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Crisis management effectiveness indicators for US meat and poultry recalls

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Abstract

Policy makers within the US Department of Agriculture (USDA) complement the role of meat and poultry plant managers in food recalls. The increasing frequency and scale of recalls raise questions whether sufficient attention is placed on these events. Three measures of recall effectiveness are introduced to evaluate this public-private crisis management process. Managerial and technical variables are compared to these measures of effectiveness. Results from regression models suggest that recalls carried out by the smallest sized plants, those that took place after Pathogen Reduction/Hazard Analysis Critical Control Point implementation, and recalls involving processed products are more effective. Little evidence of differences was found in the effectiveness of the crisis management process between meat plants compared with poultry plants or for plants that are part of a larger firm. Despite USDA's stated focus on recalls with more severe public health consequences, there is no evidence that Class I or microbiological recalls are more effectively managed.

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Keywords: Food safety; Meat and poultry recalls; Pathogen reduction/hazard analysis critical control point; Recovery rate

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Introduction

Effective crisis management within the food system requires prompt and complete responses to food safety problems to ensure consumer confidence. As an example, meat and poultry recalls in the US have been subjected to increasing scrutiny over recent years with concern being voiced about the appropriateness of a predominately voluntary process. The Federal government has a limited ability to require firms to conduct recalls. Yet it is in the best interest of firms to pursue proven crisis management practices to reassure their customers. It is unclear if all firms recognize this situation or if additional policy is required to strengthen government oversight or control. Given this environment, various bills have been presented to the US Congress, particularly following large recalls of nearly 19 million pounds of ground beef over concerns of contamination with *Escherichia (E.) coli* O157:H7 and 27.4 million pounds of chicken and turkey products potentially contaminated with *Listeria monocytogenes* in 2002.¹

The Food Safety and Inspection Service (FSIS) of US Department of Agriculture (USDA) is the main regulatory agency responsible for the safety of meat and poultry products. In 1998, FSIS set up a working group to evaluate its recall policy and provide recommendations. The group's findings emphasized how to strengthen risk communication channels between the agency, firms and related parties and how to maximize product recovery (Axtell et al., 1998). Nevertheless, a subsequent report by the US General Accounting Office (GAO) suggested that further action was necessary (GAO, 2000).

This paper uses the database of meat and poultry recalls maintained by FSIS covering 1994–2002 to test for effectiveness of crisis management, using new benchmark measures that focus on the timeliness and impact of the process. Only with an effective recall process can the public health effects of food safety problems encountered by firms be minimized.

Several studies have examined FSIS meat and poultry recall events, mainly to consider the economic and financial incentives provided by recalls to encourage private food safety controls. Lusk and Schroeder (2002); Marsh et al. (2004); Salin and Hooker (2001); Thomsen and McKenzie (2001) and Wang et al. (2002) examined the effect of meat and poultry recalls on firm's stock price, market returns, consumer demand and societal reactions. Teratanavat and Hooker (2004) present a summary of key trends in the FSIS recall data set. Shiptsova et al. (2002) examined the effect of recall costs on profitability and competitiveness of the beef, pork, and poultry industries using data from 1995 to 1999. Other studies provide descriptive statistics and summaries of the US Food and Drug Administration (FDA) recall data for microbial contamination and undeclared allergens, see Wong et al. (2000) and Vierk et al. (2002) respectively. However, no study has yet been conducted which analyzes the

¹ One example of legislation that would provide USDA with mandatory recall authority is the *Unsafe Meat and Poultry Recall Act* (H.R. 2273).

relationship between recall effectiveness, as defined from a policy perspective, and possible explanatory factors.

This study constructs three measures which indicate the overall effectiveness of this public-private crisis management regime. The measures are not intended to estimate the cost of a recall but to assess the extent to which consumers are protected by current practices and, if not, to recommend policy improvements. Several characteristics, which may influence recall effectiveness, are included in an attempt to reveal useful information for firms and policy makers to help assess whether recall strategies need to be adjusted for different cases. These measures are unique to the literature on the economics of food safety.

Meat and poultry risk management and recall process

FSIS performs inspection activities and enforces regulations to ensure that meat, poultry, and egg products are wholesome and accurately labeled. The agency encourages improvements in the safety of these products through various programs. In 1996, FSIS started to implement a new food safety program, the Pathogen Reduction/Hazard Analysis Critical Control Point (PR/HACCP) system, which emphasizes hazard identification and prevention throughout a plant's process, as a move away from the detection of potential problems at the end of the production line (FSIS, 1996; USDA, 1996). Recent research has focused on the overall effectiveness of this risk management program, which is required in all meat and poultry slaughter and processing plants. As one measure of policy effectiveness, it has been suggested that PR/HACCP has led to a significant reduction in the numbers of foodborne illnesses from *Salmonella* (FSIS, 2002a).

