food safety process controls. The model also needs to account for food safety investment. Meanwhile, types of recalls are distinguished by recall characteristics. We provide a detailed discussion of the empirical models after first describing the data.

Data:

The data comes from FSIS and includes all plants that produced ground beef and were tested for *Salmonella* over the 1999-2014. This period of time covers the years after the Hazard Analysis Critical Control Point Rule (PR/HACCP) Rule was implemented until the year when FSIS changed its pathogen testing protocol. The testing of ground beef for *Salmonella* over the course of the study period was done in sample sets of 53 spanning a period of days or weeks. Thus, testing could begin in one year and extend into the next year, leaving a partial sample set for analyses. Ground beef plants were expected to meet a standard allowing no more than four samples (7.5 percent) to test positive for *Salmonella*. Plants that exceeded this performance

standard were subjected to greater oversight but continued production.

Salmonella test results are not available for each plant-year because FSIS conducts *Salmonella* testing based on volume of production and past performance on *Salmonella* tests. As a result, some plants may have had multiple test cycles per year while others may not have been tested at all. We dropped observations with 30 or fewer *Salmonella* samples to ensure that small, partial samples did not distort our results.¹ Our final data set includes the results of tests for *Salmonella* in ground beef in 1,371 ground beef plants. From these data, there were 4,378 usable plant-year observations. Each plant year observation included the share of samples testing positive for *Salmonella* over one year. The maximum number of samples for any plant was 161, giving a range of samples taken for any plant of 30 to 161. More than 99 percent of the plant-year observations in our final data set had between 30 and 106 test samples and two-thirds had 53 samples (one set).

Tables 4 and 5 show how *Salmonella* levels vary for ground beef products by recall class (table 2) and over the event period. Table 4 shows that plants with recalls have consistently higher levels of *Salmonella*. Table 5 shows that *Salmonella* levels are highest during the event year (recall year) and drop afterward.

Data on plant characteristics and plant food safety process controls comes from the FSIS public health database has the number of animals slaughtered, plant characteristics, and plant process controls (performance of HACCP tasks and SSOPs). SSOPs include pre-operational SSOPs, which are cleaning and sanitation tasks performed at the beginning or end of the production day, and operational SSOPs, which are cleaning tasks performed during production. HACCP process control tasks are tasks performed under each plant's HACCP plan. HACCP plans outline tasks necessary for the plant to maintain food safety.

Data on product recalls comes from the FSIS website. These data include the pounds of meat recalled, reason for recalls, number of illnesses, etc. There were 169 separate recalls with sufficient data in at least one year. Below, we examine the statistical linkages between types of recalls and variables representing performance on *Salmonella* tests, recall information, and plant characteristics and food safety process control. Then we evaluate the effect of recall information and plant characteristics and process controls on performance on *Salmonella* tests over the time period surrounding a product recall.

Empirical Models

We first examine the characteristics that distinguish plants with recalls from those that have no recalls and consider factors associated with different types of recalls. Then, we evaluate the performance of plants with recalls on *Salmonella* tests over an event period extending from one to three years before the recall to one to three years afterward. The purpose of this second test is to see if plants with recalls have records of poor performance on *Salmonella* tests and whether that performance changes after it suffers a recall. We interpret an improvement as an increase in food safety effort (investment) as hypothesized by Shavell (1984) and Marino (1997).

Empirical Model of the Characteristics Distinguishing Recall types

There were approximately 200 plants that produce ground beef that had a Class I recall over 1999-2014 and 1,371 plants overall. Class I recalls are comprised of plants with recalls due to *E. coli* 0157:H7 and other pathogens, allergens, and foreign materials, such as glass or metal. We want to be able to distinguish among groups. In particular, we want to know if any measure of food safety process control can be linked to recalls and whether these food safety process controls or other distinguishing characteristics vary across recall types.

We reason that plants with recalls for allergens, foreign materials, and other types of quality control failures suffer recalls due to general quality control failures whereas plants with recalls due to pathogens have recalls because of poor sanitation. The class of recalls due to pathogens can be further divided into subgroups of plants with recalls due to pathogens passed on from slaughter operations (*E. coli* or *Salmonella*) and those with recalls due to pathogens affecting finishing operations and further processed products, such as *Listeria monocytogenes*. In an analysis, we have two major groups of recall types: plants with recalls and plants without recalls. We then would like to further examine plants with recalls due to pathogens and other plants with recalls due to a quality control failure. Finally, we would like to contrast plants with recalls due to *E. coli* or *Salmonella* with those with recalls due to *Listeria monocytogenes*.

