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Product Recalls in the Meat and Poultry Industry: Key Drivers of Supply Chain Efficiency and Effectiveness

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Product Recalls in the Meat and Poultry Industry: Key Drivers of Supply Chain Efficiency and Effectiveness

Vijaya Chebolu-Subramanian and Gary Gaukler

Abstract

There has been a significant increase in the number, size, and severity of food product recalls in the United States in the past decade. Additionally, the pressure to reduce costs has caused many food supply chains to off-shore production activities, making the logistics of recall events more challenging and costly for these supply chains. Thus, there is a strong need for research that can help identify the determinants and key drivers of supply chain efficiency and effectiveness with respect to food recall events. We focus our investigation on meat and poultry supply chains in the United States. Through an empirical analysis of over 500 recall events recorded in the government tracking database during the 2005-2013 period, we identify and test key factors that impact the product recall process in contemporary food supply chains. We conduct a statistical regression analysis to examine the impact of recall strategy, hazard type and the supply chain entity detecting the hazard on the time to recall and the amount of product recovered at closure. Future work also aims to investigate the impact of supply chain structure, reverse logistics and the potential impact of traceability (e.g., RFID) and condition monitoring (e.g., temperature sensors) on recall outcomes.

Keywords: supply chain management, food recalls, meat and poultry industry, safety hazards

1. Introduction

Over the past decade the size, severity and number of food products recalled in the United States has increased significantly. Additionally, in the year 2003 most recall cases were categorized as class I recalls, i.e., for foods that pose the greatest risk of illness or death (Dyckman and Lansburgh, 2004). The increasing complexity of food supply chains and off-shore production activities is making the logistics of recall events more challenging and costly for these supply chains (Roth et al., 2008). There is also no specification or emphasis on product safety for products thus sourced which makes them more vulnerable to the risk of recalls (Lyles et al., 2008).

Recalls are often costly and have a damaging impact on the entities involved. For example, in January 1999 samples from a meat and poultry processing plant in Arkansas of the Thorn Apple Valley Inc Company tested positive for listeria. The plant operations were shut down and products worth \$30 million were recalled. As a result the Thorn Company faced \$ 5.1 million in losses of production and sales and reported \$184 million as debt and filed for bankruptcy (Skees et al. 2001).

Raw foods of animal origin such as meat and poultry are found to be the most likely to be contaminated and susceptible to foodborne illness carrying pathogens such as listeria as compared to other food groups. Also foods that mingle the products of many individual animals, such as ground beef, are particularly hazardous because a pathogen present in any one of the animals may contaminate the whole batch. For example a single hamburger may contain meat from hundreds of animals or a broiler chicken carcass can be exposed to the drippings and juices of many other birds that went through the same cold water tank after slaughter (Centers for Disease Control and Prevention Food safety, 2011). According to Kramer et al. (2005), most major meat processors in the U.S. have been involved in a recall at some point in time. Consequently, we focus our investigation on meat and poultry supply chains that sell products to end customers in the United States.

The initiation of a product recall primarily occurs as a result of periodic quality control inspections carried out by regulatory agencies or firms themselves in the supply chain. Other less frequent modes of detection are through customer complaints or foodborne illness outbreaks (Teratanavat et al., 2005), (Dyckman and Lansburgh, 2004). The product recall is then communicated to the public through a recall announcement issued by the Food and Safety Inspection Services (FSIS) or the United States Department of Agriculture (USDA). This is followed by efforts by the firm to recover the entire recalled product spread along the supply chain. The closure of the case is recorded on satisfactory completion of the recall process as evaluated by the firms themselves and the regulatory agencies (FSIS-USDA recalls and public health alerts, 2014).

The increase in product recalls has led to an increasing acceptance by companies, consumers, regulators and investors that recalls are an inevitable part of conducting business and the focus has now shifted to the timing and timeliness of a recall (Berman, 1999) (Hora, et al, 2011).

