Recall Event Timing: Measures of Managerial Performance in U.S. Meat and Poultry Plants

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ABSTRACT

This study investigates the performance of meat and poultry plant managers in discovering and responding effectively to food safety problems that lead to product recalls. Timing is used as a performance measure of managers' response to recalls of food, using survival distributions of times between production and recall, and recall case duration. The objectives are to understand how these time periods vary across plants and to determine factors explaining such variability. Survival distributions are estimated using the Kaplan-Meier and life table methods. Subgroups of the population are compared using plots of the estimated survival functions and statistically compared using log-rank and Wilcoxon tests. Managers at large plants, in multi-plant firms, and at plants with prior recall experience do not perform better. Cox regressions indicate that government agency sampling programs enhanced the speed of discovery, and that national distribution networks contributed to the risk that cases remained open for a longer period. [EconLit citations: D210, Q180.] © 2005 Wiley Periodicals, Inc.

1. INTRODUCTION

Managers in U.S. meat and poultry plants are responsible for conducting effective product recalls should a food safety problem arise. These recalls have received heightened public awareness over recent years following several events that each exceeded 10 million pounds (Table 1). Most recently in 2002, nearly 19 million pounds of ground beef contaminated with *E. coli* O157:H7 and 27.4 million pounds of chicken and turkey products contaminated with *Listeria monocytogenes* were recalled. The Food Safety and

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TABLE 1. Recall Incidents with More Than 10 Million Pounds

Year	Recall Sizes (Pounds)	% of Total Pounds for the Year	Company	Products	Problem
1997	25,000,000	88	Hudson Foods	Ground beef	*E. coli* O157:H7
1998	35,000,000	76	Bil Mar Foods	Hot dogs/packaged meats	*Listeria monocytogenes*
1999	35,000,000	88	Thorn Apple Valley	Frankfurters & lunch combinations	*Listeria monocytogenes*
2000	16,895,000	74	Cargill Turkey Products	Ready to eat turkey & chicken products	*Listeria monocytogenes*
2001	14,600,000	46	Bar-S Foods Company	Various meat products	*Listeria monocytogenes*
2002	19,000,000	32	ConAgra Beef Company	Fresh ground beef	*E. coli* O157:H7
2002	27,400,000	47	Pilgrim's Pride Corp. (Wampler Foods)	Fresh and frozen ready to eat turkey and chicken products	*Listeria monocytogenes*

Source: Teratanavat and Hooker (2004)

Inspection Service (FSIS) of the U.S. Department of Agriculture (USDA) is the main regulatory agency responsible for the safety of meat and poultry products. In 1998, FSIS evaluated its recall policy and developed recommendations to improve the process through reducing communication problems between the agency, firms, and related parties and maximizing product recovery (Axtell, et al., 1998).

Recalls remain voluntary with a great emphasis placed on the performance of plant managers. Indeed, implementation of enhanced food safety risk management regulations such as the Pathogen Reduction (PR)/Hazard Analysis Critical Control Point (HACCP)-based program shifted responsibility for ensuring the safety of the food supply from a government agency to meat and poultry plant managers (FSIS, 1996). Managers have an obligation to prevent problems related to food safety and to ensure that remaining problems are adequately addressed should they occur (Axtell, et al., 1998). Meanwhile, FSIS maintains oversight of the overall food safety management system, coordinates with plant managers, and provides assistance when needed. Even though the PR/HACCP program is proving to be an effective tool in controlling food risk (FSIS, 2003), it does not eliminate or detect all hazards or contaminated products. Unsafe products may enter the market, as shown by periodic incidents or outbreaks of foodborne illnesses.

The timing of recall events is an important public health issue and a means of protecting consumers from potential hazards and minimizing incidents of foodborne illnesses. Each day that a problem remains unfound and/or a recall announcement delayed, more consumers are at risk. If meat and poultry products are adulterated and/or misbranded, it is important for managers to detect the problem as early as possible after slaughter or processing and initiate a recall. The longer these unsafe products remain in commerce, the greater likelihood that they will cause illness or injury (Axtell, et al., 1998). In addition, such delay may result in welfare losses because consumers do not have information about product contamination. This creates food safety risk and uncertainty at the time of purchase and recall announcement (Foster & Just, 1989). Within a risk management framework, it is important that problems are detected promptly and a product recall initiated as early as possible. During a meat and poultry recall, it is also necessary to ensure that potentially hazardous foods are removed from commerce as quickly as possible.

Even though the recall process is voluntary, meat and poultry plant managers cannot realistically avoid a recall in the event that potentially unsafe foods have entered the market. Though FSIS cannot order or mandate a recall, it can, and does, threaten the removal of inspectors if a firm fails to comply with a recommendation to recall product. FSIS also ensures that the recall is properly issued and handled (FSIS, 2002). Therefore the role of FSIS in meat and poultry recalls is to closely monitor the effectiveness of managers' recall procedures and to provide scientific and technical advice. Since meat and poultry firms are fully responsible for product recalls, critical timing indicators are important evaluative tools in considering managerial performance. Performance in detecting and responding to food safety problems may vary depending on the plant's capability and managers' effort level (Elbasha & Riggs, 2003; Worth, 1999).

To date, there has been no direct study of these critical timing issues for recalls. Salin, Hooker, and Teratanavat (2002) first examined the relationship between the U.S. food safety system, particularly PR/HACCP, and food recall risk. Their study considered the time before failure, defined as the period elapsed under PR/HACCP before a recall occurred. Focusing on two different time points, this study applies similar time-to-event statistical procedures to examine the speed of problem discovery and case duration. The objectives of this study are to understand how these times relate to managerial performance

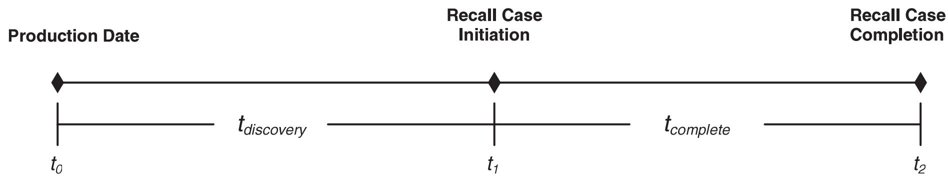

Figure 1 Defining Time Points of Interest for Recall-Related Events

generally and more specifically to examine variations across plants and the factors explaining such variability.

The following section provides a background on managerial performance in detecting problems and organizing recalls and discusses factors that may affect the metrics of problem discovery time and case completion time. The following sections summarize the data and statistical model then report key findings. Implications for more effective plant management are also presented.

2. BACKGROUND

2.1 Defining Time Points for Recall-Related Events

There are two time points that are of interest in this study: discovery time and completion time of a food recall case. Each has a different initiation and ending date but they share the same unit of analysis—the number of days in the period (Figure 1). First, discovery time, $t_{\text{discovery}}$, is defined as the number of days from production to recall initiation, which represents the period taken to discover a problem. Discovery time represents the maximum period that potentially unsafe products have been available in the market prior to the problem being found and a recall announced.[1] Second, completion time, t_{complete}, is defined as the number of days from the recall case opening to completion. Case closure criteria are agreed upon by FSIS and the firm (FSIS, 2000).

