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An Examination of Meat and Poultry Recall Effectiveness and Efficiency

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Abstract: Measures of the effectiveness and efficiency of meat and poultry recalls are proposed including the proportion of recall product retrieved (recovery rate), time to complete a case, and the ratio of these variables and the statistical evidence is examined. Regression models suggest no significant improvement in the recall process over time or following the PR/HACCP implementation. The key result from this research is that one way to improve the recall process is to discover problems early. The sooner problems are found, the more likely that affected products are recovered and the lower the time to complete the recall.

Keywords: Meat and poultry recalls, PR/HACCP, recovery rate, case completion time, count data models

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Introduction

Meat and poultry recalls have been subjected to increasing scrutiny over recent years with concern being voiced about the effectiveness and efficiency of a predominately voluntary process. This has led to various Bills being presented to Congress, particularly following large product recalls such as the recent recall of nearly 19 million pounds of ground beef over concerns of contamination with *E. coli* 0157:H7[1]. The Food Safety and Inspection Services (FSIS) of 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 recall policy and to provide recommendations, which emphasized how to reduce communication problems between the agency, firms and related parties and how to maximize product recovery (Axtell et.al, 1998). With this action, it is assumed that FSIS focused efforts on improving the recall process, yet the report by the U.S. General Accounting Office (GAO) suggested that further actions are needed (GAO, 2000).

This paper uses the online database of meat and poultry recalls maintained by FSIS. In part, the methodology employed allows for an evaluation of the overall food safety management system in place, with particular reference to the specifics of the FSIS recall process. Only with an effective recall process can the public health impact of food safety problems encountered by firms be mitigated. To accomplish this goal the government has emphasized a risk analysis approach consisting of risk assessment, risk management, and risk communication. These three elements are interdependent. Risk assessment is the first step providing an estimate of the likelihood and severity of harm, reported as quantitative or qualitative data. It consists of three

[1] A current example of legislation that would provide USDA and FDA with mandatory recall authority is the *Safe and Fair Enforcement and Recall for Meat, Poultry, and Food Act* (S.2803 H.R. 5230).

components; hazard identification, hazard characterization, and exposure assessment and knowledge of the market. Risk management ensures that only strictly qualified policies are selected using information from the risk assessment. Risk communication involves information exchange between government, industry, and consumers and occurs throughout the risk analysis process to ensure transparency.

FSIS performs inspection activities and enforces regulations to ensure that meat, poultry, and egg products are wholesome and accurately labeled and encourages the improvement of the safety of these products through various programs. Recently, FSIS has implemented a new safety program, the Pathogen Reduction / Hazard Analysis Critical Control Point (PR/HACCP) system, which emphasizes hazard identification and risk 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). This program is designed to identify potential hazards and develop a comprehensive plan to prevent or control them. PR/HACCP can also be regarded as a risk management program. Associated research has focused on the overall effectiveness of this program, which is now required in all meat and poultry slaughter and processing plants. It has been suggested that PR/HACCP has led to a significant reduction in the numbers of foodborne illnesses from *Salmonella* (FSIS, 2002).

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 following an investigation of problems. The recall strategy suggests how widespread the recall should be including affected businesses (wholesale or retail) and consumers (region of country), describes any public warning to be issued, and explains how effectiveness checks will be implemented and verified. The agency also communicates the recall to consumers and contacts all parties involved through press releases to ensure that these affected products are retrieved from the market.

Even though the recall 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, 2000; 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. As part of its risk management strategy, FSIS decides when the case is complete, meaning that no further action is required, through a determination that the firms have made all reasonable efforts to retrieve and appropriately rework or dispose of the recalled products.

There are several studies that use related FSIS meat and poultry recall data. Salin and Hooker (2001), Wang et al. (2002), and Thompson and McKenzie (2001) examined the effect of meat and poultry recalls on firm's stock price, market returns, and societal reactions. Other studies provide descriptive statistics and summaries of FDA recall data due to microbial contamination and undeclared allergens, see Wong et. al. (2000) and Vierk et. al. (1999) respectively. However, no study has yet been conducted which analyzes the relationship between recall effectiveness and efficiency and possible explanatory factors such as information about recalled products and firms involved. The objectives of this study are to evaluate if there has been a change in the effectiveness and efficiency of the recall process over time and to conduct exploratory research on effectiveness and efficiency measures and recall information. Several characteristics, which may influence recall effectiveness and efficiency, are included in this study in an attempt to reveal useful information for FSIS to help assess whether recall strategies need to be adjusted for different recall cases based on such characteristics.

Data and Methodology

Defining the Measures of Recall Effectiveness and Efficiency and Explanatory Variables

This study quantitatively examines the effectiveness and efficiency of the recall process using three indicators; the recovery rate, the speed of the recall, and the ratio of recovery rate-completion time. The recovery rate measures effectiveness and represents the proportion of recalled volume actually recovered from the market. The speed of the recall action, an indicator of efficiency, indicates the number of days to complete the case. It is reasonable to assume that a recall process is effective if it results in more product recovered and that a recall is efficient if it takes a short period to complete. However, there may be incidents where the recall case remains open for a longer period in order to gain a higher rate of product recovery. Even though the priority placed by FSIS on the amount recovered and the speed of the recall process is unclear, it can be assumed that a faster recovery rate per day while cases remain open is preferred. Thus, the recovery rate-completion time ratio is included as another measure of the relative efficiency of the recall process[2].

Although there is no reference or a previous study suggesting factors that may influence the recall process, this study groups variables into four categories including product specific, firm specific, timing, and others and tests if there is any relationship between these variables and the indicators of recall effectiveness and efficiency. Different regression models are applied for each measure of recall effectiveness and efficiency. The full model including all explanatory variables is estimated to examine if information available to FSIS when a recall occurs can be jointly used to explain changes in these measures. Further, regression models with separate explanatory variables for each category are estimated. These models allow the tests of joint significance of each individual category of information and the comparison of explanatory powers and impacts on effectiveness and efficiency measures.