All of these groups have binary outcomes, suggesting we could use a series of logit or probit regressions. However, we would lose information because a recall for pathogens is conditional on having a recall in the first place etc. As an alternative, we could use an ordered logit regression if there is a natural ordering of outcomes. However, we cannot rank by the health consequences because each of the recall types is a Class 1 recalls, the most severe type. Moreover, most health outcomes are not reported. Similarly, we cannot order by costs because

the cost of product removal, liability costs, and other producer costs are not reported and the costs of health effects cannot be estimated.

Another possible model is a multinomial regression. This model assumes a baseline, e.g. no recalls, and calculates the probabilities that other recall types differ from that baseline. We reject this model because it assumes independence of irrelevant alternatives, i.e. if one option is added, then the likelihood of all options are affected proportionately (Koppelman and Bhat, 2006). For example, if a regulator issued a rule that it would no longer recall products containing allergens, then the group comprised of plants without any recalls would capture all the gain and the group comprised of recalls due to pathogens would not change at all. However, a multinomial regression would allocate the change in shares proportionately between the “no-recall” group and the pathogen group.

Another way to view recalls is as a hierarchical process. First, there is a recall and then there are recall types. Nested logits are a general hierarchical form often used in random utility models with several alternative choices. Alternatives are grouped such that members of each group (branch) is affected similarly by unobserved effects. These are used frequently in consumer choice models for restaurants, transportation modes, etc. Recalls, however, are not choices among alternatives. Rather, they are exogenous food safety process control failures in which the type of recall is conditioned on having a recall and each successive recall category is conditioned on the previous broader category in a sequential ordering. In this framework, the first stage contrasts plants with recalls with plants without recalls; the second stage contrasts plants with recalls due to pathogens versus plants with recalls due to allergens, foreign objects, or other non-pathogen contaminant. Finally, the last stage, we want to examine *E coli* or

Salmonella (two types of pathogens that may be introduced during slaughter) versus *Listeria monocytogenes*, which is more associated with further processing.

We use a three-stage sequential logit regression (Van Ophem and Schram, 1997) to model recalls (equation 1). In this framework, subsets are put into mutually exclusive groups in which unobservable variables are correlated. The population of plants available for the first transition in the sequential logit includes all FSIS-inspected ground beef plants that had *Salmonella* testing over 1999-2014. The population of plants for the second transition is restricted to the plants that had at least one Class 1 recall and the population of plants for the third transition are only those plants that had a recall due to a pathogen.

We model the transition probability of having a Class 1 recall (P_{Rit}) as:

$$(1) \quad \widehat{P}_{Rit} = \frac{\exp(\alpha_A + \beta_A S_{i,t} + \gamma_A \mathbf{B}_t + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it})}{1 + \exp(\alpha_A + \beta_A S_{i,t} + \gamma_A \mathbf{B}_t + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it})},$$

model the transition probability of having a recall for pathogens in a given year ($\widehat{P}_{Pit}$), conditional on having a recall, as:

$$(2) \quad \widehat{P}_{Pit} = \left(\frac{\exp(\alpha_A + \beta_A S_{i,t} + \gamma_A \mathbf{B}_t + \rho_A \mathbf{R}_{it} + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it})}{1 + \exp(\alpha_A + \beta_A S_{i,t} + \gamma_A \mathbf{B}_t + \rho_A \mathbf{R}_{it} + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it})} \right) \Big|_{P_{Rit} = 1};$$

and model the transition probability of having a recall for *E. coli* O157:H7 or a virulent form of *Salmonella* in a given year ($\widehat{P}_{Eit}$), as:

$$(3) \quad \widehat{P}_{Eit} = \left(\frac{\exp(\alpha_A + \beta_A S_{i,t} + \gamma_A \mathbf{B}_t + \rho_A \mathbf{R}_{it} + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it})}{1 + \exp(\alpha_A + \beta_A S_{i,t} + \gamma_A \mathbf{B}_t + \rho_A \mathbf{R}_{it} + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it})} \right) \Big|_{P_{Pit} = 2}$$

where $S_{i,t}$ is performance of plant i on *Salmonella* tests in year “ t ”, expressed as the share of samples testing positive for *Salmonella*; $\mathbf{B}_t$ is a vector of economic environment variables and

includes the time trend and the industry average percent of samples testing positive for *Salmonella* recalls for pathogens (stage 3) in the previous year; $\mathbf{R}_{i,t}$ is a vector of variables representing characteristics of recalls and includes whether the recalled product was ground beef; whether the reason for the recall was a consumer illness or routine testing, and thousands of pounds of recalled products; $\mathbf{K}_{it}$ is a vector of plant characteristics shown in previous research to have affected performance on *Salmonella* tests and includes thousands of employees, plant age, and whether the plants slaughters animals, is part of a multiplant firm, and further processes meat or poultry; $\mathbf{H}_{it}$ is a vector of sanitation and food safety process control variables and includes the share of pre-operation or operation sanitation tasks and HACCP compliance tasks not in compliance with FSIS standards.