2.2 Managerial Performance: Discovering Problems and Organizing Recalls

To efficiently detect potential hazards in a timely manner, meat and poultry plant managers need to install good inspection or testing programs, including rapid detection technologies and staff training. A well-developed recall plan can be an effective *ex ante* risk management tool that facilitates and organizes a product recall more effectively. Not all plants can afford a good inspection program that discovers problems quickly, nor do all plants have well established recall plans to better handle events. Large plants tend to have more staff and well-established safety programs including sanitation and process controls and laboratory capabilities (Ollinger & Mueller, 2003). A recent survey of meat and poultry plants by Ollinger, Moore, and Chandran (2004) suggested that investment in food

[1]Firms can use market withdrawals, voluntary removal of food products that do not violate the acts enforced by FSIS, or stock recoveries, voluntary removal of products that have not been distributed (FSIS, 2000). However, this study focuses only on recalls, in which adulterated or misbranded meat and poultry products have already been shipped from the plant.

safety technology varies across plant sizes. Larger plants tend to invest more on equipment and testing technologies, whereas smaller plants rely more on manual sanitation and more frequent adjustments to plant operations. All sizes of firms can insure against recall costs and in particular the potential costs of litigation and damages. A recall insurance package can mitigate negative economic impacts (*ex post*) related to food safety problems (Doeg, 1995). However, such insurance can be costly; thus, larger plants may be more able to afford it. Skees, Botts, and Zeuli (2001) argue that recall insurance can motivate earlier recalls and/or the adoption of more effective food safety management systems such as HACCP. Even so, coverage of these insurance instruments is incomplete, providing a marginal incentive to manage food safety risk at best. A recent example is the 2002 Pilgrim's Pride recall (see Table 1), expected to cost $100 million with only 50% likely to be covered by the insurance policy.[2]

Food safety regulation compliance costs vary across plant sizes (Hooker, Nayga, & Siebert, 2002). It is thus reasonable to consider whether economies of scale play an important role in broader measures of food safety management performance such as recalls. Smaller sized plants may need assistance from FSIS due to limited staff and budgets; performance of management at such plants may not be as effective as that at larger plants. Firms that own more than one plant should also have better food safety systems in place (managerial economies of scope) and thus perform better than firms that own a single plant.

The effort level of management is important in determining plant performance during a recall. Elbasha and Riggs (2003) suggest that firms have an incentive to enhance food safety management efforts when expected benefits exceed costs of prevention. Such effort levels depend on the manager's realization of the benefits of handling a recall in a timely manner, which may include the minimization of associated costs, the limitation of liability claims, and the protection of brand capital, reputation, and public image (Thomsen & McKenzie, 2001). Managers who value such issues will place more effort on discovering problems at an early stage and completing recall cases as quickly as possible. Once a recall starts, plants incur communication costs, product disposition costs, and overhead (GAO, 2000). When a problem is discovered promptly and a recall completed in a short period, these costs can be minimized.

Another expense that a plant manager can control when a recall is properly handled is product liability (Marino, 1997; Welling, 1991). The longer hazardous products remain in the marketplace, so the potential for, and probability of, product liability claims and law suits increase. The likelihood of both civil and criminal action taken by federal or state agencies also increases for longer cases. Nonetheless, legal liability may provide a limited incentive to meat and poultry plants as there are few lawsuits related to foodborne illness that go to trial (Buzby, Frenzen, & Rasco, 2001). Regardless of the cost associated with a rare loss in court a highly publicized trial may severely harm a firm's image (Ollinger & Ballenger, 2003).

Managers also want to avoid or minimize indirect costs such as reduced sales/revenue and a lower stock price in the capital market. Jarrell and Peltzman (1985) analyzed recall events in the pharmaceutical and automobile industries and found that indirect costs are likely to be far greater than direct costs. In addition, adverse publicity can damage a company's reputation and financial health. Evidence suggests that producers of branded products must invest more in food safety than producers of unbranded products. Companies spend a lot of money to protect the public image of a brand involved in a recall; otherwise

[2]Retrieved November 19, 2003 from http://just-food.com

consumers may switch to other brands or sources if these products are not perceived to be safe (Ollinger & Ballenger, 2003). Meat product recalls were also found to negatively affect meat demand during 1982–1998, with consumers switching to non-meat substitute products (Marsh, Schroeder, & Mintert 2004).

Salin and Hooker (2001) investigated firm-specific reputation impacts through the changing valuation of publicly traded food processing firms and found statistically significant evidence of a negative effect on returns for recalls over various time frames. Thomsen and McKenzie (2001) similarly used daily security prices to quantify the impact of a recall on shareholder wealth and found significant losses when companies are implicated in a recall involving serious food safety hazards.

Since expected costs of product recalls vary, it seems reasonable to presume that managerial performance in discovering problems and facilitating recalls may differ among meat and poultry plants. Plants that have more staff and resources—large plants and firms with multiple plants—can be expected to have better established inspection and recall management programs. The effort to protect the wealth of owners or shareholders and maintain brand equity may also be most relevant to management of larger operations. Therefore, the first two hypotheses test whether larger plants and multi-plant firms better manage recall events than smaller plants and single-plant firms. Larger plants and multi-plant firms are expected to be able to detect the problem and/or complete a recall case sooner than smaller plants or single plant firms with fewer resources.

Hypothesis 1: Recalls involving larger plants are initiated within a shorter period after production and are completed sooner than those involving smaller plants.

Hypothesis 2: Recalls involving multi-plant firms are initiated within a shorter period after production and are completed sooner than those involving single-plant firms.

Managers at firms that have previously recalled products should be more cautious and better able to handle the event when it happens again. Having a plan for a product recall that supports an organized, efficient, and timely response is critical to eliminate danger to the public and in reducing the financial impact on an organization. The most effective and logical way to survive a product recall is to prepare in advance. Prior planning can prevent poor performance (Booth, 1993). Thus, the next hypothesis tests if firms with repeat events better manage recall events than first-time recall firms. Firms that have been involved with a recall event in the past should have been able to improve their inspection and crisis management systems and subsequently perform better recalls.

Hypothesis 3: Recalls involving firms with repeated events are initiated within a shorter period after production and are completed sooner than those involving first-time recall firms.

2.3 Factors Affecting Problem Discovery and Case Completion Time

Unsafe or improperly labeled meat and poultry can be discovered in different ways: by the company that manufactured or distributed the food, through test results taken by FSIS as part of regular sampling programs, and via consumer complaints and epidemiological data submitted by state and local public health departments, other USDA agencies, and other federal agencies (FSIS 2002). The period between discovery of a problem and a subsequent product recall may depend on how the problem is found. Generally, food safety hazards would be expected to be detected faster through FSIS sampling and laboratory tests conducted by the plant, as compared to detection after consumer complaints or outbreak events.