The **product** or case specific category includes factors describing the individual product being recalled such as recall size (weight in pounds), product shelf life (raw or processed food), recall class[3], hazard type[4] (biological, physical, and chemical hazard), and whether the product is imported. Since the 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 the completion time. In general, the larger the recall size, the longer time it takes to remove affected products from the market. Products with short shelf life such as ground beef may have lower recovery rate and take less time to complete the case, as these products are less likely to be left in the retail store when problems are discovered. If the recall process is effective, higher recovery rate and shorter completion times are desirable outcomes for cases involving more serious issues such as class 1 and biological hazards.

The **firm** or plant specific factors capture the effect of the PR/HACCP program[5], plant size, and location where the recall case originated[6]. The implementation of PR/HACCP can

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[2] The authors thank Dr. Tim Habb for his suggestion to use this measure of relative recall efficiency.

[3] According to FDA and USDA, recalls can be classified into 3 classes, I, II, and III, depending on the potential negative health consequences.

[4] Foodborne biological hazards include 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. Chemical hazards involve naturally occurring or artificial contaminants arising in the production or processing of foods. Physical hazards include cases when hard foreign objects are found in food products.

[5] Large plants have more than 500 employees. Small plants have between 10 and 500 employees. Very small plants have less than 10 employees or less than $2.5 million in sales. Large plants were required to have PR/HACCP systems in place by January 26, 1998, while the regulation for small plants and very small plants had implementation dates of January 25, 1999 and January 25, 2000, respectively.

imply an improvement in hazard control and inspection during the production processes. Such improvement may indirectly facilitate the recall process, which is likely to result in a higher recovery rate and shorter completion time. Larger plants are expected to be more efficient in dealing with product recalls because they tend to have better food safety technology and more staff to handle problems. Location of firm is also included in the model to examine if the recall effectiveness and efficiency varies across regions.

The **timing** category includes the period between production date and problem discovery date, a time indicator over the study period, and the season in which the firm announced the recall. The sooner the problem is discovered, the more affected product can be removed in a shorter period because items may not yet be distributed to different levels of the supply chain. It is easier to recall products that are still in manufactures' warehouses than to remove products that are on supermarket shelves or in consumer homes. The improvement in recall effectiveness and efficiency over time can be captured by the time indicator included in the model. If FSIS has been successful in improving its' recall program, an increase in the recovery rate and a decrease in the number of days to complete recall cases over time are expected. Seasonal factors are included in the model to examine if recall effectiveness and efficiency varies across throughout the year.

Other characteristics are also included such as the distribution level represented the number of states affected products were distributed, the depth of recall[7], how the problem was discovered[8], and whether the firm provided a press release to the public. Cases which products distributed nationwide are likely to have lower recovery rates and longer completion times than

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[6] The American Meat Institutes (AMI) classification of states into six regions is used; Pacific, Mountain, North Central, South Central, North Atlantic, and South Atlantic.
[7] The depth of recall, as defined by FSIS, includes consumer, user (restaurants), retail, and wholesale levels.

cases which products marketed locally. Products distributed within the early stages of the supply chain such as wholesalers or retailers should be relatively easier to retrieve compared to those distributed to consumers or restaurants. It is interesting to assess if recall effectiveness and efficiency depends on how the problem was discovered and whether a press release results in improved measures of effectiveness and efficiency.

Data Collection and Explanatory Analysis

FSIS provides recall summaries on the website http://www.fsis.usda.gov/OA/recalls/rec_intr.htm. This site contains information about recall dates, identifying codes, company names, location where the report of incidents took place, recalled products, reason and description, and size of recall and recovery in pounds. The recall data is updated regularly and is currently available on the FSIS website from 1994. In most cases, press releases are also available. Since 1998, FSIS has provided recall information in a single format called a Recall Notification Report (RNR). The RNR contains the same information provided in the report summary with additional information on production date, how problems were discovered, distribution level, and depth of recall. Teratanavat and Hooker (2001) analyzed the data and conducted a trend analysis of these recalls.

In this study, only those recall cases that are reported to be complete are included. Thus, only cases opened and closed during the period 1994 to 2000 are assessed. Recalls in 2001 and 2002 are not included because recovery data and closure dates are not yet available. Since RNR was not available prior to 1998, two data sets are used in this study to examine the effects of this additional information on the measures of recall effectiveness. The first data set includes all

[8] Problems can be discovered through FSIS microbial sampling, by firms, consumer complaints, foodborne illness incidents, and other epidemiological data by local and state public health department.

information available on the summary reports from 1994 to 2000 with 321 observations, while the second data set uses the data from 1998 to 2000 with 168 observations.

The descriptive statistics of the dependent and independent variables included in the models are presented in tables 1 and 2. During 1994 to 2000, the average amount of recalled product recovered was 50.3 percent while it took an average of 172 days to complete a recall case. The data from 1998 to 2000 provides similar statistics; the average recovery rate was 48.9 percent and the completion time was 174 days. The average ratio of the recovery rate and the time for case completion in both data sets imply that 0.36-0.41 percent of product is recovered each day a case remains open. Approximately 7 percent of the observations report zero percent recovery. It is also possible that the actual amount of product recovered exceeds the amount the firm initially announced because firms or FSIS may discover later that the recall case was more serious that it was originally thought to be. In these cases, the amount of product to be removed from the market may be extended, as can be seen when the recovery rate goes beyond 100 percent[9].

Most of the descriptive statistics of the explanatory variables are similar for the two data sets. Considering first the variables in the product specific category, the average size of these recalls was 460,642 pounds[10]. Of these recalls, some 74 percent involved processed foods, which have longer shelf lives compared to raw or fresh products[11]. Class I and II recalls account for 74

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[9] The actual recovery rate, even beyond 100 percent, is included in the regression models.

[10] This high figure is strongly influenced by few very large, outlier recall cases including 25 million pounds by Hudson Foods (1997), 35 million pounds by Bil Mar Foods (1998), 35 million pounds by Thorn Apple Valley (1999), and 17 million pounds by Cargill Turkey Products (2000). The summary statistics reported that 24% of total cases are less than 1,000 pounds, 54% between 1,000 and 100,000 pounds, and only 4% larger than one million pounds (Teratanavat and Hooker, 2001). However, these outlier observations 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.