Performance of Plants on Salmonella tests over the Event Period

The sequential logit regression identifies characteristics that distinguish plants across recall types. However, it does not show changes in performance due to product recalls. In particular, we would like to examine the hypothesis put forth by Shavell (1984), Schmitz (2000), and Marino (1997) that the costs of a product recall encourages investment in safety. More specifically, we consider whether food safety performance - the percent of samples testing positive for *Salmonella* - changes after a recall. An improvement in performance can be viewed as an investment in food safety process controls.

We construct an event window ranging from three years before to three years after a recall and regress dummy variables for the event years and control variables for plant

characteristics and performance on sanitation tasks on the share of samples testing positive for *Salmonella*. We then measure the changes in performance on *Salmonella* tests from before to after the recall (equation 4). We use a tobit regression and account for clustered standard errors.

$$(4) \quad S_{it} = \omega_A \mathbf{T}_{i,t} + \gamma_A \mathbf{B}_t + \rho_A R_{i,t} + \varphi_A \mathbf{K}_{it} + \delta_A \mathbf{H}_{it} + \varepsilon_{it}$$

where most variables are the same as those described above; $\mathbf{T}$ is a vector of event years ranging from minus 3 to plus three years after the event year the industry effects variables include a binary variable for whether the recall was for *E coli* / *Salmonella* and the year of the recall.

All variables are defined in table 3. The $\mathbf{B}$ variables include a control for industry performance on *Salmonella* tests and a time trend. The $\mathbf{R}$ variables are characteristics of recalls. The $\mathbf{K}$ variables are plant characteristics. Ollinger and Moore (2008) found that larger plants had better food-safety performance in the chicken-slaughter industry but not in the ground-beef industry; including plant size (number of employees) as an explanatory variable allows us to revisit that conclusion. We also include a binary variable or whether the plant uses meat from its own slaughter operations as meat inputs because vertically-integrated plants, which have greater control over inputs, may be able to attain better food-safety outcomes (Ollinger and Moore 2008). Another binary variable indicates whether the plant is part of multi-plant firm. Muth, Fahimi, and Karns (2009) found that the vintage of plant capital is correlated with lower *Salmonella* levels in hog and chicken slaughter plants and further-processing plants, so we include plant age as a proxy for age of capital. We also include a binary variable identifying whether the plant does further processing.

The model also has three R variables, which reflect compliance with Standard Sanitation Operating Practices (SSOPs) and Hazard Analysis Critical Control Procedure tasks, as monitored and recorded by FSIS inspectors. Ollinger and Moore (2008) found that higher rates of compliance with SSOPs and HACCP tasks led to improved performance on *Salmonella* tests. We separately account for pre-operational SSOPs, which are cleaning and sanitation tasks performed at the beginning or end of the production day, and operational SSOPs, which are cleaning tasks performed during production.

Results:

In equations 1-3 we outlined a sequential logit regression used to examine differences in recall types. Regression results and their clustered standard errors are given in tables 6 and 7. The key variables are the share of samples testing positive for *Salmonella* and the characteristics of recalled products. Results show that the likelihood of any type of Class 1 recall (allergen, pathogen, plastic, or other contaminant) occurring rises with higher levels of *Salmonella*. A 10 percent increase in the share of samples testing positive raises the likelihood of having a recall by about 5.2 percent. The second stage results indicate that, conditional on a recall occurring, there is no association between *Salmonella* levels and the recall being due to pathogens (rather than an allergens or other non-pathogen reason). The third stage, which is conditional on a recall for a pathogen, shows that *Salmonella* levels are higher for plants with recalls due to *E. coli* or *Salmonella* than at plants with recalls for *Listeria monocytogenes*. A 10 percent increase in *Salmonella* levels increases the likelihood of recall for *E. coli* or *Salmonella* by about 53 percent.

Other results indicate that there is a time trend of about a 1.1 percent increase in the number of recalls each year. Additionally, a ten percent increase in the number of employees increases the probability of a recall by about 1.3 percent, plants that are part of a multi-plant firm have a 10 percent higher chance of having a recall, and a 10 percent increase in plant age raises the likelihood of a recall by much less than 1 percent. Sanitation had a mixed impact. A 10 percent increase in the share of operational SSOPs that are noncompliant raises the likelihood of a recall by about 8.3 percent while a 10 percent increase in share of HACCP tasks not in compliance with standards reduces the likelihood of a recall. These conflicting results may be due to a lack of variation in performance of tasks. Table 3 shows that less than 1-percent of all HACCP tasks were out of compliance and about 2.5-percent of pre-operation sanitation tasks were not in compliance.