To ensure the safety of the food supply beyond slaughter and processing plants, FSIS conducts microbial testing and investigates potential problems associated with products after they enter the supply chain, including those in warehouses and retail outlets. FSIS uses recalls as a risk management tool (of final recourse) to protect consumers from foods that may cause negative health consequences. The strategy suggests how widespread the recall should be, including affected businesses and consumers, describes any public warning to be issued, and explains how effectiveness checks will be implemented and verified. The agency also communicates information about the recall to consumers and contacts all parties involved through press releases to ensure that affected products are retrieved from the market.

Even though the process is voluntary and there is no statutory authority for FSIS to order recalls, producers and/or distributors generally promptly comply with recall requests (FSIS, 2000a; GAO, 2000). Failure to remove contaminated or violative products from commerce may result in negative publicity, consumer complaints, liability lawsuits, and damage to company reputation. FSIS therefore works closely with the industry at every step of the recall process to guarantee that products are removed from the food supply. The recalling firm is expected to perform effectiveness checks during the recall and inform FSIS of the results. The main purpose of these checks is to verify that the recalling firm has provided adequate notice and that all

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consignees have located products and followed the recalling firm's instructions² (FSIS, 2000b). As part of its crisis management strategy, FSIS verifies whether the recall action has been conducted in an appropriate way, based in part on these reports, to determine if firms have made all reasonable efforts to retrieve and rework or dispose of the recalled products. The recall process is considered effective when adequate notice about the recall has been provided to all consignees by the firm conducting the recall and when consignees have located and controlled product, following the recalling firm's instructions (FSIS, 2004). The recall case is ended, with no further action required, when FSIS and the recalling firm are in agreement that the product subject to recall has been removed and proper disposition or correction has been made. Only then, the Emergency Response Division, Office of Public Health and Science, issues the final document stating that the recall is terminated (FSIS, 2000b).

Defining measures of recall effectiveness

The US meat and poultry recall system described above functions through the voluntary cooperation of the industry within the bounds of regulatory supervision and threats of legal action. There are competing forces and incentives involved in achieving the balance between quality and costs that characterize the system. This assessment of the varying forces that shape the system and ability to conduct an impactful crisis management process draws upon the disciplines of business management and policy analysis to develop measures of recall effectiveness and hypotheses that can be tested with the available data.

Much of the debate about recalls has centered on the question of timeliness (GAO, 2000). GAO's perspective stresses the urgency of response when contamination in the food supply is discovered. Therefore measures of effectiveness that highlight the time-sensitivity of the recall process: the recovery rate, the speed or duration of the case, and the ratio of recovery rate-completion time offer an important assessment. For a recall process to be effective a large proportion of product should be recovered or returned back to producers in a prompt manner. As shown in Table 1, the effectiveness measures are defined as:

- 1. The *recovery rate* is the proportion of volume recovered to the total volume recalled.
- 2. The *completion time* measures speed of the recall action, in the number of days to close the case. This is a direct measure of timeliness, the focus of GAO's evaluation.

 $^{^{2}}$ The effectiveness check should contain the following information: the number of consignees notified of, and responding to, the recall communication, the quantity of product each consignee had on hand, the quantity of product returned to each consignee, and an estimated time for completion of the recall (FSIS, 2000c).

Hypotheses to be tested

Business management models discussing the role of intangible assets, skills, information and learning provide a perspective on food safety risk management efforts such as PRHACCP as a form of process control. As part of these efforts an effective crisis management process should be able to quickly identify faults and respond, because it exists in a world in which the "costs of poor quality exceed the cost of developing processes which produce high quality products" (Mazzocco, 1996).

Due to the complexity of the meat and poultry slaughter and processing system, there are a variety of factors that contribute to, or constrain, the potential effectiveness of crisis management. Indicators of such factors available in the data can be grouped into two sets; *managerial factors* and *technical factors* of the recall. Some of these factors are beyond the control of plant management or (potentially) FSIS, others could serve as a focus of enhanced control under a mandatory recall program should evidence suggest a need. For example, if a certain type of plant or product is associated with less effective crisis management then public health may be better served by a reallocation of plant and FSIS resources towards these recalls.

A set of *managerial factors at the plant level* are hypothesized to influence the effectiveness of recalls. Plant size, whether the plant is part of a larger firm, the history of crisis management at the plant and timing variables are all evaluated.