The time it takes to recall a product and the amount of product recovered has a direct impact on the cost and severity of a recall event. As the time to recall increases the amount and spread of the recalled products increases as more products make their way into the hands of the consumers (Smith et al. 1996), (Berman, 1999), (Hora et. al, 2011). This in turn may have lead to an increase in investigation costs, reimbursement costs, medical costs etc. Consumers also expect a more efficient and effective recall from a brand of high reputation (Dawar and Pillutla, 2000). Therefore an increase in the time to recall and amount of product recovered may have an effect on liability costs and brand value.

However, the “time to recall” has been given different connotations in research reflecting in its various operational definitions. Johnson-Hall (2012) measure it as the time between the beginning of the shelf life of the last produced product and the issue of the recall announcement and Hora et al. (2011) measure it as the time between the first sales of the recalled product and the time of the recall announcement. Tertanavat et.al (2005) denotes it as the “completion time” and

quantifies it as the time between the announcement of the recall and the completion of the recall case.

In our work unlike in previous research we define the “time to recall” as the difference between the initial time of production of the product and the time of the recall announcement. A hazard in a product can be detected anytime starting from the first production of the product in the supply chain. A lower time to recall indicates an efficient upstream detection of the hazard close to the time of its production and this in turn will minimize the impact of the recall as the possibility of the product spreading through the downstream supply chain and reaching the customer will be preempted (Hora et al, 2011), (Johnson-Hall, 2012). Therefore through our definition of the “time to recall” we aim to analyze key factors which influence the detection efficiency of a recall.

Once a product has been recalled it is the responsibility of the firm recalling the product to trace, track and effectively recover the entire recalled product from the supply chain and also inform all the other affected entities of the recall. The FSIS and USDA also determine the effectiveness of a recall by conducting “effectiveness checks” to ensure that all entities in the supply chain are aware of the recall and that the recalled product has been completely recovered (FSIS-USDA recalls and public health alerts, 2014).

A lower time to recall implies a quicker detection of the hazard which in turn may lead to a more effective recovery of the product in the supply chain as the spread of the product through the downstream supply chain, specifically to the consumer will be minimized. This is especially true of perishable products with shorter shelf lives as compared to durable products as the consumption or disposal of the product near the end of its shelf life will impact recovery rates (Johnson-Hall, 2012). We also analyze whether factors impacting the “time to recall” have a similar impact on “amount of product recovered”. Through this we aim to gain insights into the supply chain visibility and tracking capabilities of the recalling entity and its partners.

Figure 1 illustrates the various stages in the recall timeline. It also depicts the specific period of the recall timeline, the products and the time span of the data under scrutiny in various studies in literature and the focus of our research. In line with recent work we aim to test the efficiency and effectiveness of meat by measuring the “total time to recall” and the “recovered product” of an event according to our definition through an empirical study of meat and poultry recalls during the period 2005-2013.

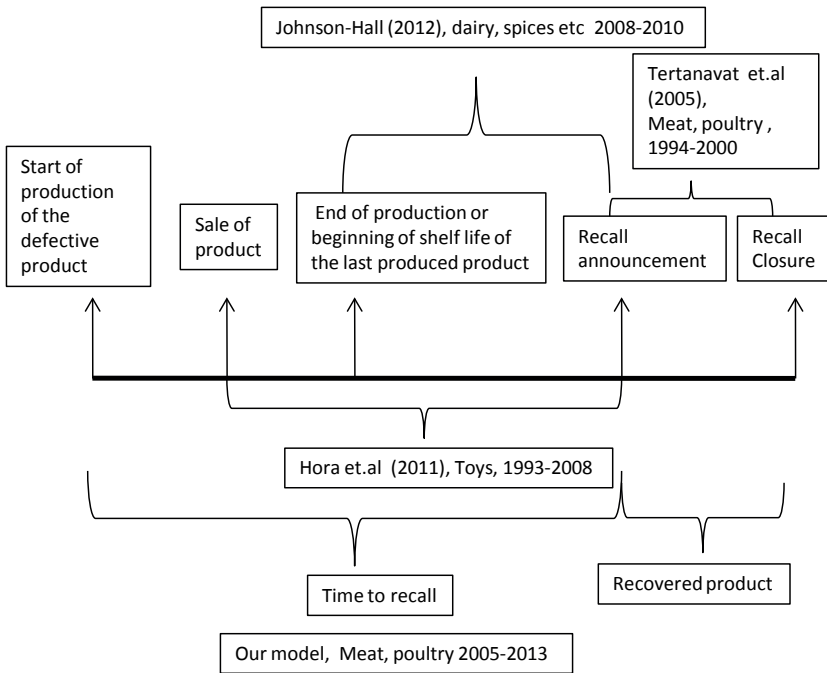


Fig. 1: Focus of literature and our model

2. Related Literature

Research in the area of food contamination has dealt with a range of issues from investigations on the effectiveness of recall operations as well as predictive

models for bioterror attacks and implementation of traceability systems. Here, we provide a broad overview of related research and then narrow down the scope of our work.