It could be that plants have very high *Salmonella* levels in the years before or the year of the recall. Thus, we dropped the data observations of the year of a recall and years that were either one, two, or three years before the recall. There was no change in results. Together, these results suggest plants with recalls typically have higher level of *Salmonella* than plants without recalls even during years of recalls or years leading up to a recall.

Equation 4 outlined a model of performance on *Salmonella* tests over an event window spanning from at least five years before a recall to five years afterward. Table 8 gives the results for that model. Results show that *Salmonella* levels are 1.4 to 1.8 percent higher for plants during the year of a recall and not statistically different from zero before or after the recall. Results also show that plants with recalls due to routine testing had lower *Salmonella* levels, as did plants subject to larger recalls. Plants producing raw ground beef products, on the other

hand, had higher levels of *Salmonella*. Performance on SSOPs and HACCP tasks had no impact on *Salmonella* levels.

Discussion:

Table 4 indicates that *Salmonella* levels were about 25 percent lower in plants without recalls relative to plants with recalls. The regression results are consistent with these raw data, showing a strong association between *Salmonella* levels and any plant with a Class 1 product recall over 2000-2014. This effect was robust to several variations of the model. The result also held when we dropped years in which *Salmonella* levels of plants with recalls were higher, i.e. the three years before the recall and the year of the recall.

Salmonella levels were higher in plants with recalls, but they still were, on average, very much below the FSIS standard for ground beef. At the time of this study, FSIS established a standard for ground beef equal to 5 samples testing positive out of 53 samples taken, or about 9.4 percent. The *Salmonella* level for plants with recalls was 2.6 percent – less than one-third the FSIS standard and a level exceeded by about 25 percent all plants. About 70 percent of all ground beef plants had *Salmonella* levels of less than 2-percent. Plants with recalls accounted for about 24 percent of the plant-level observations in the sample but comprised about 29 percent of all plants with *Salmonella* levels above 5-percent, 6-percent, or 7-percent *Salmonella* levels. Thus, the *Salmonella* level data suggest a modestly higher risk of a product recall for plants with poor performance on *Salmonella* tests.

The improvement in performance on *Salmonella* tests over the event window surrounding the year of the recall are consistent with Shavell (1984) who argued that plants underinvest in food safety before a recall and that the cost of a recall encourages plants to increase investment. In the case of ground beef, plants invested sufficiently in food safety to reach a performance level on *Salmonella* tests equal to the FSIS standard. Costs of a recall, therefore, include greater food safety costs, lost market value (Thompson and McKenzie, 2001), and lower prices (Piggot and Marsh, 2004; Thompson, Shiptsova, and Hamm, 2006).

Overall, results indicate that plants with recalls perform worse on *Salmonella* tests than plants without recalls. These plants met the FSIS *Salmonella* tests below the FSIS standard but were disproportionately represented in the group of plants with a level of performance greater than 50 percent of standard and less than the standard. Plants with recalls had higher levels before the recall than after, suggesting that the discipline imposed by a recall compelled plants to improve their performance. One way to reduce recalls may be to encourage better performance on *Salmonella* tests via market mechanisms, such as providing better information to buyers about performance on *Salmonella* tests.

Conclusion

The article makes several contributions to the literature on food safety and information disclosure in credence attributes. Economists (Shavell, 1984; Schmitz, 2000; Marino, 1997) argue that the costs of a product recall, including the direct and liability costs and the costs of a lost reputation for safety, encourage investment in safety. Heretofore, there has been little

empirical evidence supporting this argument. This paper helps fill that void by presenting evidence that plants perform poorly on *Salmonella* tests during the event year and improve their performance afterward. Moreover, the paper shows that plants with recalls have persistently higher levels of *Salmonella* over the 1999-2014 period.

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Table 1: Frequency of all Class I recalls: 1998-2014

Year	Bacteria	Allergen	Processing	Lack Inspection	Class_I
1998	16	0	3	0	19
1999	32	0	4	1	40
2000	47	0	1	0	49
2001	36	7	5	0	48
2002	62	19	3	0	74
2003	28	10	3	0	42
2004	22	11	0	0	35
2005	34	7	3	0	44
2006	13	9	0	0	23
2007	31	13	7	0	45
2008	20	6	0	1	29
2009	23	11	0	2	35
2010	24	14	3	2	37
2011	25	33	4	5	46
2012	19	25	0	5	38
2013	18	23	5	4	44
2014	5	29	0	5	32
Total	455	217	41	25	680

Source: Economic Research Service, based on FSIS administrative data.