While conforming to a design/process standard is a sunk cost, which disadvantages smaller firms, according to Antle (1996), flexibility in implementation of PR/ HACCP (with elements of performance as well as process standards – Jensen and Unnevehr (2000)) means that both large and smaller firms should be able to adopt systems that are equally effective in preventing food contamination. Even a small firm can hire expertise for the one-time design of a system that accommodates its' circumstances. Therefore, overall food safety management under PR/HACCP is argued to be scale neutral. Recent research suggests that this may not be the case (Hooker et al., 2002; Ollinger and Mueller, 2003). Scale factors can impact certain features of management; particularly the expertise and record keeping ability that are key success factors in a crisis management situation such as a recall. A smaller plant, in which management cover many duties, is unlikely to be able to devote as much effort to closing a recall case, both in terms of data analysis and communications with customers and regulators.

PR/HACCP is implemented at the plant level. However, if the facility is part of a larger operation (multi-plant firm) one may expect a more efficient recall process if management expertise is shared and specialization of skills facilitated. Similarly, if

Table 1	
Descriptive statistics for dependent and independent variables	

Туре		Description	Mean	SD	Min	Max
Dependent varia	bles					
Precovery	Continuous	Recovery rate (percent)	49.00	50.32	0	650.94
Completion	Continuous	Total days to complete the recall (days)	157.52	89.78	2	616
Pratio	Continuous	Ratio of recovery rate and completion time (percent/day)	0.41	0.57	0	6.23
Explanatory var	riables					
Managerial fact	ors					
Slarge	Binary	Plant size: large $(1 = yes; 0 = no)$	0.24	0.42	0	1
Ssmall	Binary	Plant size: small $(1 = yes; 0 = no)$	0.52	0.50	0	1
Svsmall	Binary	Plant size: very small $(1 = yes; 0 = no)$	0.24	0.42	0	1
Numberplant	Binary	Numbers of plants (1 = multi-plant firm; 0 = single-plant firm)	0.36	0.48	0	1
Repeated	Binary	Repeated recall at the plant level $(1 = Yes, 0 = No)$	0.19	0.39	0	1
HACCP	Binary	PR/HACCP implemented at time of recall $(1 = yes; 0 = no)$	0.68	0.47	0	1
Date	Continuous	Range from 1 to 9 representing year 1994 to 2002	6.09	2.67	1	9
Technical factor	·s					
Meatpoultry	Binary	Meat or poultry plant (1 = Meat; 0 = Poultry)	0.72	0.46	0	1
Logpound	Continuous	Log value of total pounds of recalled product	8.76	2.95	1.39	17.37
Processed	Binary	Processed vs. raw fresh products ($1 = $ processed food; $0 = $ raw or fresh products)	0.76	0.43	0	1
Class1	Binary	Class I recall $(1 = yes; 0 = no)$	0.75	0.43	0	1
Class2	Binary	Class II recall $(1 = yes; 0 = no)$	0.18	0.39	0	1
Class3	Binary	Class III recall $(1 = yes; 0 = no)$	0.07	0.24	0	1
Hbiological	Binary	Hazard type: biological $(1 = yes; 0 = no)$	0.69	0.46	0	1
Hchemical	Binary	Hazard type: chemical $(1 = yes; 0 = no)$	0.16	0.35	0	1
Hphysical	Binary	Hazard type: physical $(1 = yes; 0 = no)$	0.15	0.36	0	1

Note:

1. Number of observations = 429.

2. Approximately 5.6% and 3.7% of all recall cases during 1994 to 2002 had recovery rates equal to 0% and greater than 100%, respectively.

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a plant has previous experience with a recall, later episodes should be more effective if management has learned through the process.

A set of timing factors are hypothesized to influence the effectiveness of recalls. These are whether the recall occurred in the pre- or post-PR/HACCP timeframe and the year of the recall. Even though the regulation does not directly discuss the recall process, implementation of PR/HACCP should indirectly impact how firms handle meat and poultry recalls due to enhanced record keeping. Further, under PR/HACCP, meat and poultry plants should have better inspection programs that can detect food safety problems faster facilitating recalls and removing affected products from the market at an early stage of the supply chain. A binary variable (PR/ HACCP) represents an intercept shifting factor for the pre-versus post-PR/HACCP regulatory environment. In addition to the implementation of PR/HACCP protocols, the time period of the analysis was marked by changes in many factors. Food safety technology, microbiological (and other) detection sensitivity, communication channels, and consumer awareness have all progressed over the period studied (FSIS, 2001). To evaluate the role of these combined dynamic factors a spline function (Greene, 2000, p. 324) is used. This specification allows for the time trend to have different characteristics in the pre-PR/HACCP period compared with the post-PR/HACCP period using a multiplicative interaction term (Date*PR/HACCP).