There are several papers in literature which attempt to arrive at a better understanding of a food contamination event by using an “event study” approach to analyze consumer perceptions, stock market reactions and loss of brand equity post product recall. For example, Jonge et al. (2007) attempt to understand the determinants influencing consumer perceptions of food safety incidents. Marsh et al. (2004) empirically test the shift in consumption patterns and change in consumer demands in the face of a food contamination event.

There are other papers which analyze the fallout of a food contamination event on shareholders, stock markets and company valuations (Salin and Hooker, 2001).

The use of mathematical modeling and simulation for a specific case of food contamination has also been the theme of other work in this area. For example, Weiser et al. (2013) utilize network graphs to trace back an e.coli outbreak in Germany along the supply chain and Tromp et al. (2010) use specific historic data to model the transmission of salmonella through a broiler supply chain.

However, in a recent survey Akkerman et al. (2010) review quantitative operations management approaches to food safety and quality and stress the need for more research in this area.

Johnson- Hall (2012) also states that although the USDA and the FDA (Food and Drug Administration) recommend that recalls should be issued promptly and completed there are no regulations in place to enforce this and in most cases the authorities are unaware of how companies carry out the recalls. Therefore recent studies stress the need for extensive work in this area that can help identify key drivers of supply chain efficiency and effectiveness with respect to food recall events.

From an empirical and statistical data analysis perspective Hora et al. (2011) investigate the major factors influencing the time to recall in the toy industry and

attempt to address the question of why it takes so long to recall a defective product.

Meat and poultry recalls are regulated by the USDA and FSIS while the FDA regulates other food products such as vegetable, fruits and dairy products. A testimony to a senate subcommittee states that though both agencies engage in inspection activities their authorities, responsibilities, policies, procedures, training and enforcement strategies are quite different (FSIS testimony, 2005).

Johnson-Hall (2012) analyzes the influence of supply chain factors on recalls administered by the FDA through an econometric analysis of recall data. However this study does not analyze the amount of recovered product at closure. In our work by investigating meat and poultry recalls administered by the USDA we also hope to compare and contrast the impact of agency level differences on recalls.

Teratanavat et al. (2005) analyze meat and poultry prior to the year 2000. They use statistical regression to analyze impact of size of firm, stock market reaction, and difference between firms which implemented food quality safety process and firms which have not on the recall process. In our work we study the influence of recall strategy, detection entity and hazard type on the efficiency and effectiveness of a recall.

Mainly, as depicted in Figure 1 through our analysis of the time to recall and amount of product recovered we aim to gain insights into pre as well as post contamination capabilities (detection and tracking) of supply chain entities. Therefore we hope that this work will contribute to the current body of literature on recalls.

3. Methodology

In the following sections we present our data for this study and describe the variables and the modeling methodology.

3.1 Data

Data is recorded for meat and poultry recalls from the USDA-FSIS recall tracking database for the years 2005 -2013 for all completed recall cases, i.e., cases closed and moved to the archive (FSIS-USDA recalls and public health alerts, 2014). Therefore recent years such as 2013 may still have open ongoing recalls. The cases prior to 2005 do not contain complete data and are not considered. Our initial sample consisted of 570 cases (Figure 2). It should also be noted that the USDA-FSIS online database is a dynamic list, as cases get closed the FSIS moves records from “current” list to the “archives” adding to the number of completed cases.