Many factors can also explain the variation in completion times. It appears reasonable to assume that products distributed within a single state will be easier to identify and recover than those distributed in many states or nationwide. The recall notification level can also imply how far potentially unsafe products have been distributed in the food supply chain, including to wholesalers, retailers, or consumers. If recalled products have reached the consumer level, more time and effort may be required to coordinate and communicate with the multiple parties involved to remove these products. Other factors that may influence the speed of recall are case severity, recall size, and amount recovered. Regardless of managerial effort, recall events that involve class I hazards (the most serious risks to consumers) or a large amount of affected product may require a longer period to ensure that consumers are sufficiently protected. In many cases, recall cases are extended in an attempt to recover all products from the market, as shown by higher recovery rates.

3. METHODS

3.1 Data

Meat and poultry recall data from 1998 to September 2003 were taken from Recall Notification Reports (RNR) and summaries maintained by FSIS.[3] Since 1998, FSIS has provided recall information in the RNR, a single format that contains data about production date, recall initiation date, identifying codes, company name, location of incident, recalled products, reason and description, size of recall and recovery in pounds, how problems were discovered, distribution level, and depth of recall. The recall summary only provides the recall closure date for events prior to 2001. Closure data from 2001 to 2003 were obtained via a Freedom of Information Act request made to FSIS. Teratanavat and Hooker (2004) present a summary of key trends and characteristics of U.S. meat and poultry recalls.

This study only includes domestic recall cases for plants having a PR/HACCP program in place at the time of recall to ensure that there is no implementation effect across plants. Because the implementation date for the PR/HACCP program varied across plant size, this study includes recalls from large plants beginning January 1998, from small plants beginning January 1999, and very small plants beginning January 2000. These plants are grouped based on their annual sales/revenues and number of employees, (Table 2). Muth, Wohlgenant, Karns, & Anderson, (2003) present a detailed description of meat and poultry plant characteristics.

The information on plant size (large, small, or very small) and number of plants within the firm (single or multiple) was obtained from the Field Automation and Information Management division of FSIS.[4] All recall cases are compared to determine if the plant previously experienced a recall since 1994. If the record showed a previous recall, these cases are coded as “repeated” events.

There were 359 recall cases between January 1998 and September 2003, of which 338 cases were completed at the time of data collection. The 21 cases that remained open are used for the problem discovery time analysis, not the case completion time (i.e., no censoring occurs in the data set). From Table 2, it can be seen that large plants account for 22 percent of all recall cases, whereas small and very small plants account for 52 percent

[3]Available at http://www.fsis.usda.gov/Fsis_Recalls/index.asp
[4]http://www.fsis.usda.gov/OFO/faim/faimmain.htm

TABLE 2. Description of Plant Characteristics

	Description	Percent
1. Plant Size[a]		
Large	Plants with more than 500 employees	22.3
Small	Plants with between 10 and 500 employees	52.4
Very small	Plants with less than 10 employees or less than $2.5 million in sales	25.3
2. Number of Establishments[b]		
Single	Firm with single plant	65.9
Multiple	Firm with several plants	34.1
3. Plant Experienced Recall Events		
First-time Recall	First recall event for the firm since 1994	80.2
Repeated Recall	The firm had recalled products since 1994	19.8

[a]Information on plant size and number of establishments is available at the Field Automation and Information Management Division

[b]Total number of recalls from 1998 to 2003–359.

and 25 percent of recalls, respectively.[5] Approximately 66% of recall cases are from single plant firms and 80% of cases involved plants that had not experienced a recall event since 1994. The descriptive statistics, in Table 3, show that discovery time and completion time varies across plants. Larger plants, multi-plant firms, and firms with repeated recalls have cases that take longer to discover and complete. However, the variation in the timing of events is relatively large within each group.

3.2 Statistical Method to Analyze Recall-Event Timing

Statistical approaches that allow for conditioning on time are appropriate for this research, similar to the methods used by Agarwal, Sarkar, and Echambadi (2002) in their analysis of the life cycles of firms and industry evolution. Following Salin, Hooker, and Teratanavat (2002), this study applies a nonparametric approach as an initial step in analyzing survival functions and related hazard functions (Lee, 1992). The nonparametric method is chosen because the theoretical distribution of the survival time of interest is unknown. It is first assumed that T, the event time of an individual recall, is a random variable with some unknown probability distribution. In this context, T can be the discovery time ($t_{\text{discovery}}$) or the completion time (t_{complete}). There are several equivalent ways to describe probability distributions of survival times, such as survival functions, cumulative distribution functions (cdf), probability density functions (pdf), and hazard functions (Hosmer & Lemeshow, 1999).

The survival function depicts the probability that an event has not occurred at time t, and is defined as:

$$\begin{aligned} S(t) &= \Pr\,(\text{the event will not occur at least at time } t) \\ &= \Pr(T > t). \end{aligned} \tag{1}$$

[5]In 2001, there were 300 federally inspected large plants, 2,300 federally inspected small plants, and 3,400 federally inspected very small plants (FSIS, 2001).

TABLE 3. Descriptive Statistics of Recall-Related Events across Groups

	Large Plant ($n = 80$)		Small Plant ($n = 188$)		Very Small Plant ($n = 91$)	
Time (Days)	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Discovery[a]	72.24	74.43	60.43	113.05	40.97	181.37
Completion[b]	182.66	83.33	146.08	65.83	117.93	64.75
	Multi-Plant Firm ($n = 73$)		Single-Plant Firm ($n = 286$)			
	Mean	Std. Dev.	Mean	Std. Dev.		
Discovery[a]	88.02	134.92	43.02	122.37		
Completion[b]	176.72	80.34	131.50	64.15		
	Firm with Repeated Recall ($n = 123$)		First-Time Recall Firm ($n = 236$)			
	Mean	Std. Dev.	Mean	Std. Dev.		
Discovery[a]	72.65	128.51	54.52	128.89		
Completion[b]	161.10	76.70	143.44	71.85		

Note. Total observations = 359 cases.

[a]Discovery time is defined as time from production date until the problem is discovered and recall initiated.

[b]Completion time is defined as time from recall case opening to completion.

By definition, the survival function is closely related to the cdf of time before the event:

$$\begin{aligned} S(t) &= 1 - \Pr(T < t) \\ &= 1 - \mathrm{F}(\mathrm{t}), \text{ where F (t) denotes the cdf.} \end{aligned} \tag{2}$$

The pdf is the derivative or slope of the cdf

$$f(t) = \frac{dF(t)}{dt} = -\frac{dS(t)}{dt}. \tag{3}$$

The hazard function describes the conditional failure rate, or the probability of failure during a very small interval, given survival up to the beginning of the interval. The hazard function is defined as:

$$h(t) = \lim_{\Delta t \to 0} \frac{P(t \leq T \leq t + \Delta t | T \geq t)}{\Delta t} \tag{4}$$

Because the data included in this study are not censored, the interpretation of different functions related to the survival distribution of the recall-related events is straightforward and is summarized in Table 4. The related survival distributions are estimated using the Kaplan-Meier and life table methods. The Kaplan-Meier estimate is based on individual survival times while the life-table estimate groups survival times into intervals (Lee, 1992).