A set of *factors describing the technical nature of the recall* are hypothesized to influence the effectiveness of recalls. These include the type of inspection environment (meat or poultry plant), the size of the recall, the type of product recalled (processed or raw) and the severity of the recall (Class and hazard type).

The inspection environment, microbiological (and other) hazards, performance standards, slaughter, and processing technologies applied vary between meat and poultry plants (NAS, 2003). Therefore a simple test of the difference between meat as opposed to poultry plants may highlight an important technical aspect of the effectiveness of recalls.

Large recalls are likely to be more difficult to execute effectively, leading to lower recovery rates and longer periods to complete the case. The size of the recall is measured in pounds of product recalled, not volume recovered. Processed, as opposed to raw meat and poultry products, generally have longer shelf lives. ³ This should enhance the identification and recovery of product during a recall and make longer recalls technically feasible (processed products can realistically still be in distribution, retail and/or consumers control for a longer time). Recalls of processed foods are expected to be more effective.

Regulatory models of feedback drawn from the policy analysis literature (e.g., Olson, 1997) are based on the premise that regulators respond to signals from external stakeholders. FSIS has at least two sets of key stakeholders: meat and poultry plant managers and the general consuming public. These stakeholder groups may offer

³ The authors are aware that different raw or processed foods have a range of shelf lives. One processed food may last three months, whereas another may last a few years. To capture this effect, product shelf life should be treated as a continuous variable. However, FSIS recall data does not provide such information; an indicator variable, 0 for raw food and 1 for processed food, is assigned instead.

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conflicting feedback to an action by the regulator, in which case their relative influence may simply cancel out. One clear proposition would be that both camps of external stakeholders would approve of prioritizing the responses to the most severe food safety problems. The proxies for severity are Class I recalls and biological hazards. ⁴ Such a notion of prioritization does not simply suggest cases be closed quickly. There may be instances when these severe cases need to remain open longer with a firm trying to remove as much unsafe product from the market as possible. Thus, it is necessary to consider both measures (i.e., recovery rate and case duration) simultaneously when determining whether the firm manages severe cases effectively. Businesses would respond favorably to effective handling of cases that might invoke legal liability and support their ethical business practices.

Methodology and data issues

Data

FSIS recall summaries (available at http://www.fsis.usda.gov/OA/recalls/rec_intr.htm) contain information about recall dates, identifying codes, company names, location of incidents, recalled products, reason for, and size of, recall and recovery in pounds. In most cases, press releases are also available. Data for 2001 and 2002 were made available to the authors by FSIS following a *Freedom of Information Act* request. Plant sizes were retrieved from the USDA/FSIS Field Automation and Information Management Division database (available at http:// www.fsis.usda.gov/OFO/FAIM/faimmain.htm). The recall data used in this study are from 1994 to 2002 with a total of 429 observations.

The effectiveness measures examined in this study are a mix of performance indicators in percentages and duration, or count data. All three indicators are censored at zero, which requires appropriate econometric testing and procedures described below.

PR/HACCP timing

The post-PR/HACCP period varies chronologically as the regulation was phased in for smaller sized plants. Large meat and poultry slaughter and processing plants (those with more than 500 employees) were required to have PR/HACCP systems in place by January 26, 1998. The regulation for small plants (having between 10 and 500 employees) became effective January 25, 1999, and finally for very small plants

⁴ FSIS groups food recalls into three Classes I, II, and III depending on the potential adverse health consequences (FSIS, 2002b). Class I is the most serious case involving a health hazard situation with a high possibility of severe disease or death if people consume these food products. Following the *Food Code* foodborne hazard specification, biological hazards includes bacterial, viral and parasitic organisms. Cross-contamination and improper food processing and handling are the main reasons that these pathogens are found in food products.

(fewer than 10 employees or less than \$2.5 million in annual sales) on January 25, 2000 (Teratanavat and Hooker, 2004).

Descriptive statistics

Descriptive statistics are shown in Table 1 with explanations grouped into managerial and technical factors. During 1994 to 2002, the average amount of recalled product recovered was just under 50% while it took an average of 158 days to complete a recall case. The average ratio of the recovery rate and the time for case completion implies that 0.41% of product is recovered each day a case remains open. It is possible that the actual amount of product recovered exceeds the amount announced as can be seen when the recovery rate goes beyond 100%. ⁵

In the managerial category half of the recall cases were from small plants, one third of these plants were part of a larger operation and 19% of plants had experienced more than one recall over the period studied. The timing variables show that recall cases still occur under PR/HACCP and throughout the study period. The averages of 68% implementation of PR/HACCP and date = 6 (corresponding to 1999) highlight this temporal distribution.