Table 2: Frequency of Ground Beef Class I Recalls: 1998-2014
(Plants Tested by FSIS for *Salmonella* only)

Year	<i>E. coli</i>	<i>Salmonella</i>	<i>Listeria monocytogenes</i>	Allergen/Other Class 1	Total
1998	6	1	1	0	8
1999	5	0	3	2	10
2000	18	0	6	1	25
2001	17	0	6	1	24
2002	12	0	5	5	22
2003	7	0	3	6	16
2004	6	0	1	2	9
2005	4	1	0	1	6
2006	7	0	2	1	4
2007	16	0	0	3	19
2008	5	0	1	1	7
2009	6	2	1	6	15
2010	6	0	2	2	10
2011	9	1	0	7	17
2012	4	1	2	5	12
2013	3	0	0	5	8
2014	0	0	0	5	5
Total	131	6	33	53	217

Source: Economic Research Service, based on FSIS administrative data.

Table 3. Variable definitions and their mean, minimum, and maximum values

Empirical variable	Definition	Mean	Min	Max
Sequential Logit Regression				
Independent Variables				
Food Safety Performance				
Share <i>Salmonella</i>	Share of samples testing positive for <i>Salmonella</i>	0.023	0.00	0.484
Industry Effects				
Time	Time trend starting in 1998	7.0	0	16
Industry Percent <i>Salmonella</i>	Annual mean ground beef plant <i>Salmonella</i> results	0.023	0.012	0.069
Characteristics of Recalled Product				
Raw ground beef product recalled	One if product is raw ground beef; else zero.	0.652	1.0	0.00
Routine	One if reason for recall is routine testing; else zero		1.0	0.00
Consumer illness	One if reason for recall is a consumer illness or complaint and zero otherwise.	0.259	1.0	0.00
Thousands pounds recalled	Pounds of product recalled in millions.	0.332	.00004	21.7
Plant Characteristics				
Thousands of Employees	Plant employment in thousands.	0.139	0.001	4.80
Plant has Slaughter Operations	One if plants slaughters chickens; else zero.	0.113	0.0	1.0
Is Plant part of multi-plant firm	One if owner has more than one plant; else zero.	0.148	0.0	1.0
Plant age	Current year minus year meat grant issued	12.32	0.0	79.0
Further Processing	One if plant further processes meat; else zero.	0.387	0.0	1.0
Sanitation Tasks				
Percent Positive noncompliant Operation SSOPs	Share of SSOPs required during operations in compliance with standards.	0.014	0.00	0.329
Percent Positive noncompliant Pre-Operation SSOPs	Share of SSOPs required before operations in compliance with standards.	0.025	0.00	0.333
Percent Positive noncompliant HACCP Tasks	Share of HACCP tasks not in compliance with standards.	0.006	0.00	0.308
Tobit Regression of <i>Salmonella</i> Levels over the Event Window (additional variable only)				
Dependent Variable:				
Share <i>Salmonella</i>	Share of samples testing positive for <i>Salmonella</i>	0.025	0.00	0.246
Independent Variables:				
Event Period				
Three years before recall, etc	One if year is three years before recall; else zero.	0.066	0.0	1.0
Three years after recall, etc.	One if year is three years after recall; else zero.	-	0.0	1.0
Industry and Recall Effects				
Year	Year in which product was recalled	2005	1999	2014
Number of plants with recalls		158		

Source: Economic Research Service, based on FSIS administrative data.
HACCP, FSIS, and SSOP are acronyms for Hazard Analysis and Critical Control Program, Food Safety and Inspection Service, and Standard Sanitation Operating Procedures.

Table 4: *Salmonella* levels for ground beef plants without recalls and with recalls due to *E. coli* and non-*E. coli* from 1999-2014.

(1) Year	(2) No recalls	(3) All recalls	(4) Allergen/ other recall	(5) Recalls for <i>E. coli</i> or <i>Salmonella</i>
1999	0.041	0.045	0.038	0.050
2000	0.031	0.042	0.036	0.047
2001	0.029	0.033	0.034	0.032
2002	0.023	0.037	0.031	0.041
2003	0.013	0.028	0.009	0.043
2004	0.013	0.025	0.014	0.034
2005	0.013	0.015	0.012	0.017
2006	0.018	0.026	0.022	0.028
2007	0.022	0.024	0.011	0.033
2008	0.020	0.024	0.013	0.027
2009	0.019	0.019	0.019	0.020
2010	0.020	0.020	0.013	0.023
2011	0.019	0.023	0.019	0.024
2012	0.020	0.019	0.021	0.018
2013	0.011	0.015	0.010	0.017
2014	0.012	0.015	0.019	0.013
Mean, all years	0.020	0.026	0.020	0.029
Observations	3,532	846	306	540

Source: Economic Research Service, based on FSIS administrative data.