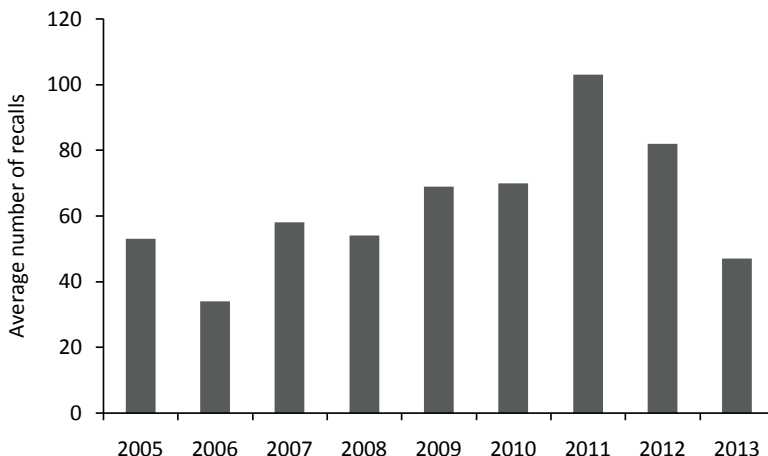


Fig. 2: Annual number of meat and poultry recalls

A recall announcement is issued by the recalling firm independently or on the recommendation of the FSIS. The recall announcement on completion contains the following information:

1. Date of the recall

2. Name of the recalling company (e.g. National beef packing, Taylor farms)
3. Product type (e.g. Beef sausage, Pork pie, Chicken dip)
4. Position (in some cases) and location of the recalling entity (e.g. processing center from Washington, supplier from Pennsylvania)
5. Scope of recall: List of states across which the recall was initiated
6. Hazard type: The hazards described in the data can be classified as:
 - a. Mislabeling: This hazard occurs when the company mislabels the ingredients in the product, interchanges labels between products, changes product content but does not change the corresponding label etc. These errors may in turn lead to omission of the list of allergens in the product which the customer needs to be cautioned against, e.g.: milk, eggs and peanuts.
 - b. Contamination: Contamination in the product may occur due to pathogens (e.coli, listeria), presence of foreign matter (plastic pieces, metal) or when certain required production practices are not followed (undercooking of meat, temperature not maintained).
 - c. Violation of regulations by firms: e.g. an uninspected facility in production, lack of food safety processes.
 - d. Others: A small number of announcements do not have any specified hazard type.
7. Injuries/illnesses (if any)
8. First and last date of production: The recall announcement consists of a series of products; therefore we record the first and last production date over all the products listed.
9. Best before date for the product (earliest and latest): We record the earliest and the latest best before dates over all products listed in the announcement.
10. Mode of discovery of the hazard and entity discovering it:
 - a. Inspection or investigations conducted by supply chain entities or the FSIS

- b. Reports of injury/illness to consumers tracked by FSIS or other regulatory authorities and linked to a certain product
 - c. Customer complaints: The customer in this case may be a third party customer such as a food service provider and not necessarily a retail consumer.
11. Hazard level classification: The recalls are classified into the following levels according to severity:
- a. Class I: For products that predictably could cause serious health problems or death.
 - b. Class II: For products that might cause a temporary health problem, or pose only a slight threat of a serious nature.
 - c. Class III: For products that are unlikely to cause any adverse health reaction, but that violate FDA labeling or manufacturing regulations.
12. Number of units of the product recalled (in lbs)
13. Number of units of the product recovered on recall closure (in lbs)

We conduct an initial scenario analysis of the recall process and correlate it to the data above as depicted in Figure 3.

3.2 Model

We now describe the variables in our model.

Dependent variables

The dependent variables in our model are the time to recall and amount of product recovered.

1. Time to recall

The time to recall is the difference between the time the product is first produced and the time of the recall announcement. The recall announcements may include several product varieties, for e.g.: the September 2013 product recall by Siberoni in Oregon involved beef pelmeni (ravioli) and chicken pelmeni. In the case of several production dates for products in a given announcement we record the

earliest production date in the given product list. The date of recall is recorded directly from the case record.

The detection time ranged from 1 to 1096 days for the cases considered from 2005-2013. A natural log transformation of the number of days for the time to recall was utilized to eliminate any skewness.