[11] The authors are aware that different raw or processed foods have a range of shelf lives. One processed food may last 3 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.

and 21 percent respectively with two-thirds of the cases related to biological hazards. More than 90 percent were domestic cases, meaning that products are manufactured and marketed in the U.S. In the firm specific category, 40 and 70 percent of firms had implemented PR/HACCP at the time of the recall over the 1994 and 2000 and 1998 and 2000 periods, respectively. Almost half of the recall cases were from small plants and about one third of all cases originated in the north central area. Recall cases were distributed equally across the four seasons. Data from 1998 to 2000 indicates that, on the average, it took 44 days from the production date to the time that a problem was discovered. Almost half of the recall cases were distributed as far as the consumer level and problems were mostly determined by FSIS through regular sampling. A press release was made available in almost 80 percent of all recall cases.

Ordinary Least Square (OLS) and Count Data Models

An OLS model is used to examine the linear relationship between the recovery rate, the recovery rate-time ratio, and factors that may influence recall effectiveness.[12] Variables that report a frequency, for example 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, Fletcher, and McWatter, 1999), the duration of unemployment, the number of doctor visits (Cameron and Trivedi, 1986), the number of trips to recreation sites (Haab and McConnell, 2002) and so forth.

[12] A relatively small number of zeros occur in the recovery rate and the recovery-time ratio series (some 7% of all observations). Greene (2000) suggests that when the data is significantly truncated or censored OLS results in inconsistent estimates. Tobit estimates are available upon request, however these findings are consistent with the OLS model which are reported here for ease of interpretation.

In this study, both censored and count data modeling techniques can be applied when the speed of the recall process is used as the dependent variable because the time is censored at zero taking positive values only. The count data regression models such as Poisson or Negative Binomial, nonetheless, may be more appropriate than Tobit or Truncated models since the number of days taken to complete the case are nonnegative integers (Haab and McConnell, 2002). In this model, Y_i is the number of days to complete the recall. This variable is assumed to be drawn from a Poisson distribution with parameter λ_i. The probability that the number of days equals y can be written as (Cameron and Trivedi, 1986):

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

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.

$$E[y_i|x_i] = \quad \lambda_i \quad = \quad \exp(x_i\,\beta) \qquad (2)$$

$$L(\beta|x,y) \quad = \quad \prod_{i=1}^{n} \frac{\exp(-e^{x_i\beta})\,e^{(x_i\beta)\,y_i}}{y_i!} \qquad (3)$$

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, nevertheless, the conditional variance of the dependent variable is far 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, Monfort, and Trognon, 1984). Cameron and Trivedi (1998) suggest a more generalized model with the relaxation of the equality property of the conditional mean and variance. The negative binomial model was proposed, modifying the Poisson to have a gamma distributed error term (ε) in the mean.

$$\lambda_i = \exp(x_i\beta + \varepsilon) \tag{4}$$

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

$$f(y|\lambda_i,\alpha) = \frac{\Gamma\left(y_i + \frac{1}{\alpha}\right)}{\Gamma(y_i+1)\,\Gamma\left(\frac{1}{\alpha}\right)}\left(\frac{\frac{1}{\alpha}}{\frac{1}{\alpha}+\lambda_i}\right)^{\frac{1}{\alpha}}\left(\frac{\lambda_i}{\frac{1}{\alpha}+\lambda_i}\right)^{y_i} \tag{5}$$

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:

$$E[y_i|x_i\beta] = \lambda_i = \exp(x_i\beta + \varepsilon) \tag{6}$$

$$Var[y_i|x_i\beta] = \lambda_i(1+\alpha\lambda_i) \tag{7}$$

It is noted that if α = 0, the negative binomial model becomes the Poisson model; as a result, a test of α = 0 assesses both over-dispersion and the nested model (Haab and McConnell, 2002).

Results and Discussion

As shown in tables 3 to 8, the regression results are similar for the two data sets, 1994 to 2000 and 1998 to 2000 and for the two sets of models; the full model with all variables and the models with separate variables from the specific categories. The following analysis will focus on the data from 1998 to 2000, unless the results of the two data sets differ, allowing the influence of all variables to be discussed. Also, more emphasis is given to the models that separately include variables in each category, enabling the joint significance of each variable group to be tested. Any differences in these regression results are discussed.

Dependent Variable: Recovery Rate

According to the joint significant test, using the F-statistic, the hypothesis that all parameters, even under different categories, are equal to zero at the 0.1 level cannot be rejected (tables 3 and 4). The result from the F-test and small R^2 implies that no strong linear relationship exists between descriptors of the recalled product and the recovery rate.

A limited amount of information about the firm and timing appear to account for changes in the recovery rate. It is surprising to see that larger plants are likely to have a lower recovery rate than smaller plants. However, whether PR/HACCP was implemented when the recall took place or the plant location is not significant at the 0.1 level. The time until the problem is discovered has a negative correlation with the recovery rate. This result is expected showing that the probability that affected products can be recalled is lower when they have been in the market for a long period.

Other factors such as product shelf life, recall class, hazard type, location, season, distribution level, and press release do not appear to have any impact on the recovery rate, according to the regression models. If the recovery rate is used as a measure of recall effectiveness, little inference can be drawn from these explanatory variables. The result also shows that the recovery rate has not increased over time and that PR/HACCP implementation did not increase the recovery rate, implying that there has been no improvement in recall effectiveness.

Dependent Variable: Completion Time

The negative binomial model, as shown in tables 5 and 6, is more appropriate than the Poisson count model because the hypothesis of no over-dispersion ($\alpha = 0$) is rejected at the 0.01

level. According to the likelihood ratio test, it is shown that all explanatory variables can be used jointly to explain the variation in completion time. Information on the product specific and timing categories are also shown to have a significant impact on this efficiency measure. Using different criteria of model selection such as Adjusted-R^2, Akaike Information Criteria (AIC), and Schwarz criteria (SC), the product specific is likely to better explain changes in the completion time. The regression results show that recall size, distribution level, and time until problem is discovered have impacts on the completion time. The results from the 1994 to 2000 data also suggest that recall class and PR/HACCP affect the time to complete the recall case.