Considering the technical category, 72% of recalls originated in meat plants, the average size of recalls varied considerably over the period, peaking to over 1 million pounds per recall in 1998. ⁶ The summary statistics are strongly influenced by seven cases; 25 million pounds by Hudson Foods (1997), 35 million pounds by Bil Mar Foods (1998), 35 million pounds by Thorn Apple Valley (1999), 17 million pounds by Cargill Turkey Products (2000), 14.6 million pounds by the Bar-S Food Company (2001), 19 million pounds by ConAgra (2002), and 27.4 million pounds by Wampler Food (2002). While these outlier observations affect the average in the raw data, they do not have a significant effect on any of the measures of recall effectiveness discussed in this paper. The regression models without outlier observations (available upon request) are not significantly different from the models with these observations included. Three quarters of these recalls involved processed foods, which have longer shelf lives than raw or fresh products. Classes I and II recalls account for 75% and 18%, respectively with two-thirds of the cases related to biological hazards.

Model selection for recovery rate analysis

The recovery rate and the recovery-duration ratio are percentages potentially censored at zero. Greene (2000) suggests that when the dataset is truncated or censored, OLS estimates are inconsistent. Approximately 5.6% of all observations reported zero recovery. Therefore, a censored regression model (Tobit) is used to examine the relationship between the recovery rate, the recovery rate-duration ratio, and fac-

⁵ The actual recovery rate, even beyond 100%, is included in the regression models.

⁶ The log transformation of the volume of product recalled (logpound) is used to avoid scale effects.

tors that may influence recall effectiveness. The structural equation for the Tobit model is

$$y_i^* = x_i \beta + \varepsilon_i,\tag{1}$$

where $\varepsilon_i \sim N(0, \sigma^2)$. y_i^* is a latent variable of the recovery rate (and the recovery–duration ratio) when they are greater than zero and is censored for values less than or equal to zero. The observed y_i is defined by the measurement equation,

$$y_{i} = \begin{cases} y_{i}^{*} & \text{if } y_{i}^{*} > 0, \\ 0 & \text{if } y_{i}^{*} \leqslant 0. \end{cases}$$
(2)

The expected value of y_i given all explanatory variables (x_i) can be derived as follows

$$E[y_i \mid x_i] = \Phi\left(\frac{x_i\beta}{\sigma}\right) \left(x_i\beta + \sigma \frac{\phi(x_i\beta/\sigma)}{\Phi(x_i\beta/\sigma)}\right),\tag{3}$$

where $\phi(.)$ is the probability density function and $\Phi(.)$ is the cumulative distribution function of $x_i\beta/\sigma$. The parameters (β and σ) can be estimated using the maximum likelihood method (Greene, 2000; Long, 1997). Chi-square tests are applied to determine whether parameter estimates are statistically significant. To check the robustness of the results, joint hypothesis tests are included (likelihood ratio or LR test) for variables that have more than one category within a group, such as plant size, recall class, and hazard type.

Model selection for completion time

Variables that report a frequency such as the number of days to complete a recall case, are often investigated using count data models (Long, 1997). Count data models have been applied in various research disciplines such as agricultural economics, economics, political science, and/or medical sciences. Examples include the number of times that shoppers decide to purchase irradiated meat products (Rimal et al., 1999), the duration of unemployment, the number of doctor visits (Cameron and Trivedi, 1986), the number of trips to recreation sites (Habb and McConnell, 2002), and so forth.

In this study, both censored and count data modeling techniques are applied when the duration of the recall case is the dependent variable, because the time is censored at zero. Count data regression models such as Poisson or Negative Binomial are more appropriate than Tobit or Truncated models since the number of days taken to complete the case are non-negative integers (Habb and McConnell, 2002). In this model Y_i is the number of days to complete the recall, assumed to be drawn from a Poisson distribution with parameter λ_i . The probability that the number of days equals any particular value can be written as (Cameron and Trivedi, 1998):

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$$\Pr(Y_i = y) = \frac{e^{-\lambda_i} \lambda_i^{y_i}}{y_i!} \quad y = 1, 2, \dots$$
(4)

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The parameter λ_i , representing the conditional probability of the dependent variable, is an exponential function of a constant and exogenous variables to ensure the non-negativity of Y_i . The mean parameter, also called the exponential mean, and the likelihood function are shown below. The coefficients (β) can be estimated using the maximum likelihood method.

$$E[y_i \mid x_i] = \lambda_i = \exp(x_i\beta), \tag{5}$$

$$L(\beta \mid x, y) = \prod_{i=1}^{n} \frac{\exp(-e^{x_i \beta})e^{(x_i \beta)y_i}}{y_i!}.$$
(6)