Time to recall = Time of recall announcement - Time of initial production of the product

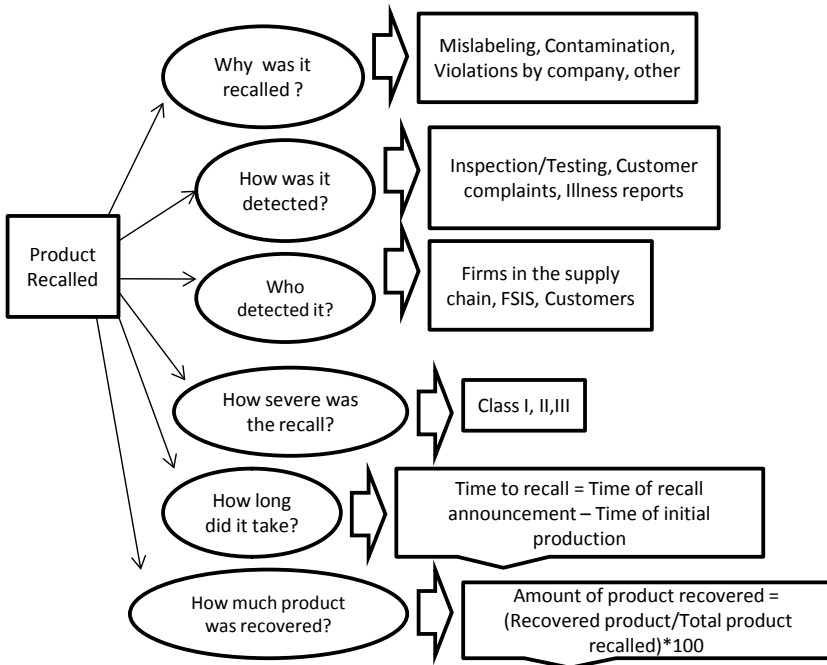


Fig. 3: Scenario analysis

2. Amount of product recovered

The amount of product recovered at the closure of the recall is recorded in the case details issued by the regulatory agencies. However, the probability of a

larger amount of product being recovered is more when the amount of product initially recalled is larger. Therefore as in Tertanavat et al. (2005) we record the amount of product recovered relative to the total product recalled as a percentage.

Amount of product recovered (%) = (Amount of product recovered/ Total product recalled)*100

Independent variables

The independent variables in our model are the recall strategy, supply chain entity detecting the hazard and hazard type.

1. Recall strategy

Recall strategies have been characterized relative to whether or not illness or injury has been associated with the defective product at the time of the recall (Chen et al., 2009), (Hora et al., 2011). Johnson -Hall (2012) state that preventative recall strategies are indicated when no injuries or illnesses related to the defective product have been confirmed prior to the recall. In contrast, reactive recall strategies are indicated when injury or illnesses have been confirmed and are linked to the defective product prior to the recall.

Preventive recall strategies have been associated with delays in recalls in prior studies as companies may have a tendency to delay recalls to prevent repercussions on their stock value, brand etc (Chen et al., 2009), (Hora et al., 2011). However, Johnson-Hall (2012) find that these results do not hold for food products primarily because recalls associated with an illness are largely underreported.

We test a similar hypothesis as in literature for our data to confirm whether it holds for meat and poultry recalls. We also hypothesize that a preventive recall strategy will be associated with a larger amount of product recovered as the occurrence of illnesses indicates downstream spread and consumption of the product thus hampering recovery efforts which is absent in this scenario. As in other studies we code 0 for reactive and 1 for a preventive strategy.

- *Hypothesis 1: Product recalls with preventive recall strategies are associated with a longer time to recall as compared to those with reactive recall strategies.*
- *Hypothesis 2: Product recalls with preventive recall strategies are associated with a larger amount of recovered product as compared to those with reactive recall strategies.*

2. Detection entity

As seen in the data description in section 1.3.1 the detection entity which detects the hazard in the product can be the firm or its supply chain partners, regulatory agencies (FSIS, USDA, CDC etc) or a customer. It has been hypothesized in previous studies that recalls detected by external entities (customers and regulatory agencies) indicate a lower recall detection competence of the supply chain entities and will have a longer time to recall, on average, than recalls detected by internal entities (firms and their supply chain partners) which indicates higher recall detection competence (Johnson-Hall, 2012).