The parameters generated by the count data models, unlike the OLS, do not have a direct interpretation. First, the focus is on the conditional expectation of the dependent variable ($E[y|x]$) , instead of the dependent variable (y) itself. Second, the marginal effect, or the effect of changes in explanatory variables on the conditional mean of the dependent variable, varies across individual recall events because each one has different values of the x_i's (Cameron and Trivedi, 1998). It is noted that marginal effects of the individual with mean characteristics are generally reported using the average of each explanatory variable and that different forms of variables such as continuous, discrete, or logarithm require different formula to estimate the marginal effect. The marginal effects of independent variables computed from coefficient estimates evaluated at the sample means of explanatory variables are reported in table 9.

The results show that both the size of the recall and the time until the problem was found are positively correlated with completion time. With a larger recall it is reasonable to expect a longer time to remove products from the market. Additionally, the longer it takes to discover the problem, the more likely it is that it will take more time to complete the case because products may already be further along the supply chain. The significant negative coefficient estimate at the 0.05 level of the date variable implies that the recall process now takes less time to complete as compared to the earlier years within the sample. This can be interpreted as an improvement of the recall process over time if the completion time is used as the measure of recall efficiency.

The coefficient estimate of the distribution level is statistically significant at the 0.01 level, indicating that recall cases in which products are distributed or marketed to multiple states take more time to complete than do recall cases in which products are distributed locally. The result from the 1994 to 2000 data shows that Class I and II recall cases are likely to take more time than Class III. It is reasonable to assume that more serious recalls involving Class I and II hazards require more time for product inspection and recovery to ensure that contaminated products are removed from the market. FSIS may also leave these cases open for a longer period based on their greater human health risk. Moreover, the regression model with all variables included suggests that recall cases were completed in a shorter period when the firms involved have implemented PR/HACCP. More evidence is needed however to confirm that PR/HACCP is likely to improve the efficiency of the recall process.

Dependent Variable: Recovery Rate - Completion Time Ratio

The higher R^2 estimate in this model indicates that these explanatory variables better explain the variation in the ratio of recovery rate and completion time than that in the recovery rate alone. As the ratio captures the relative recovery rate per day the cases remained open, it may be a better criterion for examining the relative efficiency of the recall process. Nonetheless, as in the case of recovery rate, no strong linear relationship exists between descriptors of recalled product and the recovery rate-completion time ratio. The F-tests fails to reject the null hypothesis that all explanatory variables are not statistically significant at the 0.1 level. Even though data from 1994 to 200 provide significant results, most parameter estimates are not statistically significant based on the t-values.

Most information about recalled products can not be used to draw inferences about this ratio, except for the product shelf life. The regression result from 1994 to 2000 data shows that a faster recovery rate per day is seen for processed food as compared to raw or fresh food, indicated by a significant positive parameter estimate. Factors such as recall class, hazard type, or domestic/imported products do not have a statistically significant impact on the recovery rate-completion time ratio at the 0.1 level. As for the firm specific, large plants tend to have lower daily recovery rates than small and very small plants. The daily recovery rate of large plants may be increased by integrating better crisis management programs. Neither PR/HACCP implementation, nor firm location has statistically significant effects at the 0.1 level. The full model with 1994 to 2000 data, however, provides different result where PR/HACCP has positive effect on the recovery rate-completion time ratio.

According to the data from 1994 to 2000, the significant negative estimate for the date of the incident suggests that the recovery rate per day has slightly decreased over the period. It can be shown that the relative reduction in the recovery rate has been slightly greater than the improvement in the speed to complete the case over time. The time before the problem is discovered seems to have a minor positive effect on this relative efficiency measure, implying that higher recovery rates per day while cases remain open are expected. Seasonal differences have no role in explaining changes in this ratio. Other factors such as distribution level, depth of distribution, how problems were found, and press releases do not have a significant impact on the recovery rate-completion time ratio.

Conclusion

This exploratory research shows that the linear model structure cannot fully capture the impact of recall information on effectiveness/efficiency measures and that the marginal effects vary across these measures. With low explanatory power, no inference can be drawn from recall case information about changes in the recovery rate and the ratio. Nonetheless, there exist stronger statistical relationships between explanatory variables and the completion time. In general the main factors that affect recall efficiency, though FSIS or firms do not have any direct control over these, are recall size, class, and distribution level. The recall data does not suggest recall effectiveness and efficiency is affected by domestic/imported products, location, season, how the problem was discovered, or the existence of a press release.

The results also show no significant improvement in the recall process regardless of the criteria used to examine effectiveness and efficiency, as measured by the recovery rate, the time to complete recall cases, and the recovery rate-completion time ratio. Even though the time trends suggest that it now take less time to complete cases, the recovery rate has been decreasing over time. The data does not show strong evidence to support the contention that firms, which have implemented PR/HACCP, can better handle recalls. One way to improve recall effectiveness and efficiency is to discover problems as early as possible. The earlier the problem is found, the more affected products are likely to be recovered and the less time it takes to complete the recall case. The increasing use of “rapid” microbiological tests, for example, should have a positive impact on recall effectiveness.

The data and the regression results do not provide enough evidence to draw conclusions about the overall effectiveness of recalls such as their changing pattern over time, variability among firms' and recall case characteristics. The weak explanatory power of the current models must be addressed before policy or firm strategy recommendations can be forwarded. Further study is needed to justify if the recovery rate, case completion time, and/or their ratio are appropriate measures of the effectiveness and efficiency of the recall process.