TABLE 4. Interpretation of Survival Distributions in the Context of Recall Related Events

Survival Distribution	Recall Related Events: Discovery Time ($t_{\text{discovery}}$)	Completion Time (t_{complete})
T	Period from production date to recall case opening.	Period from recall case opening to closing.
$S(t)$	Probability that the problem is not found until time t.	Probability that the recall case remains open at time t.
$F(t)$	Probability that the problem is found before time t.	Probability that the recall case is completed before time t.
$h(t)$	Probability that the problem will be found during the next period, given that it has not been discovered at time t.	Probability that the recall case will be completed in the next period, given that it remains open at time t.

Subgroups of a population can be compared using the plots of the estimated survival functions. The shape of the survival distribution depends on the proportional relationship between the number of surviving cases (d_i) and the number of observations (n_i) at a given time i.

$$\hat{S}(t) = \prod_{t(i)\leq t} \frac{n_i - d_i}{n_i} \tag{5}$$

The pattern of one survival function lying above another means the group defined by the upper curve has a longer period before the event occurs compared to the group defined by the lower curve (Hosmer & Lemeshow, 1999). Statistics which compare different survival functions are the log-rank and Wilcoxon tests. These two tests share the same null hypothesis that there is no difference in survival functions across subgroups but they differ in the weight assigned to observed survival times. The log-rank test applies an equal weight to all observed failure times, whereas the Wilcoxon test places a larger weight on early failure times than late failure times. Both tests are applied here to rigorously evaluate the hypotheses. The main criterion applicable to this study when using these tests is that the survival curves do not cross. The two test statistics have the chi-square distribution with degrees of freedom equal to the number of subgroups minus 1.

Cox's proportional hazards model, a multiple regression technique that requires no assumptions on the mathematical form of the underlying probability distribution (Cox, 1972), is used to assess the relationship of key factors to the hazards of the timing of a recall. The model embodies the assumption that different plants have hazard functions that are proportional to one another, yielding a ratio of hazard functions for those two plants that does not vary with time. The specification of the proportional hazard model is:

$$h_f(t) = h(t; x_f) = h_0(t)\exp(x_f'\beta) \tag{6}$$

where $h_0(t)$ is a baseline hazard function, $\mathbf{x}_f$ is a vector of explanatory variables for plant f, and $\boldsymbol{\beta}$ is a vector of regression parameters to be estimated. Two proportional hazard regressions were estimated in this study; one that examined the source of discovery to explain discovery time, and another that related factors in product distribution to the hazard

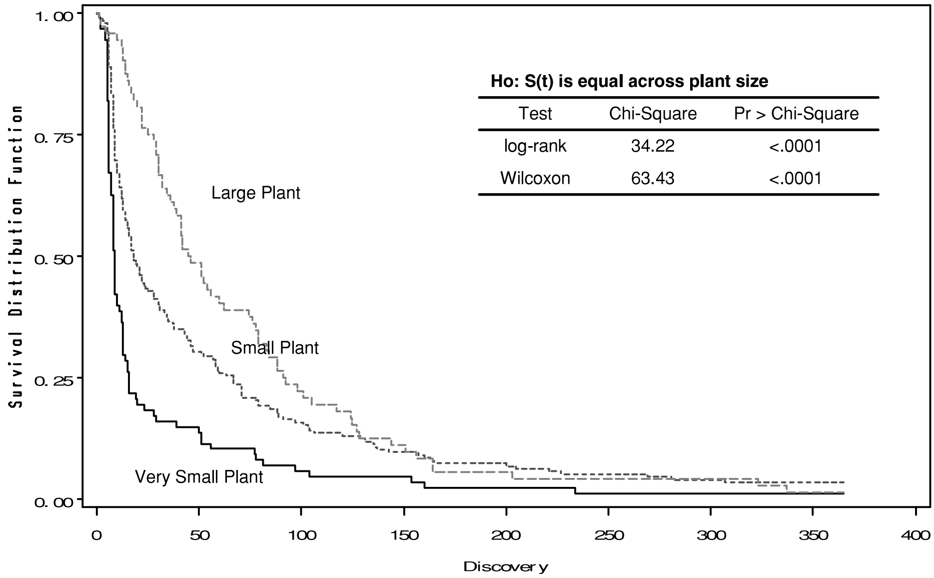

Figure 2 Kaplan-Meier Estimates of Survival Function for Different Plant Sizes: Time from Production to Recall

function for duration of a recall case. The model was estimated using a maximum likelihood technique in SAS 8.0 (Allison, 1995; Smith & Smith, 2001).

4. RESULTS

4.1 Time from Production to Recall Case Initiation

The survival time ($t_{\text{discovery}}$) represents the period that the problem was not detected following production. A long duration of discovery time is undesirable because it leads to a higher likelihood of risk exposure to consumers. A short survival time, or a higher hazard rate for $t_{\text{discovery}}$, indicates short duration of discovery time and is preferred because this suggests a prompt identification and announcement to consumers. Products can then be recalled at an early stage in the supply chain, shortly after the production date. The plots of the Kaplan-Meier estimates of survival functions on discovery time (Figures 2–4), suggest that the probability that the problem is not yet found decreases dramatically during the first month between production and recall. The steep portion of the survival distribution functions (Figure 2) indicates that for most recall events, problems are detected within a month of the production date. The smaller decline in the survival functions (flatter portion of the curves) after the first month suggests that few recall cases remain undetected for long periods.

Meat and poultry plants of different sizes have distinct survival functions (Figure 2). Both statistics, the log-rank and Wilcoxon tests, indicate a consistent rejection of the hypothesis that there is no difference in survival functions across plant sizes ($p < 0.001$).[6]

[6]The presented results are three-way comparisons, pair-wise tests are consistent.

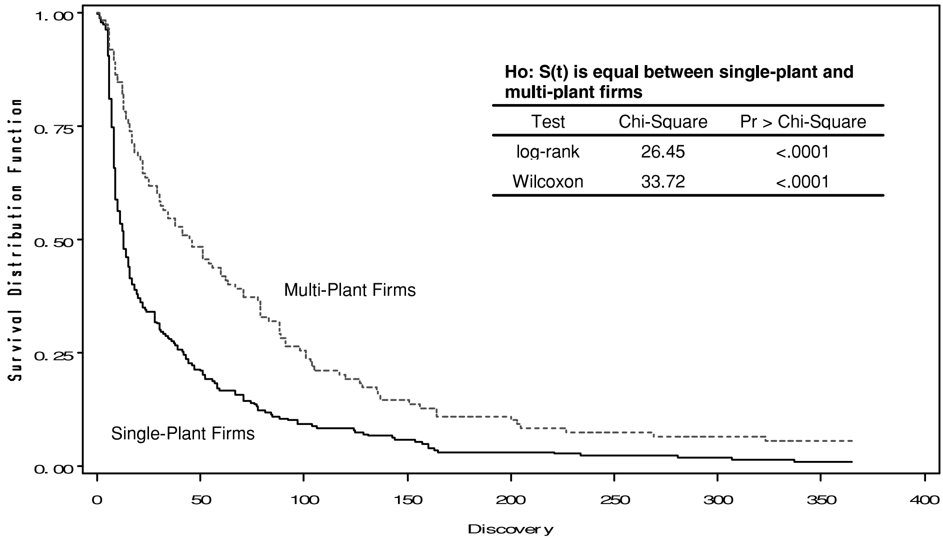

Figure 3 Kaplan-Meier Estimates of Survival Function for Single-Plant Firms and Multi-Plant Firms: Time from Production to Recall