Table 5: *Salmonella* levels for ground beef plants with recalls due to *E. coli* and plants with non-*E. coli* recalls over a period from five years before to four years after their recalls.

(1)	(2)	(3)	(4)
	All Recalls	Allergen/Other recalls	<i>E. coli</i> Recalls
	Share of samples testing positive for <i>Salmonella</i>		
-5	0.032	0.040	0.027
-4	0.028	0.028	0.028
-3	0.033	0.030	0.034
-2	0.033	0.026	0.038
-1	0.034	0.025	0.039
0	0.036	0.020	0.043
1	0.024	0.015	0.028
2	0.019	0.016	0.020
3	0.021	0.009	0.028
4	0.014	0.007	0.016
5	0.021	0.010	0.027
Mean, all years	0.027	0.021	0.030
Observations	510	170	340

Source: Economic Research Service, based on FSIS administrative data.

Table 6. Marginal Effects of Performance on *Salmonella* Tests of Ground-Beef Plants on Nested Recall Outcomes Using a Sequential Logit Regression Model,1999–2012

	Stage 1:	Stage 2:	Stage 3:	Stage 1:	Stage 2	Stage 3
	Recall vs. No Recall	Recall for Pathogen vs. Other Recall	Recall for <i>Salmonella</i> or <i>E. coli</i> vs <i>Listeria</i>	Recall vs. No Recall	Recall for Pathogen vs. Other Recall	Recall for <i>Salmonella</i> or <i>E. coli</i> vs <i>Listeria</i>
<i>Salmonella</i> share	0.519*** (0.173)	-0.470 (0.625)	3.980 (4.060)	0.511*** (0.217)	-0.636 (0.589)	5.390** (2.320)
Industry Trends						
Time	0.011*** (0.003)	-0.011 (0.009)	0.046 (0.030)	0.010*** (0.003)	-0.016 (0.010)	0.050** (0.021)
Industry Percent Positive <i>Salmonella</i>	4.280*** (1.160)	0.860 (1.920)	6.89*** (1.990)	1.430 (1.250)	-4.740 (4.410)	11.800 (8.300)
Characteristics of Recalled Products						
Raw ground beef product recalled				-	0.625*** (0.156)	1.280*** (0.435)
Routine Testing				-	0.410*** (0.134)	0.303 (0.330)
Consumer illness				-	4.960 (3.290)	4.470*** (1.430)
Thousands pounds recalled				-	0.081 (0.076)	2.830** (1.430)
Plant Characteristics						
Thousands of Employees	-	-	-	0.130*** (0.042)	-0.050 (0.073)	0.330* (0.180)
Does plant have Slaughter Operations	-	-		0.002 (0.041)	0.124 (0.149)	0.603* (0.370)
Is Plant part of multi- plant firm	-	-	-	0.10*** (0.032)	0.310*** (0.120)	-0.202 (0.182)
Plant age	-	-	-	0.002** (0.001)	0.008* (0.005)	-0.004 (0.008)
Further Processing				0.017 (0.030)	0.204** (0.105)	-0.467* (0.225)
Sanitation and Process Control Tasks						
Percent Positive noncompliant Operation SSOPs	-	-	-	0.835*** (0.323)	-1.020 (1.150)	5.140* (2.840)

Percent Positive noncompliant Pre-Operation SSOPs	—	—	-	-0.216 (0.250)	0.256 (0.952)	-2.890 (2.290)
Percent Positive noncompliant HACCP Tasks	—	—	-	-1.980** (0.826)	-2.380 (2.660)	-5.730 (4.080)
Wald χ^2	31.40 (LL=3,152)			50.37 (LL=2542)		
Observations	4,378			3,998		

Source: Economic Research Service, based on FSIS administrative data.

HACCP, FSIS, and SSOP are acronyms for Hazard Analysis and Critical Control Program, Food Safety and Inspection Service, and Standard Sanitation Operating Procedures.

Notes: Stage 1 is whether the plant had a product recalled over study period; Stage 2 is if the recall was due to a pathogen or some other cause; Stage 3 is if the pathogen was *E. coli* or *Salmonella*, both of which are pathogens that can naturally occur in cattle or ground beef.