We further propose that a supply chains detection competencies can also be an indicator of their supply chain visibility and tracking capabilities and will in turn impact the amount of affected product recovered post- recall. We code 0 for detection by an external agency and 1 for detection by an internal agency.

- *Hypothesis 3: Product recalls with recall detection by external entities are associated with a longer time to recall as compared to those detected by internal entities in the supply chain.*
- *Hypothesis 4: Product recalls with recall detection by external entities are associated with a smaller amount of recovered product as compared to those detected by internal entities in the supply chain.*

3. Hazard type

From the description of the hazard in the recall notice, we classified the hazard type as “mislabeling”, “contamination”, “violation of regulations” and “others”. The

hazard type “violation of regulations” and “others” constituted a very small percentage of recalls and therefore were not considered for further analysis.

The detection of hazard type can occur through testing or sampling or the occurrence of an illness. Mislabeling generally occurs when the internal composition of the product is changed (due to change of suppliers, ingredients etc) but the label is not changed accordingly. This is tougher to detect through testing or sampling as compared to testing for a common foodborne illness causing pathogen. Also mislabeling can be considered to be an external hazard wherein the product by itself is not hazardous to the population as a whole but the packaging fails to mention the presence of ingredients which may be hazardous or unacceptable to a certain section of the population. In the case of contamination the product is internally hazardous in its composition and harmful to anyone consuming the product.

We thereby hypothesize that mislabeling may take longer to detect and hence recall and also lead to a lower amount of recovered product. We code 0 for contamination and 1 for mislabeling.

- *Hypothesis 5: Product recalls with a hazard type of mislabeling are associated with a longer time to recall as compared to those with hazard type of contamination.*
- *Hypothesis 6: Product recalls with hazard type of mislabeling are associated with a smaller amount of recovered product as compared to those with hazard type of contamination.*

Control variables

We control for the year of recall with 2013 as the base year.

4. Method

Our final sample consisted of 397 recalls after eliminating cases with incomplete information for any of the variables in our model. Tables 1 and 2 show the means, standard deviations and correlations for all the variables.

We show the bivariate relationship between the dependent and independent variables in Figures 4-6. It can be seen that 90% of the recall strategies were preventive in nature, internal detections resulted in 23% of the total product recalls and 63% of the recalls were due to a contamination hazard.

To investigate the multivariate relationships with all the independent and control variables, we analyze the data using ordinary least squares (OLS) regression analysis. In order to employ OLS regression, we first check that the data did not violate underlying assumptions related to normality, homoscedasticity, and multicollinearity.

To verify the assumption that error terms in the models are normally distributed, we performed the Shapiro-Francia-W test for normality. We could not reject the null hypothesis that there is no difference between the cumulative distribution of the error terms against the theoretical normal distribution ($p < 0.38$), confirming the normality of the data. The presence of heteroscedasticity in residual errors violates a critical assumption of OLS regression (homoscedasticity). Thus, to confirm that the variance of residual error is constant for all values of an independent variable, we ran White's test and we could not reject the null hypothesis of no heteroscedasticity in both tests ($p < 0.04$). In order to test for multicollinearity, we checked the bivariate correlations and found that the variables did not demonstrate high correlations among them. Therefore, our data does not appear to be affected by multicollinearity.

The results of the OLS regression with time dummies and 2013 as the reference, for the time to recall and the amount of product recovered are presented in Table 3 and Table 4.

Variables	Mean	Standard deviation
1.Time to recall (days)	3.74	1.74
2.Amount of product recovered (%)	42.7	36.2
3.Recall strategy:Preventive	0.90	0.28
4.Recall strategy: Reactive	0.10	0.28
5.Detection entity:Internal	0.23	0.42
6.Detection entity:External	0.77	0.42
7.Hazard type: Mislabeling	0.37	0.49
8.Hazard type: Contamination	0.63	0.49