Larger plants have higher survival functions in all time periods, implying a higher probability that a problem remains undetected for a long period at larger plants. The life table survival estimates, presented in Table 5, provide the failure rates, representing the probability that the problem will be detected by the end of each period, and the estimate

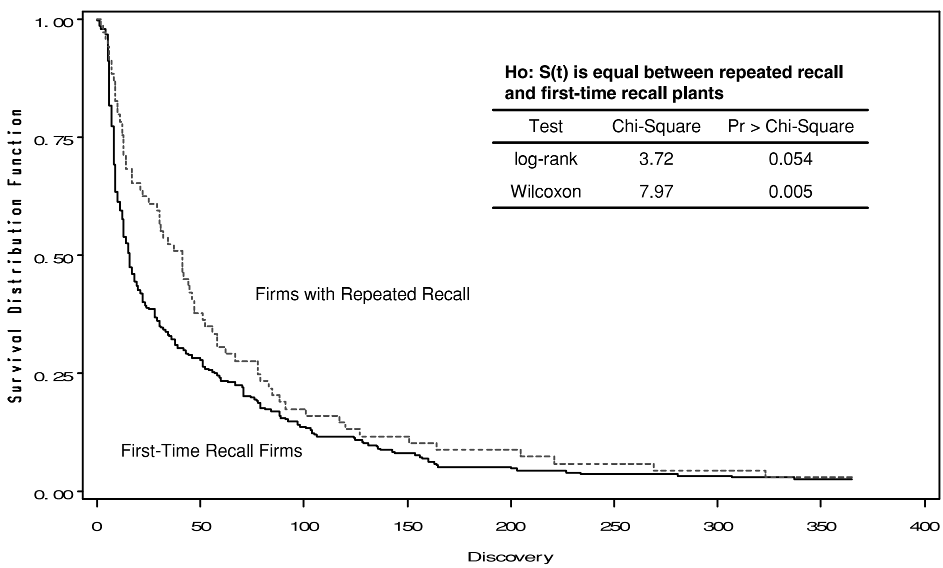

Figure 4 Kaplan-Meier Estimates of Survival Function for Firms with Repeated Recall and First-Time Recall Firm: Time from Production to Recall

TABLE 5. Life Table Survival Estimates for Time from Production to Recall

Period (days)	Large Plant		Small Plant		Very Small Plant	
	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]
0–30	0.292	0.011	0.59	0.028	0.841	0.048
30–90	0.736	0.015	0.831	0.014	0.932	0.013
90–180	0.944	0.014	0.927	0.009	0.977	0.011
180–270	0.958	0.003	0.955	0.005	0.989	0.007
270–360	0.986	0.011	0.966	0.003	0.989	0.000
>360	1.000		1.000		1.000	

	Single-Plant Firm		Multi-Plant Firm	
	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]
0–30	0.687	0.035	0.4	0.017
30–90	0.896	0.017	0.718	0.012
90–180	0.97	0.012	0.891	0.010
180–270	0.978	0.004	0.936	0.006
270–360	0.991	0.010	0.945	0.002
>360	1.000		1.000	

	First-Time Recall Firm		Firm with Repeated Recall	
	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]
0–30	0.64	0.031	0.406	0.017
30–90	0.845	0.013	0.812	0.017
90–180	0.95	0.011	0.913	0.008
180–270	0.964	0.004	0.956	0.007
270–360	0.975	0.004	0.971	0.004
>360	1.000		1.000	

Note. Total observations = 359 cases.
[a]The failure estimate $(1 - S(t))$ is the cumulative probability that the problem can be detected by the end of the period.
[b]The hazard estimate $(h(t))$ represents the hazard function at the midpoint of each period.

of the hazard functions. Eighty-four percent of recall cases involving very small plants are initiated within 30 days of the production date, as compared to 29% for large plants and 59% for small plants.

Recall cases involving single-plant firms are likely to be discovered in a shorter period than those involving multi-plant firms (Figure 3). The log-rank and Wilcoxon tests confirm that the estimates of the survival functions for the two groups are significantly different ($p < 0.05$). The life table survival estimates in Table 5 show that more than 68% of recall cases involving single-plant firms are initiated within 30 days of production, whereas only 40% of recalls involving multi-plant firms start during the 30-day period after production.

Firms experiencing their first recall discovered problems earlier than did firms that had a previous recall (Figure 4). The log-rank and Wilcoxon tests suggest that the estimates of these survival functions are significantly different ($p < 0.05$). Sixty-four percent of recall cases involving first-time recall firms were initiated within 30 days of production, as compared to only 41% of recalls involving firms with repeated recall (Table 5).

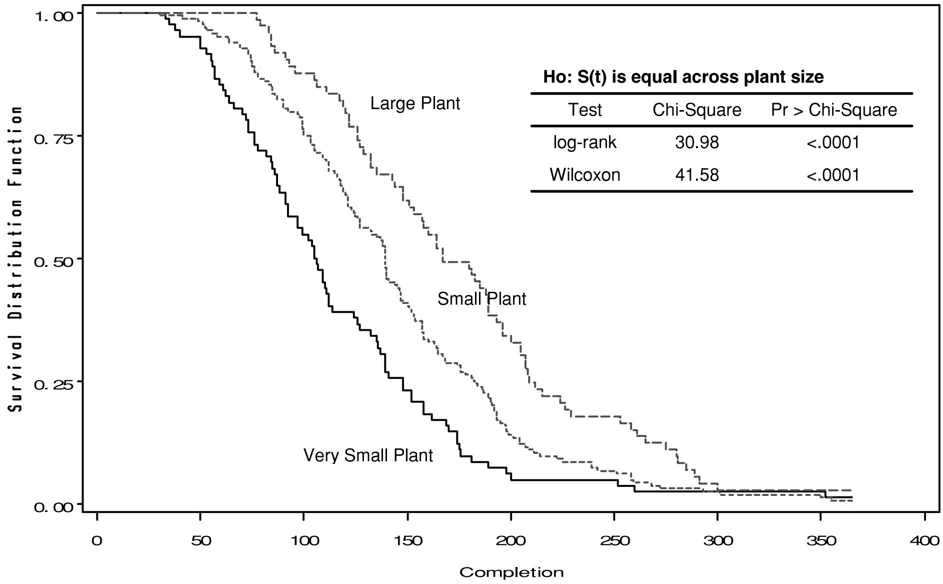

Figure 5 Kaplan-Meier Estimates of Survival Function for Different Plant Size: Time from Recall Case Opening to Completion

4.2 Time from Recall Case Opening to Completion

The initial flat portion of the plots of the Kaplan-Meier estimates of survival functions for completion time (Figures 5–7) suggests that most recalls last a certain minimal period, approximately 30 days, before termination. Meat and poultry plant managers, with FSIS's oversight, must ensure that consumers are protected from potential risk and that unsafe products are removed from the market before the recall case is closed. After such a period, more and more recalls are completed and the probability that the case remains open, represented by the survival function for completion time, becomes smaller over time at a constant and rapid pace. Generally, a shorter case duration is desirable because it implies more effective recall management. Nonetheless, in some cases, recalls may need to be extended for a longer period when they involve more serious risks that require more attention and caution from plant managers or regulators. The recall case is completed, with no further action required, when FSIS and management of the recalling firm agree that the product subject to recall has been removed and proper disposition or correction has been made (FSIS, 2000).