Plant-level clustered standard errors in parentheses.

*, **, *** = 0.10, 0.05, and 0.01 levels of significance, respectively.

Table 7. Marginal Effects of Performance on *Salmonella* Tests of Ground-Beef Plants on Nested Recall Outcomes Using a Sequential Logit Regression Model, 1999–2012

	Stage 1:	Stage 2:	Stage 3:	Stage 1:	Stage 2	Stage 3
	Recall vs. No Recall	Recall for Pathogen vs. Other Recall	Recall for <i>Salmonella</i> or <i>E. coli</i> vs <i>Listeria</i>	Recall vs. No Recall	Recall for Pathogen vs. Other Recall	Recall for <i>Salmonella</i> or <i>E. coli</i> vs <i>Listeria</i>
<i>Salmonella</i> share	0.519*** (0.173)	-0.470 (0.625)	3.980 (4.060)	0.511*** (0.217)	-0.086 (0.382)	5.620** (2.680)
Industry Trends						
Time	0.012*** (0.003)	0.002 (0.009)	0.048*** (0.018)	0.011*** (0.003)	-0.010 (0.010)	0.042** (0.020)
Industry Percent Positive <i>Salmonella</i>	4.280*** (1.160)	0.960 (3.530)	14.600** (6.890)	1.430 (1.250)	-2.140 (2.560)	-5.080** (2.200)
Characteristics of Recalled Products						
Raw ground beef product recalled	-	0.551*** (0.136)	1.144 (0.960)	-	-	-
Routine Testing	-	0.325*** (0.093)	0.313** (0.141)	-	-	-
Consumer illness	-	0.847*** (0.268)	3.340 (1.116)	-	-	-
Thousands pounds recalled	-	0.124 (0.113)	2.420 (1.690)	-	-	-
Plant Characteristics						
Thousands of Employees	-	-	-	0.130*** (0.042)	-0.010 (0.050)	0.250** (0.120)
Does plant have Slaughter Operations	-	-		0.002 (0.041)	0.002 (0.084)	-0.031 (0.056)
Is Plant part of multi- plant firm	-	-	-	0.098*** (0.033)	0.105 (0.081)	0.080** (0.037)
Plant age	-	-	-	-0.002* (0.001)	0.002 (0.003)	-0.004 (0.002)
Further Processing				0.017 (0.030)	0.026 (0.056)	-0.192*** (0.049)
Sanitation Tasks						
Percent Positive noncompliant Operation SSOPs	-	-	-	0.835*** (0.323)	-0.160 (0.563)	1.180* (0.630)

Percent Positive noncompliant Pre-Operation SSOPs	—	—	-	-0.216 (0.250)	0.016 (0.492)	-0.456 (0.347)
Percent Positive noncompliant HACCP Tasks	—	—	-	-1.980** (0.826)	0.070 (1.710)	0.821 (1.490)
Wald χ^2	31.40 (LL=2824))			50.37 (LL=2846)		
Observations	4,378			3,998		

Source: Economic Research Service, based on FSIS administrative data.

HACCP, FSIS, and SSOP are acronyms for Hazard Analysis and Critical Control Program, Food Safety and Inspection Service, and Standard Sanitation Operating Procedures.

Notes: Stage 1 is whether the plant had a product recalled over study period; Stage 2 is if the recall was due to a pathogen or some other cause; Stage 3 is if the pathogen was *E. coli* or *Salmonella*, both of which are pathogens that can naturally occur in cattle or ground beef.

Plant-level clustered standard errors in parentheses.

*, **, *** = 0.10, 0.05, and 0.01 levels of significance, respectively.

Table 8 Tobit Results of *Salmonella* levels over Event Windows Spanning Seven, Five, and Three Years: All recalls.