Tab. 1: Means and standard deviations of the variables

Variables	1	2	3	4	5	6	7	8
1	1.00							
2	-0.32	1.00						
3	-0.06	0.17	1.00					
4	0.06	-0.17	-1.00	1.00				
5	-0.11	0.15	0.17	-0.17	1.00			
6	0.11	-0.15	-0.17	0.17	-1.00	1.00		
7	-0.38	-0.05	-0.24	0.24	-0.10	0.10	1.00	
8	0.38	0.05	0.24	-0.24	0.10	-0.10	-1.00	1.00

Tab. 2: Correlations for the variables

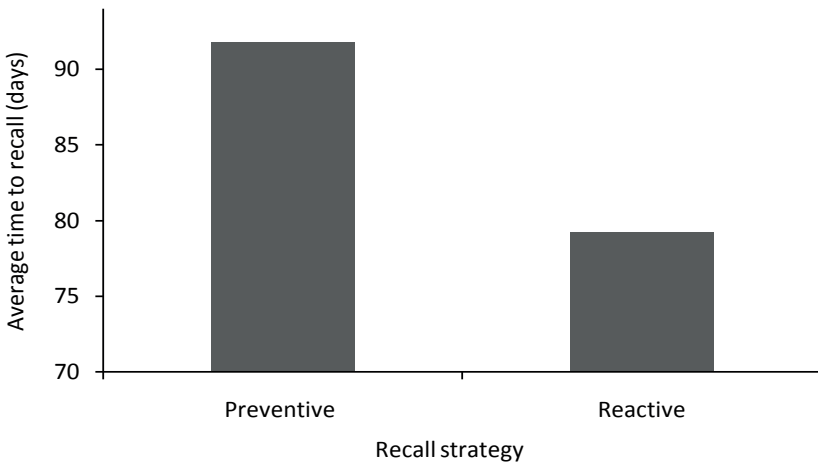


Fig. 4a: Bivariate relation between average time to recall and recall strategy

5. Discussion

We now interpret the results of the OLS regression. At the 5% significance level our coefficient's estimates are significant whenever the t-statistic is greater than 1.96 or lesser than -1.96 or the p-value is less than 0.05. Similar to the findings of Johnson-Hall (2012) our results also do not support hypothesis H1 that a preventive recall strategy in the supply chain will result in a longer time to recall in contrast to a reactive recall strategy at a 0.01 significance level. However, hypothesis H2 is supported as we find that a preventive recall strategy in the supply chain will result in a larger amount of recovered product than a reactive recall strategy. The coefficient of this variable is positive and significant.

We also find that hypothesis 3 is supported and detection by an external entity will result in a longer time to recall as compared to detection by an internal entity at a 0.01 significance level. Hypothesis 4 which states that detection by an external entity is associated with a smaller amount of recovered product in contrast to detection by an internal entity such as supply chain firms and their partners is also supported.

The high t-statistic and very low p-value for mislabeling confirms that it is the most significant coefficient. The results also support Hypothesis 5 that mislabeling is associated with a longer time to recall in contrast to the hazard type of contamination. It can also be seen that Hypothesis 6 is supported and a hazard type of mislabeling results in a smaller amount of product recovered as compared to a hazard type of contamination.

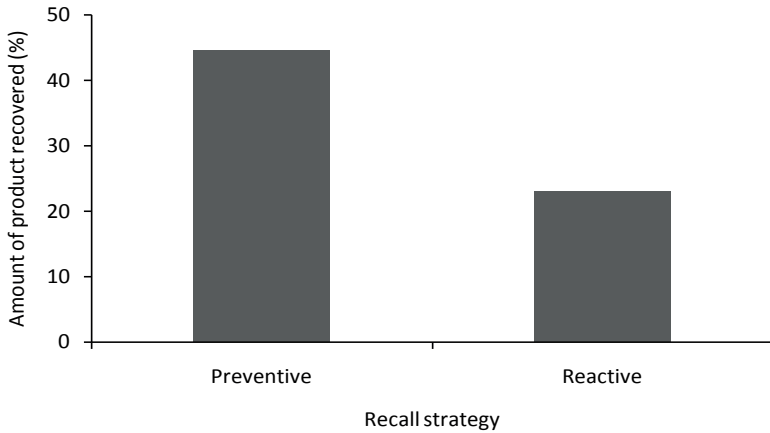


Fig. 4b: Bivariate relation between amount of product recovered and recall strategy