The log-rank and Wilcoxon tests suggest that the estimates of survival functions for completion time are significantly different across plant sizes ($p < 0.001$, see Figure 5).[7] The survival functions also vary with respect to the number of plants owned by firms ($p < 0.001$, see Figure 6). There is also weak evidence suggesting a difference in estimates of the survival functions between first-time recall plants and repeated recall plants ($p < 0.1$; see Figure 7). The life table survival estimates in Table 6 show that large plants are involved with recall cases that remain active for a longer period than small and very

[7]The presented results are three-way comparisons, pair-wise tests are consistent.

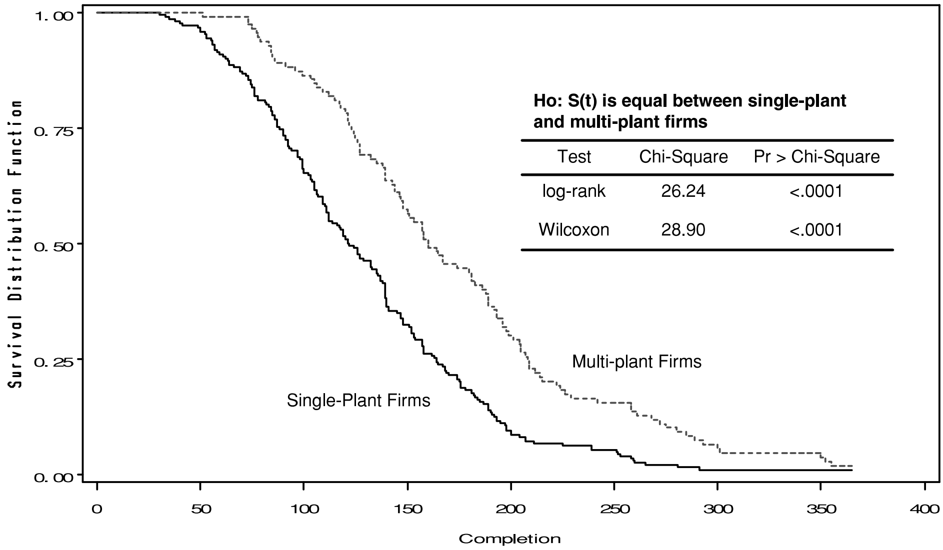

Figure 6 Kaplan-Meier Estimates of Survival Function for Single-Plant Firms and Multi-Plant Firms: Time from Recall Case Opening to Completion

small plants. Whereas over 90% of recall cases involving very small plants are completed within 180 days, only 52% of large plants' recalls and 74% of small plants' recalls were completed in the same time period. Approximately 80% of recalls involving single-plant firms are completed within 180 days, as compared to 55% completed for multi-plant firms.

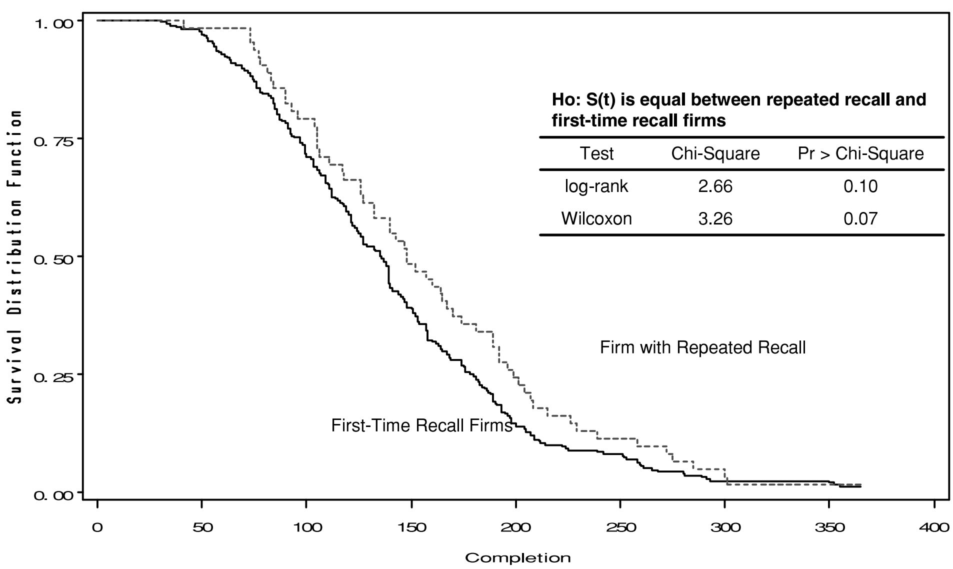

Figure 7 Kaplan-Meier Estimates of Survival Function for Firms with Repeated Recall and First-Time Recall Firm: Time from Recall Case Opening to Completion

TABLE 6. Life Table Survival Estimates for Time from Recall Case Opening to Completion

Period (days)	Large Plant		Small Plant		Very Small Plant	
	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]
0–30	0.000	0.000	0.000	0.000	0.000	0.000
30–90	0.082	0.001	0.173	0.003	0.366	0.007
90–180	0.517	0.007	0.738	0.011	0.912	0.016
180–270	0.873	0.013	0.963	0.017	0.976	0.013
270–360	0.973	0.014	0.994	0.016	0.988	0.007
>360	1.000		1.000		1.000	

	Single-Plant Firm		Multi-Plant Firm	
	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]
0–30	0.000	0.000	0.000	0.000
30–90	0.252	0.005	0.109	0.002
90–180	0.819	0.014	0.554	0.007
180–270	0.981	0.018	0.882	0.013
270–360	0.990	0.007	0.982	0.016
>360	1.000		1.000	

	First-Time Recall Firm		Firm with Repeated Recall	
	Failure[a]	Hazard[b]	Failure[a]	Hazard[b]
0–30	0.000	0.000	0.000	0.000
30–90	0.215	0.004	0.145	0.003
90–180	0.751	0.012	0.645	0.009
180–270	0.958	0.016	0.903	0.013
270–360	0.988	0.013	0.984	0.016
>360	1.000		1.000	

Note. Total observations = 338 cases.
[a]The failure estimate $(1 - S(t))$ is the cumulative probability that the case is completed by the end of the period.
[b]The hazard estimate $(h(t))$ represents the hazard function at the midpoint of each period.

The probability of completion time falling within any particular time frame is only slightly different for plants with first-time recall and plants with repeated recall.

4.3 Multiple Regression Models of Food Recall Event Timing

The evidence from the survival distributions presented in the previous sections has not addressed the obvious question of why these patterns have occurred. While the data available from FSIS records is extremely constrained, some key factors can be examined in a multiple regression framework using Cox's proportional hazards model. Those factors are categorized as monitoring, distribution, and severity. In addition, a general time trend was used in the regressions. These factors help to frame the discussion on the strengths and limitations of the proposed timeliness measures and to develop further thought on assessments of managerial performance.