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Table 1: Descriptive Statistics of Dependent Variables

Dependent Variables	Definition	Data from 1994 to 2000 (321 Observations)				Data from 1998 to 2000 (168 Observations)			
		Mean	**Std. Dev.**	**Min.**	**Max.**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
RECOVERY	Recovery rate (%) = Amount recovered / amount recalled *100	50.30%	(0.525)	0.00%	650.9%	48.90%	(0.586)	0.00%	650.90%
TOTALDAYS	Number of days to complete case	171.54	(108.22)	2.00	616.00	174.32	(104.58)	35.00	616.00
RATIO	Recovery rate (%) / Number of days to complete case	0.41%	(0.578)	0.00%	6.23%	0.36%	(0.390)	0.00%	2.08%

Table 2: Description of Explanatory Variables

Explanatory Variables	Definition	Data from 1994 to 2000		Data from 1998 to 2000	
		Mean	Std Dev.	Mean	Std Dev.
Product/ Case Characteristics					
LNPOUND	Log value of total pounds of recalled products	3.9214	(1.218)	3.8725	(1.310)
SHELFLIFE	Short/long shelf life (1=processed food; 0=raw or fresh products)	0.7383	(0.440)	0.7308	(0.445)
CLASSI	Class I recall (1=yes;0=no)	0.7414	(0.439)	0.8407	(0.367)
CLASSII	Class II recall (1=yes;0=no)	0.2118	(0.409)	0.1264	(0.333)
CLASSIII	Class III recall (1=yes;0=no)	0.0312	(0.174)	0.0330	(0.179)
BIOLOGICAL	Hazard type: Biological (1=yes;0=no)	0.7041	(0.457)	0.7747	(0.419)
CHEMICAL	Hazard type: Chemical (1=yes;0=no)	0.0467	(0.211)	0.0330	(0.179)
PHYSICAL	Hazard type: Physical (1=yes;0=no)	0.1371	(0.344)	0.0659	(0.249)
DOMESTIC	Domestic/ Imported products (1=domestic;0=imported)	0.9190	(0.273)	0.9396	(0.239)
Firm/ Plant Characteristics					
HACCP	HACCP implementation during recall incidence (1=yes;0=no)	0.3988	(0.490)	0.7033	(0.458)
LARGE	Plant size: Large (1=yes;0=no)	0.2368	(0.426)	0.2198	(0.415)
SMALL	Plant size: Small (1=yes;0=no)	0.4642	(0.499)	0.4725	(0.501)
VSMALL	Plant size: Very small (1=yes;0=no)	0.1745	(0.380)	0.2143	(0.411)
MOUNTAIN	Location where recall occurs: Mountain region (1=yes;0=no)	0.0779	(0.268)	0.0659	(0.249)
PACIFIC	Pacific region (1=yes;0=no)	0.0935	(0.292)	0.1099	(0.314)
NATLANTIC	North Atlantic region (1=yes;0=no)	0.1713	(0.377)	0.1923	(0.395)
SATLANTIC	South Atlantic region (1=yes;0=no)	0.0966	(0.296)	0.1209	(0.327)
NCENTRAL	North Central region (1=yes;0=no)	0.3240	(0.469)	0.2857	(0.453)
SCENTRAL	South Central region (1=yes;0=no)	0.1620	(0.369)	0.1593	(0.367)
Timing Factors					
DISCOVERYTIME	Time from production date until the product is discovered	n/a	n/a	43.9762	(60.745)
DATE	Range from 1 to 7 representing year 1994 to 2000 Range from 1 to 3 representing year 1998 to 2000	4.4486	(2.195)	2.2143	(0.775)
FALL	Season when recall occurs: Fall (Oct-Dec) (1=yes;0=no)	0.2461	(0.431)	0.2202	(0.416)
WINTER	Winter (Jan-Mar) (1=yes;0=no)	0.2523	(0.435)	0.2202	(0.416)
SPRING	Spring (Apr-Jun) (1=yes;0=no)	0.2617	(0.440)	0.2976	(0.459)
SUMMER	Summer (Jul-Sep) (1=yes;0=no)	0.2399	(0.428)	0.2619	(0.441)

Table 2: Description of Explanatory Variables (Continued)

Explanatory Variables	Definition	Data from 1994 to 2000		Data from 1998 to 2000	
		Mean	Std Dev.	Mean	Std Dev.
Other Characteristics					
DISTRIBUTION_LEVEL	Represent numbers of states that products were distributed	n/a	n/a	11.7802	(17.451)
CONSUMER	Depth of the recall as identified by recall committee -targeting household consumers	n/a	n/a	0.4780	(0.501)
USER	Depth of the recall as identified by recall committee -targeting restaurant and other food service institutions	n/a	n/a	0.3022	(0.460)
RETAIL	Depth of the recall as identified by recall committee -targeting all retail stores	n/a	n/a	0.2143	(0.411)
WHOLESALE	Depth of the recall as identified by recall committee -targeting wholesale distributors	n/a	n/a	0.1319	(0.339)
FSIS_FOUND	Problem was discovered through test result if sample taken by FSIS	n/a	n/a	0.5989	(0.491)
FIRM_FOUND	Problem was discovered through the firm reporting the problems	n/a	n/a	0.1099	(0.314)
OTHER_FOUND	Problem was discovered through consumer complaints, foodborne illness incidents, and other epidemiological data by state and local public health department, other than USDA	n/a	n/a	0.2912	(0.456)
PRESS_RELEASE	Press Release (whether it is available) (1= yes;0=no)	n/a	n/a	0.7802	(0.415)

Notes:
1. FSIS assigns recalls into Class I, II and III depending on the severity of the potential negative health consequences.
2. Large plants have more than 500 employees. Small plants have between 10 and 500 employees. Very small plants have less than 10 employees or less than $2.5 million in sales.
3. The Food Code specifies foodborne hazard types, which are biological, chemical and physical hazards (CFSAN, 1997)
4. Total observations = 321 (data from 1994 to 2000) and 168 (data from 1998 to 2000).
5. Information on DISCOVERYTIME and variables in Other Characteristics available from 1998.