The main property of the Poisson distribution is that the conditional mean $(E[y_i|x_i\beta])$ is equal to its conditional variance (Var $[y_i|x_i\beta]$). As seen from Table 1, the conditional variance (standard deviation squared) of the dependent variable (completion time) is greater than the conditional mean, implying over-dispersion of the data. This over dispersion yields consistent coefficient estimates, but standard errors are biased downward (Gourieroux et al., 1984). Cameron and Trivedi (1998) suggest the negative binomial model, a more generalized specification that relaxes the equality of the conditional mean and variance. The negative binomial has a gamma distributed error term (ε) in the mean:

$$\lambda_i = \exp(x_i\beta + \varepsilon). \tag{7}$$

The density function is shown below where α is the over-dispersion parameter

$$f(y \mid \lambda_i, \alpha) = \frac{\Gamma(y_i + \frac{1}{\alpha})}{\Gamma(y_i + 1)\Gamma(\frac{1}{\alpha})} \left(\frac{\frac{1}{\alpha}}{\frac{1}{\alpha} + \lambda_i}\right)^{\frac{1}{\alpha}} \left(\frac{\lambda_i}{\frac{1}{\alpha} + \lambda_i}\right)^{y_i}.$$
(8)

Both parameters, α and β , can be estimated using the maximum likelihood method. With a negative binomial distribution, the conditional mean can now differ from the conditional variance

$$E[y_i \mid x_i\beta] = \lambda_i = \exp(x_i\beta + \varepsilon), \tag{9}$$

$$\operatorname{Var}[y_i \mid x_i\beta] = \lambda_i(1 + \alpha\lambda_i). \tag{10}$$

It is noted that if $\alpha = 0$, the negative binomial model becomes the Poisson model; as a result, a test of $\alpha = 0$ assesses both over-dispersion and the nested model (Habb and McConnell, 2002). The negative binomial specification for modeling the duration of recall cases is supported as the hypothesis of no over-dispersion ($\alpha = 0$) is rejected at the 0.01 level (Table 4). As in the case of recovery rate analysis, Chi-square and LR tests are applied for hypothesis testing.

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Table	2

Tobit model results - recovery rate

Explanatory variables	Estimated coefficient	Standard error	Chi-square	Marginal effect
Managerial factors				
Large	-6.194	6.946	0.80	-2.83
Vsmall	10.259*	6.921	2.90	4.69
Numberplant	-0.124	6.222	0.00	-0.06
Repeated	-7.972	6.756	1.39	-3.65
Насср	32.854*	19.795	2.75	15.02
Date	-4.271	2.845	2.25	-1.95
Haccp * Date	-1.262	3.593	0.12	-0.58
Technical factors				
Meatpoultry	0.744	6.216	0.01	0.34
Processed	12.779**	6.442	3.94	5.84
Class1	-11.043	12.997	0.72	-5.05
Class2	-10.375	12.074	0.74	-4.74
Biological	7.394	9.828	0.57	3.38
Chemical	1.095	9.724	0.01	0.50
Sigma	52.095	1.851		
Log likelihood	-2200.86			

Note:

1. Number of observations = 429. Censored observations = 24.

- 2. *Significant at 0.10 level. **Significant at 0.05 level. ***Significant at 0.01 level.
- 3. Likelihood ratio test rejects the joint hypothesis that $\beta large = \beta small = \beta vsmall (p < 0.05)$.
- 4. Likelihood ratio test fails to reject the joint hypothesis that $\beta class1 = \beta class2 = \beta class3$ (p > 0.10).
- 5. Likelihood ratio test fails to reject the joint hypothesis that $\beta biological = \beta chemical = \beta physical$ (p > 0.10).
- 6. The marginal effect is calculated by using the partial derivative of the conditional mean as follows:

$$\frac{\partial E[y \mid x_i\beta]}{\partial x_j} = \beta_j \Phi\left(\frac{x_i\beta}{\sigma}\right),$$

where $\Phi(\cdot)$ is the cumulative distribution function and all independent variables are held at their means.

Results

While the recovery rate models both pass the joint significance test, using the *F*-statistic, only a limited number of explanatory variables have a significant effect on percent recovered (alone and in the ratio with completion time) (Tables 2 and 3). Since recall size is used to derive the recovery rate and the recovery rate-completion time ratio, it is included only in the models where the efficiency measure is completion time to avoid an endogeneity problem (see Table 4 and the discussion below).⁷

⁷ Upon the recommendation of a reviewer a categorical variable reporting recall size as small (less than 10,000 lbs), medium (10,000–100,000 lbs) and large (greater than 100,000 lbs) was modeled in place of logpound (see Teratanavat and Hooker, 2004 for a further description of these recall categories). Results are consistent with those presented here, and are available from the authors upon request.