Variable	Seven year window	Five year window	Three year window
Event Period			
Three years before recall	0.013 (0.010)	-	-
Two years before recall	0.005 (0.010)	0.001 (0.010)	-
One-year before recall	0.015 (0.011)	0.011 (0.010)	0.013 (0.010)
Event Year (Year zero)	0.018* (0.010)	0.014 (0.019)	0.016* (0.009)
One-year after recall	0.008 (0.009)	0.004 (0.009)	0.006 (0.008)
Two-years after recall	-0.008 (0.010)	-0.011 (0.009)	-
Three-years after recall	0.008 (0.009)	-	-
Industry Effects			
Industry Percent Positive <i>Salmonella</i>	0.427 (0.655)	0.180 (0.576)	0.367 (0.578)
Year	-0.003*** (0.001)	-0.003*** (0.001)	-0.003*** (0.001)
Characteristics of Recalled Product			
Raw ground beef product recalled	0.020** (0.008)	0.020*** (0.008)	0.020*** (0.008)
Routine	-0.016** (0.008)	-0.016** (0.008)	-0.017** (0.009)
Consumer illness	-0.005 (0.009)	-0.005 (0.009)	-0.005 (0.009)
Thousands pounds recalled	-0.002*** (0.0004)	-0.002*** (0.0004)	-0.0017** (0.0004)
Plant Characteristics			
Thousands of Employees	0.004 (0.001)	0.004 (0.010)	0.005 (0.010)
Does plant have Slaughter Operations	0.005 (0.010)	0.006 (0.010)	0.006 (0.010)
Is Plant part of multi-plant firm	0.007 (0.007)	0.006 (0.007)	0.010 (0.007)
Plant age	0.0002** (0.00007)	0.0002** (0.00007)	0.0004 (0.0003)
Further Processing	-0.017** (0.007)	-0.016** (0.007)	-0.012* (0.007)
Sanitation Tasks			

Percent Positive noncompliant Operation SSOPs	0.163 (0.130)	0.130 (0.122)		0.144 (0.123)	
Percent Positive noncompliant Pre-Operation SSOPs	0.005 (0.400)	-0.064 (0.071)		-0.096 (0.072)	
Percent Positive noncompliant HACCP Tasks	0.005 (0.400)	0.056 (0.395)		0.036 (0.400)	
F-test	6.15***	5.57***		5.98***	
R ²	-0.15	-0.155		-0.151	
Observations	499	499		499	
Share Percent_Pos = 0	45 percent	46 percent		46 percent	

Source: Economic Research Service, based on FSIS administrative data.
HACCP, FSIS, and SSOP are acronyms for Hazard Analysis and Critical Control Program, Food Safety and Inspection Service, and Standard Sanitation Operating Procedures.

Table 9: Tobit Results of *Salmonella* levels over Event Windows Spanning Seven, Five, and Three Years: *E. coli* recalls.

Variable	Seven year window	Five year window	Three year window
Event Period			
Three years before recall	0.020* (0.012)	-	-
Two years before recall	0.013 (0.013)	0.007 (0.012)	-
One-year before recall	0.021 (0.014)	0.015 (0.013)	0.015 (0.013)
Event Year (Year zero)	0.029*** (0.010)	0.022** (0.010)	0.024** (0.010)
One-year after recall	-0.003 (0.011)	0.010 (0.011)	0.011 (0.010)
Two-years after recall	-0.003 (0.012)	-0.009 (0.011)	-
Three-years after recall	0.015 (0.013)	-	-
Characteristics of Recalled Product			
Raw ground beef product recalled	0.016 (0.012)	0.016 (0.012)	-0.015 (0.012)
Routine	-0.020* (0.011)	-0.020* (0.011)	-0.021** (0.011)
Consumer illness	-0.008 (0.011)	-0.007 (0.011)	-0.008 (0.011)
Thousands pounds recalled	-0.002*** (0.00065)	-0.002*** (0.0004)	-0.0015*** (0.0004)
Industry Effects			
Industry Percent Positive <i>Salmonella</i>	0.494 (0.466)	0.280 (0.469)	0.577 (0.652)
Year	-0.002 (0.0013)	-0.002* (0.0012)	-0.002* (0.0013)
Plant Characteristics			
Thousands of Employees	0.004 (0.001)	0.004 (0.010)	0.006 (0.010)
Does plant have Slaughter Operations	0.005 (0.010)	0.006 (0.010)	0.0005 (0.011)
Is Plant part of multi-plant firm	0.007 (0.007)	0.006 (0.007)	0.009 (0.007)
Plant age	0.0002** (0.00007)	0.0002** (0.00007)	0.0001* (0.00008)
Further Processing	-0.017** (0.007)	-0.016** (0.007)	-0.020*** (0.007)
Sanitation Tasks			

Percent Positive noncompliant Operation SSOPs	0.163 (0.130)	0.130 (0.122)	0.181 (0.129)	
Percent Positive noncompliant Pre-Operation SSOPs	0.005 (0.400)	-0.064 (0.071)	-0.061 (0.076)	
Percent Positive noncompliant HACCP Tasks	0.005 (0.400)	0.056 (0.395)	-0.162 (0.386)	
F-test	5.26***	3.19***	5.12***	
R ²	-0.130	-0.116	-0.119	
Observations	334	334	334	
Share Percent_Pos = 0	45 percent	45 percent	45 percent	

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¹ Observations with fewer than 30 ground beef samples were dropped because FSIS (2012) indicates that test results for sample sets of less than 30 observations may be biased.