Table 3: Parameter Estimates (Probability β=0) for the OLS Model, Data from 1994 to 2000
Dependent Variable: Recovery Rate

Explanatory Variables	Full Model		Effect of Product Specific Category		Effect of Firm Specific Category		Effect of Timing Factors	
Product/ Case Specific Category								
SHELF_LIFE	0.075	(0.286)	0.104	(0.123)				
CLASSI	0.105	(0.518)	0.049	(0.761)				
CLASSII	0.140	(0.361)	0.089	(0.557)				
BIOLOGICAL	0.113	(0.281)	0.165	(0.101)				
CHEMICAL	0.133	(0.464)	0.208	(0.238)				
DOMESTIC	0.090	(0.522)	0.043	(0.740)				
Firm/ Plant Specific Category								
HACCP	0.006	(0.954)			-0.026	(0.679)		
LARGE	-0.216	(0.034)			-0.238	(0.005)		
SMALL	-0.091	(0.263)			-0.104	(0.150)		
MOUNTAIN	-0.007	(0.958)			0.038	(0.757)		
PACIFIC	0.191	(0.111)			0.220	(0.052)		
NCENTRAL	0.028	(0.747)			0.063	(0.425)		
NATLANTIC	-0.113	(0.262)			-0.084	(0.367)		
SATLANTIC	-0.083	(0.481)			-0.046	(0.679)		
Timing Factors								
DATE	-0.014	(0.540)					-0.011	(0.397)
SUMMER	-0.095	(0.278)					-0.096	(0.256)
SPRING	0.016	(0.847)					0.037	(0.657)
FALL	-0.095	(0.261)					-0.112	(0.177)
F-statistic	1.441	(0.111)	1.158	(0.328)	2.220	(0.026)	1.304	(0.269)
Computed χ^2 for the LR test			4.523		13.972	*	3.840	
Critical χ^2 (d.f. = # restrictions)			10.640		13.360		7.780	
R-squared	0.079		0.022		0.054		0.016	
Adjusted R-squared	0.024		0.003		0.030		0.004	
Akaike info criterion (AIC)	1.584		1.570		1.549		1.563	
Schwarz criterion (SC)	1.807		1.652		1.654		1.621	

Note:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 321.
3. Model Selection Criteria: High value of Adjusted R-squared and Low value of AIC and SC

Table 4: Parameter Estimates (Probability β=0) for the OLS Model, Data from 1998 to 2000
Dependent Variable: Recovery Rate

Explanatory Variables	Full Model		Effect of Product Specific Category		Effect of Firm Specific Category		Effect of Timing Factors		Effect of Other Category	
Product/ Case Specific Category										
SHELF_LIFE	-0.057	(0.632)	0.003	(0.973)						
CLASSI	-0.102	(0.818)	-0.173	(0.560)						
CLASSII	0.171	(0.683)	-0.007	(0.979)						
BIOLOGICAL	0.130	(0.580)	0.135	(0.454)						
CHEMICAL	0.008	(0.985)	0.186	(0.515)						
DOMESTIC	-0.026	(0.921)	0.036	(0.857)						
Firm/ Plant Specific Category										
HACCP	0.153	(0.415)			-0.018	(0.880)				
LARGE	-0.274	(0.204)			-0.182	(0.218)				
SMALL	-0.102	(0.496)			-0.059	(0.610)				
MOUNTAIN	0.049	(0.830)			0.143	(0.467)				
PACIFIC	0.329	(0.101)			0.323	(0.049)				
NCENTRAL	-0.061	(0.699)			0.000	(0.999)				
NATLANTIC	-0.162	(0.328)			-0.127	(0.349)				
SATLANTIC	-0.054	(0.772)			0.033	(0.830)				
Timing Factors										
DISCOVERYTIME	-0.001	(0.360)					-0.002	(0.034)		
DATE	-0.206	(0.061)					-0.095	(0.119)		
SUMMER	-0.154	(0.321)					-0.141	(0.297)		
SPRING	-0.110	(0.443)					-0.063	(0.629)		
FALL	-0.263	(0.089)					-0.278	(0.048)		
Other Category										
DISTRIBUTION_LEVEL	0.000	(0.993)							-0.003	(0.208)
CONSUMER	-0.088	(0.629)							-0.017	(0.909)
USER	-0.046	(0.792)							-0.078	(0.610)
RETAIL	-0.027	(0.881)							-0.044	(0.788)
FSIS_FOUND	0.112	(0.425)							0.131	(0.219)
FIRM_FOUND	0.286	(0.179)							0.188	(0.229)
PRESS_RELEASE	0.164	(0.385)							-0.083	(0.509)
F-statistic	0.954	(0.533)	0.178	(0.983)	1.571	(0.137)	2.017	(0.079)	0.735	(0.643)
Computed χ^2 for the LR test			2.749		11.406		23.425	*	3.367	
Critical χ^2 (d.f. = # restrictions)			10.640		13.360		7.780		12.020	
R-squared	0.150		0.006		0.068		0.059		0.029	
Adjusted R-squared	0.150		-0.028		0.025		0.030		-0.010	
Akaike info criterion	1.983		1.835		1.793		1.834		1.823	
Schwarz criterion	2.485		1.958		1.951		1.946		1.964	

Note:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 168.
3. Model Selection Criteria: High value of Adjusted R-squared and Low value of AIC and SC

Table 5: Parameter Estimates (Probability β=0) for the Negative Binomial Count Model, Data from 1994 to 2000
Dependent Variable: Completion Time

Explanatory Variables	Full Model		Effect of Product Specific Category		Effect of Firm Specific Category		Effect of Timing Factors	
Product/ Case Specific Category								
LNPOUND	0.189	(0.000)	0.163	(0.000)				
SHELF_LIFE	0.085	(0.236)	0.041	(0.568)				
CLASSI	0.479	(0.006)	0.475	(0.007)				
CLASSII	0.474	(0.003)	0.420	(0.009)				
BIOLOGICAL	0.001	(0.993)	0.028	(0.800)				
CHEMICAL	0.355	(0.065)	0.355	(0.058)				
DOMESTIC	0.405	(0.006)	0.297	(0.030)				
Firm/ Plant Specific Category								
HACCP	-0.312	(0.003)			-0.028	(0.690)		
LARGE	-0.006	(0.960)			0.202	(0.041)		
SMALL	-0.089	(0.316)			0.058	(0.490)		
MOUNTAIN	0.116	(0.371)			0.023	(0.866)		
PACIFIC	0.028	(0.820)			-0.067	(0.606)		
NCENTRAL	0.028	(0.750)			-0.011	(0.902)		
NATLANTIC	0.023	(0.827)			-0.067	(0.525)		
SATLANTIC	0.010	(0.935)			0.040	(0.755)		
Timing Factors								
DATE	0.082	(0.001)					0.025	(0.120)
SUMMER	0.151	(0.095)					0.149	(0.113)
SPRING	0.109	(0.220)					0.051	(0.582)
FALL	0.180	(0.037)					0.165	(0.076)
Over Dispersion Test	-1.297	***	-1.225	***	-1.076	***	-1.076	***
Computed χ^2 for the LR test			60.480	*	13.850	*	18.800	*
Critical χ^2 (d.f. = # restrictions)			12.020		13.360		7.780	
Adjusted R-squared	0.161		0.160		-0.009		0.001	
Akaike info criterion (AIC)	11.716		11.716		11.880		11.855	
Schwarz criterion (SC)	11.963		11.822		11.997		11.925	