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Tobit model results - ratio of recovery rate to case duration

Explanatory variables	Estimated coefficient	Standard error	Chi-square	Marginal effect
Managerial factors				
Large	-0.068	0.078	0.78	-0.03
Vsmall	0.139*	0.078	3.22	0.07
Numberplant	-0.032	0.070	0.21	-0.02
Repeated	-0.099	0.076	1.68	-0.05
Насср	-0.239	0.223	1.15	-0.12
Date	-0.066 **	0.032	4.17	-0.03
Haccp * Date	0.071*	0.040	3.05	0.04
Technical factors				
Meatpoultry	0.059	0.069	0.73	0.03
Processed	0.189***	0.073	6.84	0.09
Class1	-0.056	0.146	0.14	-0.03
Class2	-0.101	0.136	0.55	-0.05
Biological	0.112	0.111	1.03	0.06
Chemical	0.018	0.109	0.03	0.01
Sigma	0.585	0.021		
Log likelihood	-382.14			

Note:

- 1. Number of observations = 429. Censored observations = 24.
- 2. *Significant at 0.10 level. **Significant at 0.05 level. ***Significant at 0.01 level.
- 3. Likelihood ratio test rejects the joint hypothesis that $\beta large = \beta small = \beta vsmall (p < 0.05)$.
- 4. Likelihood ratio test fails to reject the joint hypothesis that $\beta class1 = \beta class2 = \beta class3$ (p > 0.10).
- 5. Likelihood ratio test fails to reject the joint hypothesis that $\beta biological = \beta chemical = \beta physical$ (p > 0.10).
- 6. The marginal effect is calculated by using the partial derivative of the conditional mean as follows:

$$\frac{\partial E[y \mid x_i\beta]}{\partial x_j} = \beta_j \Phi\left(\frac{x_i\beta}{\sigma}\right),$$

where $\Phi(\cdot)$ is the cumulative distribution function and all independent variables are held at their means.

Among the managerial factors, the only statistically significant variable suggests that very small sized plants conduct more effective recalls than small plants, both in terms of the recovery rate and the recovery rate/completion time ratio. This is in contradiction to the working hypothesis.

Among the technical factors, only the processed variable has an impact on the recovery rate and ratio. As speculated products with a longer shelf life have higher recovery rates and higher recovery rate to case duration ratios. This lack of statistically significant variables suggests that whether the plant produces meat or poultry, the hazard type or severity (Classes I and II) do not influence recall effectiveness.

The regression results show that only two factors, plants part of a larger firm and recall size, affect case duration* even though the model has joint significance according to the likelihood ratio test (Table 4). The multi-plant firm result, with a statisti-

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Table	4
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Negative binomial model results - case duration

Explanatory variables	Estimated coefficient	Standard error	Chi-square	Marginal effect
Managerial factors				
Large	0.022	0.058	0.14	1.02
Vsmall	-0.018	0.061	0.09	0.98
Numberplant	0.073*	0.053	2.89	1.08
Repeated	-0.030	0.057	0.28	0.97
Hacep	0.713***	0.165	18.59	2.04
Date	0.093***	0.025	13.86	0.16
Haccp * Date	-0.166 * * *	0.031	28.84	-0.07
Technical factors				
Meatpoultry	-0.089	0.053	1.90	0.92
Logpound	0.061***	0.009	46.14	0.10
Processed	0.008	0.055	0.02	1.01
Class1	-0.012	0.111	0.01	0.98
Class2	0.007	0.102	0.00	1.01
Biological	0.073	0.084	0.77	1.08
Chemical	0.061	0.081	0.56	1.06
Sigma	0.184	0.013		
Log likelihood	278,951.97			

Note:

1. Number of observations = 429.

2. *Significant at 0.10 level. **Significant at 0.05 level. ***Significant at 0.01 level.

3. Likelihood ratio test fails to reject the joint hypothesis that $\beta large = \beta small = \beta vsmall (p > 0.10)$.

4. Likelihood ratio test fails to reject the joint hypothesis that $\beta class1 = class2 = \beta class3$ (p > 0.10).

- 5. Likelihood ratio test fails to reject the joint hypothesis that $\beta biological = \beta chemical = \beta physical$ (p > 0.10).
- 6. LOGPOUND, DATE, and HACCP*DATE are continuous variables. The marginal effect is calculated by using the partial derivative of the conditional mean as follows:

$$\frac{\partial E[y \mid x_i\beta]}{\partial x_i} = \beta_j \exp(x_i\beta)$$

where all independent variables are held at their means.