To assess the effect of monitoring, four indicator variables on how the problem was found were compiled (Table 7). FSIS sampling programs were critical to the discovery of

TABLE 7. Mean Values of Factors that May Explain Differences in Discovery Time and Completion Time Across Plants

Factor		Plant Size			Firm with Repeated Recall		Number of Establishments	
		Large	Small	Very Small	Repeated	First-Time	Multi-Plant	Single-Plant
1. How problem is found								
Ffsis[a]	Discovered by FSIS (1=yes; 0=no)	0.21	0.54	0.91	0.36	0.63	0.28	0.71
Ffirm	Discovered by firm (1=yes; 0=no)	0.43	0.29	0.03	0.42	0.21	0.42	0.17
Fconsumer	Discovered through consumer complaints (1=yes; 0=no)	0.24	0.07	0.00	0.10	0.09	0.18	0.05
Fmisc	Discovered through foodborne illness or epidemiological data (1=yes; 0=no)	0.13	0.09	0.05	0.12	0.08	0.12	0.07
2. Product distribution level								
Dsingle	Single state (1=yes; 0=no)	0.03	0.31	0.73	0.22	0.40	0.09	0.50
Dmultiple[a]	Multi-state (1=yes; 0=no)	0.54	0.49	0.25	0.45	0.43	0.53	0.39
Dnation	Nationwide (1=yes; 0=no)	0.44	0.20	0.02	0.33	0.17	0.38	0.11
3. Recall notification level								
Nconsumer	Consumer level (1=yes;0=no)	0.35	0.37	0.24	0.34	0.33	0.39	0.30
Nuser[a]	User level (1=yes;0=no)	0.25	0.30	0.37	0.30	0.30	0.22	0.35
Nretail	Retail level(1=yes;0=no)	0.35	0.26	0.32	0.32	0.31	0.33	0.29
Nwholesale	Wholesale level(1=yes;0=no)	0.05	0.06	0.07	0.04	0.07	0.07	0.06
4. Recall class								
Class1	Class I recall (1=yes; 0=no)	0.66	0.75	0.89	0.74	0.78	0.66	0.82
Class2[a]	Class II recall (1=yes; 0=no)	0.23	0.15	0.05	0.19	0.13	0.22	0.11
Class3	Class III recall (1=yes; 0=no)	0.11	0.10	0.05	0.07	0.09	0.12	0.07
5. Recall sizes and percent recovery								
Logpound	Log value of total pounds of recalled products	11.17	8.91	6.31	9.99	8.38	10.86	7.65
Recovery	Share of recalled product recovered	0.42	0.45	0.52	0.38	0.48	0.40	0.49
6. Time trend								
Date	Range from 1 to 6 representing years 1998 to 2003 to capture the changes in hazard rate during this period.	3.35	4.05	4.42	4.07	3.97	3.78	4.11

[a]Dummy variable that is omitted from the proportional hazard regressions.

problems leading to recalls at very small plants, accounting for 91% of the cases, and for a lower but still majority share of the cases (54%) at small plants. Recall cases at large plants, by contrast, only originated through FSIS sampling in 21% of the cases, while the enterprises' own monitoring and process control led to an enhanced ability to discover problems. Although fewer than half of the cases at large plants (43%) were found by the firms' own monitoring activities, this proportion was much larger than the share of self-discovered cases at small (29%) and very small plants (3%). Another notable difference in the means of discovery of problems is the relatively high share of cases traced to large plants that had been identified by consumer complaints or illness events (37%). So, while there is evidence that large plants' monitoring activities led to discovery of a substantial number of food recall cases, more than one-third of recalls had escaped detection until consumer channels.

Variables on distribution networks were used to explore how timeliness of recalls may be constrained by extensive and complex distribution channels, most of which are associated with large plants. Nearly all (97%) of the recall cases at large meat and poultry plants involved products having multi-state distribution, of which 44% were nationally distributed (Table 7). Small and very small plants' recalls were limited to a single state in 31% and 73% of the cases, respectively. A second set of distribution variables, also binary variables, indicate the level of the distribution channel that was included in the recall notification. No strong differences across plant sizes are apparent from the variables on recall notification level (Table 7).

Severity measures included in the Cox regressions are those collected by FSIS specifically, the Class designation and the pounds included in the recall. Most recalls were Class I, the most severe designation. The pounds recalled varied tremendously by plant size, with the average across cases at large plants reaching 71,000 pounds, compared with 7,405 pounds for small plants' recalls and 550 pounds on average for very small plants' recalls. Percentages of product actually recovered were included in the model as a proxy of impact on public health. A lower recovery rate implies more potentially unsafe product remained in distribution following the closure of the recall. No *ex-post* effects on human health from the products involved in the recall were included.

While there are a substantial number of indicator variables available to assess managerial performance with multivariate regressions, there is little quantifiable information about overall industry trends, policy direction, technological change, or other exogenous factors. Therefore, a time trend has been included, notwithstanding the fact that the period of observation (1998–2003) is relatively short, to serve as a general indicator of structural change and to suggest whether such changes affected the distributions of timeliness measures. The results from the Cox regression model show that the period to discover problems leading to product recalls has not changed over time, whereas it tends to take a shorter period to complete a recall case in 2003 compared to 1998 (Table 8).

Results from the Cox regression on discovery time show that the manner in which the problem is found has a significant influence on problem discovery time (Table 8). Recalls initiated on the basis of test results from the FSIS sampling program are more likely to be discovered faster than other cases. Even though firms and FSIS may become aware of misbranded and adulterated product in several ways, test results quickly gain their attention and thus lead to prompt product recalls. The hazard ratios (Table 8) show that the probability that a problem is found by firms, customers, or through foodborne illness incidents are about 53%, 33%, and 38%, respectively, of the probability that the problem is discovered by FSIS. These large and significant differences in the hazard of discovery

TABLE 8. Parameter Estimates for Proportional Hazard Regressions

Explanatory Variables	Parameter Estimate	Standard Error	Hazard Ratio
Dependent Variable: Discovery Time			
Ffirm	−0.626	0.134**	0.535
Fconsumer	−1.115	0.197**	0.328
Fmisc	−0.975	0.198**	0.377
Date	−0.055	0.041	0.946
Likelihood Ratio	62.932**		
Dependent Variable: Completion Time			
Dsingle	0.470	0.154**	1.600
Dnation	−0.395	0.186*	0.673
Nconsumer	0.276	0.150	1.318
Nretail	0.087	0.154	1.091
Nwholesale	−0.033	0.252	0.968
Class1	−0.083	0.174	0.920
Class3	−0.186	0.285	0.830
Logpound	−0.112	0.027**	0.893
Recovery	−0.179	0.156	0.835
Date	0.226	0.052**	1.254
Likelihood Ratio	121.154**		

Notes. For categorical variables, the hazard ratio is interpreted as the ratio of the estimated hazard for those with a value of 1 to the estimated hazard for those with a value of 0. For continuous variables, the estimated percent change in the hazard for a unit increase is 100 * (hazard ratio − 1).
*Statistically significant at the $\alpha = 0.10$ level. **Statistically significant at the $\alpha = 0.05$ level.

underscore the continuing importance of FSIS monitoring activities in finding problems that led to recalls in the 1998–2003 period examined. The second most important factor associated with discovery, the firm's own monitoring programs, clearly was an important but less timely route to discovering problems. This finding raises questions about the effectiveness of in-house monitoring in terms of timeliness of the recall process, but it does not rule out the possibility that such testing plays an important overall food safety management role. The result could be explored through further study of communications within a larger or multi-plant firm, especially between plant and corporate management, assessing the decision of whether to initiate a voluntary recall.