Note:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 321.
3. Model Selection Criteria: High value of Adjusted R-squared and Low value of AIC and SC

Table 6: Parameter Estimates (Probability β=0) for the Negative Binomial Count Model, Data from 1998 to 2000
Dependent Variable: Completion Time

Explanatory Variables	Full Model		Effect of Product Specific Category		Effect of Firm Specific Category		Effect of Timing Factors		Effect of Other Category	
Product/ Case Specific Category										
LNPOUND	0.155	(0.001)	0.165	(0.000)						
SHELF_LIFE	0.009	(0.922)	0.105	(0.219)						
CLASSI	0.121	(0.724)	-0.067	(0.786)						
CLASSII	0.275	(0.395)	-0.024	(0.918)						
BIOLOGICAL	0.385	(0.038)	0.225	(0.132)						
CHEMICAL	0.247	(0.408)	0.203	(0.378)						
DOMESTIC	0.418	(0.035)	0.299	(0.063)						
Firm/ Plant Specific Category										
HACCP	0.030	(0.841)			-0.146	(0.177)				
LARGE	-0.289	(0.107)			0.275	(0.043)				
SMALL	-0.282	(0.025)			0.123	(0.256)				
MOUNTAIN	0.160	(0.371)			-0.030	(0.866)				
PACIFIC	0.117	(0.472)			0.005	(0.975)				
NCENTRAL	-0.040	(0.745)			-0.025	(0.827)				
NATLANTIC	-0.094	(0.469)			-0.105	(0.393)				
SATLANTIC	0.134	(0.355)			0.155	(0.276)				
Timing Factors										
DISCOVERYTIME	0.001	(0.287)					0.002	(0.003)		
DATE	-0.088	(0.300)					-0.111	(0.033)		
SUMMER	0.117	(0.343)					0.033	(0.779)		
SPRING	0.020	(0.859)					0.024	(0.831)		
FALL	0.142	(0.241)					0.126	(0.297)		
Other Category										
DISTRIBUTION_LEVEL	0.003	(0.308)							0.010	(0.000)
CONSUMER	-0.015	(0.919)							0.147	(0.274)
USER	-0.035	(0.788)							0.065	(0.638)
RETAIL	0.082	(0.553)							0.106	(0.462)
FSIS_FOUND	0.013	(0.908)							-0.069	(0.457)
FIRM_FOUND	0.276	(0.096)							-0.012	(0.929)
PRESS_RELEASE	-0.019	(0.898)							-0.060	(0.593)
Over Dispersion Test	-1.543	***	-1.440	***	-1.281	***	-1.330	***	-1.382	***
Computed χ^2 for the LR test			22.600	*	12.070		166.910	*	5.855	
Critical χ^2 (d.f. = # restrictions)			12.020		13.360		7.780		12.020	
Adjusted R-squared	0.098		0.176		-0.018		0.048		0.092	
Log- Likelihood Value	-955.334		-1048.23		-1063.43		-974.04		-1053.77	
Akaike info criterion (AIC)	11.718		11.618		11.796		11.679		11.679	
Schwarz criterion (SC)	12.258		11.776		11.972		11.809		11.837	

Note:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 168.
3. Model Selection Criteria: High value of Adjusted R-squared and Low value of AIC and SC

Table 7: Parameter Estimates (Probability β=0) for the OLS Model, Data from 1994 to 2000
Dependent Variable: Recovery Rate-Completion Time Ratio

Explanatory Variables	Full Model		Effect of Product Specific Category		Effect of Firm Specific Category		Effect of Timing Factors	
Product/ Case Specific Category								
SHELF_LIFE	0.153	(0.041)	0.201	(0.007)				
CLASSI	0.066	(0.704)	-0.029	(0.869)				
CLASSII	0.036	(0.824)	-0.019	(0.907)				
BIOLOGICAL	0.132	(0.236)	0.218	(0.047)				
CHEMICAL	-0.065	(0.737)	0.104	(0.586)				
DOMESTIC	0.131	(0.386)	-0.007	(0.960)				
Firm/ Plant Specific Category								
HACCP	0.184	(0.095)			-0.001	(0.989)		
LARGE	-0.378	(0.001)			-0.331	(0.000)		
SMALL	-0.206	(0.018)			-0.164	(0.038)		
MOUNTAIN	-0.179	(0.189)			-0.042	(0.751)		
PACIFIC	-0.092	(0.473)			0.013	(0.910)		
NCENTRAL	-0.078	(0.400)			0.024	(0.783)		
NATLANTIC	-0.207	(0.055)			-0.113	(0.269)		
SATLANTIC	-0.271	(0.031)			-0.189	(0.127)		
Timing Factors								
DATE	-0.062	(0.012)					-0.026	(0.079)
SUMMER	-0.123	(0.190)					-0.153	(0.095)
SPRING	0.037	(0.680)					0.045	(0.616)
FALL	-0.163	(0.072)					-0.177	(0.050)
F-statistic	2.472	(0.001)	2.275	(0.036)	2.218	(0.026)	2.966	(0.020)
Computed χ^2 for the LR test			11.324	*	17.820	*	14.570	*
Critical χ^2 (d.f. = # restrictions)			10.640		13.360		7.780	
R-squared	0.128		0.042		0.054		0.036	
Adjusted R-squared	0.076		0.023		0.030		0.024	
Akaike info criterion (AIC)	1.718		1.738		1.738		1.732	
Schwarz criterion (SC)	1.942		1.821		1.844		1.791	