7. Other explanatory variables are discrete variables. The marginal effect is calculated as the factor change in the conditional mean as follows:

$$\frac{E[y \mid d = 1, x_2]}{E[y \mid d = 0, x_2]} = \frac{\exp(\beta_1 + x_2\beta_2)}{\exp(x_2\beta_2)} = \exp(\beta_1).$$

cally significant positive coefficient, suggests that these plants conduct slower recalls. Also, large recalls remain open for a longer period. Yet, without a significant parameter estimate for this variable in the recovery rate/completion time ratio model, it cannot be concluded that these are necessarily more effective recalls.

The period in which PR/HACCP was required for meat and poultry plants is associated with an upward shift in the percentage of recalled product that was recovered (Table 2). The marginal effect suggests a 15% higher share of product

was recovered following PR/HACCP. There was no significant PR/HACCP-related effect associated with the recovery rate to case duration ratio (Table 3). The post-PR/HACCP period was associated with a significantly increased case duration (2 days longer, on average, Table 4).

The findings of higher recovery rates and longer case duration in the post-PR/ HACCP period are from a simple intercept shift representation of the impact of PR/HACCP. Other factors, which may be captured by a time trend, were not found to have an impact on recovery rate (Table 2). The ratio of recovery rate to case duration, which may be thought of as an average daily amount recovered, fell significantly over the period of time studied. The marginal effect was a negative 3% per year. This finding is consistent with less effective recalls over time. The decline in the recovery rate to completion time ratio over time was mitigated substantially during the post-PR/HACCP period (Table 3), with a significant positive marginal effect (4% per year) associated with the time trend post-PR/HACCP. The completion time of recall cases was associated with a positive time trend (Table 4), although the effect was only a fraction of a day per year. Completion times appeared to decrease somewhat with time in the post-PR/HACCP period, again with very small but significant marginal effects (-0.07 days for each year in the time trend).

Discussion and conclusions

Three measures are presented and used to test hypotheses about food recalls. This research advances our knowledge about food safety crisis management efforts undertaken by meat and poultry plants presenting statistical indicators that can be used to benchmark the process. Only limited conclusions can be reached in terms of overall performance and factors that explain the effectiveness of recalls. The results provide supporting evidence that PR/HACCP implementation facilitates meat and poultry recalls but this alone does not suggest that the recall process has become more effective over time. Despite its past efforts in enhancing public health, FSIS still needs to find ways to improve the recall process, perhaps by placing even more emphasis on and re-allocate resources towards higher risk recalls (Class I, biological hazards), as they may cause more negative health consequences for consumers.

It is important to understand whether the regulatory system has different impacts on firms of different sizes. The initial hypothesis was that the overall food safety system is scale-neutral with respect to occurrence of recalls. PR/HACCP provides flexibility for firms to design their process control plans, but smaller firms may experience more difficulties compared to larger firms in executing the recall process in a timely way. Neither of these premises were supported by the evidence. There was no statistical evidence that recall cases at large plants had shorter durations than cases at smaller plants. Further, the results contradict the hypothesis that management at larger plants carry out recalls in a more effective way than smaller plants. Both the recovery rate and the ratio of recovery rate to duration are higher for very small plants compared to small plants. Though not statistically significant the nega-

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tive sign on the parameters for large plants in Tables 2 and 3 suggest they may be *less* effective than small plants in recovering product in a timely manner. FSIS should therefore pay more attention to and help facilitate those recall cases from large plants in order to improve the effectiveness of the overall crisis management process. Once again this would re-allocate resources to higher risk recalls, given the expanded scale and wider distribution of products from larger plants. While these findings suggest that difficulties remain for larger facilities, this result requires further analysis. The impact of corporate management on recall effectiveness especially for cases in which multiple plants are operated by a single firm would be one way for such research to proceed.

The major challenge facing those interested in statistical work on food recalls is that the data collection is divorced from the hypotheses of interest to business managers and regulatory authorities. Incomplete information on recalls is collected at the plant level, yet the unit of analysis for an understanding of business incentives should be the firm. Corporate ownership and business linkages may have changed during the period examined, which means that it will take further work to develop the most appropriate tests of hypotheses which more completely explore incentives for effective crisis management.

Implementation of PR/HACCP is an ongoing process, and not all of the dynamics are captured with the timing variables used here. For example, the official notices of the final regulatory changes to come under the PR/HACCP program were published beginning in 1996, and it is possible that some plants adopted PR/HACCP or other quality control systems prior to the final implementation date. Nevertheless, the post-PR/HACCP period used here starts with the required date of implementation. New microbiological testing technologies have allowed for more precise and speedy detection of problems, and when combined with evolving "zero tolerance" directives by FSIS it is reasonable to presume that this influences the prevalence of recalls and other factors that are not measured well in the data used here.

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