Logistical factors in the distribution network, namely the statewide or national scope of distribution channels, affected case completion time. Recalls where products were distributed within a single state are more likely to be completed in a shorter period than cases where products are distributed to many states or throughout the nation (Table 8). The probability that cases were completed within the same time period for single-state distribution is 160% of that for multi-state distribution. The same probability for nationwide distribution is 67% of that for multi-state distribution. The indicator variables on the depth of distribution and notification level were not found to significantly affect the likelihood of a case completion.

Controlling for severity of the recall incident is important in the application of timeliness benchmarks in making a reasonable evaluation of performance. As one might expect, cases involving a large amount of product are likely to take a longer time to complete. The negative effect of size of the case on completion time is likely justifiable given the need for larger volumes to be tracked and recovered. It is worth mentioning that the time to complete a case is not different among recall classes. Thus, despite FSIS's stated focus on recalls with more severe public health consequences, there is no evidence suggesting that class I recalls receive higher attention or are more effectively performed by meat and poultry plant managers.

5. MANAGERIAL IMPLICATIONS

Results from this study do not support the conceptual framework that managerial performance with respect to responding to food quality failures is enhanced by size and scope of the firm. All three hypotheses on the advantages of scale, efficiencies of scope for multi-plant firms, and learning through repeated recalls are tested and rejected. Large meat and poultry plants are not as timely as smaller plants in detecting problems that lead to meat and poultry recalls and in completing recalls in a timely way. Firms with multiple locations, which have more resources, perform worse than single-plant firms. It was hypothesized that managers at large plants and multi-plant firms have a pronounced incentive to maintain enhanced food safety risk and crisis management systems to be able to inspect for and detect problems and subsequently perform more efficient and effective recalls. These firms are more likely to be exposed to negative reputation impacts and suffer larger financial losses. Nonetheless, the results here suggest that plant size has a negative effect on time-based measures of managerial performance.

It must be acknowledged that the categorical variable for large plants (having more than 500 employees) does not allow for statistical control of the hazard as a proportion of the plant's output. Nevertheless, the fact that firms have flexibility to design process control systems under the PR/HACCP regulatory system led to an expectation that scale-appropriate controls would be designed. It is of particular concern that the timing of discovery was not managed better at larger plants. The pace of discovery is a function of the relationship between plant management and regulators. The finding of relatively rapid detection at very small plants may be the result of closer regulatory supervision at plants that are known to have problems, as shown by the higher percentage of cases where the problem was detected through the FSIS sampling program for smaller establishments. And, while large plants do in fact detect problems through in-house monitoring more often than smaller plants, the manner of discovery of a problem does not lead to a more timely initiation of recalls, according to our analysis of FSIS records. Also, because larger plants are involved with larger volumes of product, use different distribution channels, and market products in many states or nationwide, it takes longer to complete recall cases, regardless of managerial effort. Though these limitations to the timeliness benchmarks used here are valid, it is still important for larger plants to improve their performance in detecting problems and removing product faster as these plants account for most of the volume of product recalled.[8]

Smaller firms may be closer to their key customers or management may feel more closely tied to their brand, and therefore do not delay initiation of the recall action. Further study on the nature of brands and niche marketing strategies at smaller enterprises could be useful in assessing whether it is actually FSIS supervision or managerial choice that explains the timeliness of the smallest plants in discovering problems and initiating recall actions. Given prior research that has expressed concerns about the cost burdens of PR/HACCP on smaller plants (Hooker, Nayga, & Siebert, 2002; Ollinger, Moore, &

[8]Large plants accounted for 55% of the total volume of meat and poultry recalled between 1998 and 2003.

Chandran, 2004) this evidence of effectiveness of managing recalls in a timely way is important in understanding the potential future role of niche players in the meat and poultry processing industry.

Statistical tests of the effect of prior known problems on the timing of discovery did not provide support for more timeliness at plants that have been involved in prior recall events. Firms that had products recalled in the past should have learned from the event, be more cautious, and thus be able to handle recalls better than those plants which have never had a product recall. The results from this study do not support this expectation, suggesting that a greater emphasis be placed on learning from prior bad events. There is a clear opportunity for both management and FSIS to place more priority on plants that have repeated problems.

So, what factors contribute to such incidents? Regardless of a manager's ability to invest in a better in-house inspection program and staff effort, are there any other factors that affect the time before the problem is discovered and the time to complete recalls? Are there any indicators of performance that managers should focus on? Proportional hazards regressions were used to consider these questions and showed that cases where problems were found by FSIS via regular sampling are more likely to be discovered faster. This finding supports the importance of FSIS testing programs, even in the post-PR/HACCP regulatory environment. Given that the PR/HACCP philosophy shifts responsibility to firms, one may have expected that firms finding the problems would be the most timely means of discovering a recall case. Also, cases where products were distributed within a single state are more likely to be removed faster and thus the case completed in a shorter period, whereas cases involving a large amount of product are likely to take a longer time to complete. It is not possible to simply draw a conclusion on how timing performance varies across plants from this data because additional factors have been shown to influence recall events. These factors should be taken into account by managers and FSIS, as they appear to be reasonable measures of performance and can impact public health.

6. CONCLUSIONS

This study examines managerial performance at meat and poultry plants in discovering food safety problems and facilitating product recalls. It is hypothesized that operations with more financial resources and staff, such as larger plants or multi-plant firms, have better inspection programs to detect potential hazards that may enter the food supply chain and can better manage recall events. Furthermore, these plants were expected to have a pronounced incentive to manage product recalls, as potential losses are much higher than those for smaller plants. The same logic should apply to those plants involved in a prior product recall. The distributions of two critical time points in recall-related events vary across plants and the statistical results do not support any conclusions of the benefits from larger size of plants and scope of managerial expertise across multi-plant firms. Of course, the performance of managers in larger firms in terms of rapidly completing a recall is complicated by the extensive distribution and supply chain networks that these plants serve. Indeed, multivariate analysis of completion times provides plausible evidence that scope of distribution interferes with timely completion of recalls. With respect to discovery time, however, it is not clear why process control systems or management structures within the largest meat and poultry plants have not allowed managers to perform better than those at smaller plants based on the ability to detect contamination and initiate a recall within a short period of time after production. It is important to note that regulatory supervision and assistance by FSIS at smaller plants may help these firms detect problems sooner. Regardless, the results with respect to scale and scope of the firm are alarming and should prompt further examination of the balance between regulatory oversight and private incentives in the food system.

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