Note:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 321.
3. Model Selection Criteria: High value of Adjusted R-squared and Low value of AIC and SC

Table 8: Parameter Estimates (Probability β=0) for the OLS Model, Data from 1998 to 2000
Dependent Variable: Recovery Rate-Completion Time Ratio

Explanatory Variables	Full Model		Effect of Product Specific Category		Effect of Firm Specific Category		Effect of Timing Factors		Effect of Other Category	
Product/ Case Specific Category										
SHELF_LIFE	0.055	(0.475)	0.061	(0.364)						
CLASSI	-0.206	(0.475)	-0.291	(0.140)						
CLASSII	-0.021	(0.936)	-0.147	(0.419)						
BIOLOGICAL	0.065	(0.668)	0.159	(0.182)						
CHEMICAL	-0.199	(0.437)	-0.022	(0.907)						
DOMESTIC	-0.152	(0.375)	-0.083	(0.524)						
Firm/ Plant Specific Category										
HACCP	0.112	(0.356)			0.148	(0.054)				
LARGE	-0.172	(0.217)			-0.263	(0.008)				
SMALL	-0.001	(0.987)			-0.096	(0.210)				
MOUNTAIN	0.046	(0.755)			0.013	(0.922)				
PACIFIC	0.133	(0.301)			0.089	(0.409)				
NCENTRAL	-0.029	(0.780)			0.042	(0.605)				
NATLANTIC	-0.073	(0.493)			-0.089	(0.327)				
SATLANTIC	-0.140	(0.242)			-0.120	(0.243)				
Timing Factors										
DISCOVERYTIME	-0.001	(0.139)					-0.001	(0.004)		
DATE	-0.041	(0.562)					0.038	(0.337)		
SUMMER	-0.154	(0.126)					-0.140	(0.108)		
SPRING	-0.126	(0.174)					-0.101	(0.229)		
FALL	-0.207	(0.039)					-0.219	(0.016)		
Other Category										
DISTRIBUTION_LEVEL	-0.001	(0.681)							-0.004	(0.013)
CONSUMER	-0.056	(0.635)							-0.083	(0.401)
USER	0.019	(0.867)							-0.070	(0.481)
RETAIL	-0.016	(0.895)							-0.053	(0.619)
FSIS_FOUND	0.071	(0.435)							0.103	(0.133)
FIRM_FOUND	0.066	(0.631)							0.126	(0.215)
PRESS_RELEASE	0.082	(0.502)							0.009	(0.903)
F-statistic	1.150	(0.296)	0.602	(0.728)	1.743	(0.092)	3.401	(0.006)	1.973	(0.061)
Computed χ^2 for the LR test			3.679		9.253		114.383	*	1.559	
Critical χ^2 (d.f. = # restrictions)			10.640		13.360		7.780		12.020	
R-squared	0.175		0.020		0.075		0.095		0.074	
Adjusted R-squared	0.023		-0.013		0.032		0.067		0.036	
Akaike info criterion (AIC)	1.112		1.005		1.128		0.954		0.959	
Schwarz criterion (SC)	1.149		1.128		1.743		1.066		1.101	

Note:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 168.
3. Model Selection Criteria: High value of Adjusted R-squared and Low value of AIC and SC

Table 9: Marginal Effects Negative Binomial Count Data Model - Dependent Variable Number of Days to Complete Case

Explanatory Variables	Marginal Effect							
	Data from 1994 to 2000				Data from 1998 to 2000			
	Full Model Including all Variables		Models of Individual Categories		Full Model Including all Variables		Models of Individual Categories	
Product/ Case Specific Category								
LNPOUND	0.9834	***	0.6725	***	0.6543	***	0.5034	***
SHELFLIFE	1.0883		1.0415		1.0095		1.1104	
CLASSI	1.6146	***	1.6085	***	1.1291		0.9351	
CLASSII	1.6065	***	1.5223	***	1.3169		0.9766	
BIOLOGICAL	1.0010		1.0280		1.4691	**	1.2520	
CHEMICAL	1.4258	*	1.4266	*	1.2804		1.2250	
DOMESTIC	1.4992	**	1.3454	**	1.5195	**	1.3486	*
Firm/ Plant Specific Category								
HACCP	0.7321	***	0.9722		1.0304		0.8644	
LARGE	0.9942		1.2235	**	0.7492		1.3172	**
SMALL	0.9145		1.0595		0.7539	**	1.1309	
MOUNTAIN	1.1234		1.0236		1.1729		0.9702	
PACIFIC	1.0287		0.9355		1.1236		1.0047	
NCENTRAL	1.0287		0.9889		0.9604		0.9756	
NATLANTIC	1.0234		0.9353		0.9105		0.9000	
SATLANTIC	1.0099		1.0404		1.1436		1.1671	
Timing Factors								
DISCOVERYTIME	n/a		n/a		0.0009	***	0.0018	***
DATE	0.1307	***	0.0306		-0.0812	**	-0.0989	**
SUMMER	1.1630	*	1.1605		1.1242		1.0336	
SPRING	1.1152		1.0521		1.0205		1.0247	
FALL	1.1974	**	1.1797		1.1526		1.1343	
Other Category								
DISTRIBUTION_LEVEL	n/a		n/a		0.0037	***	0.0114	***
CONSUMER	n/a		n/a		0.9855		1.1579	
USER	n/a		n/a		0.9652		1.0668	
RETAIL	n/a		n/a		1.0852		1.1114	
FSIS_FOUND	n/a		n/a		1.0127		0.9337	
FIRM_FOUND	n/a		n/a		1.3178		0.9880	
PRESS_RELEASE	n/a		n/a		0.9809		0.9420	

Notes:
1. * significant at 0.10 level. ** significant at 0.05 level. *** significant at 0.01 level.
2. Total observations = 321 (data from 1994 to 2000) and 168 (data from 1998 to 2000).
3. LNPOUND, DISCOVERYTIME, DATE, and DISTRIBUTION_LEVEL are continuous variables. The marginal effect is calculated by using partial derivative of the conditional mean as follow

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

where all independent variables are held at their means.
4. Other explanatory variables are discrete variables. The marginal effect is calculated as the factor change in the conditional mean as follow

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