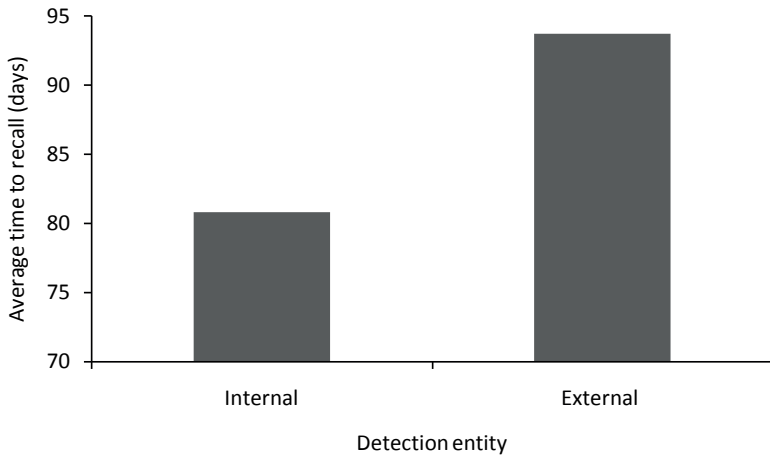


Fig. 5a: Bivariate relation between time to recall and detection entity

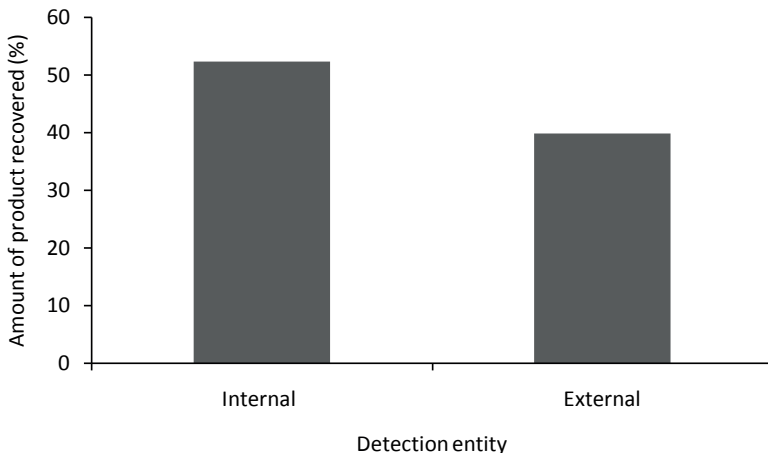


Fig. 5b: Bivariate relation between amount of product recovered and detection entity

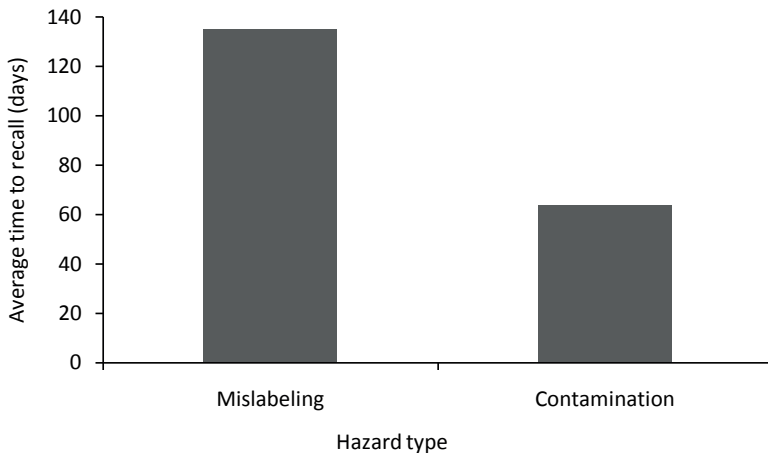


Fig. 6a: Bivariate relation between time to recall and hazard type

For time dummies in table 3, it is found that only year 2010 is significant and the results also suggest that as time progresses the time taken to recall products decreases. For time dummies in table 3, year 2005 is significant and results suggests that as time progresses the amount of product recovered increases. Our results show that recall strategy, detection entity and hazard type have a significant impact on the time to recall and the amount of product recovered which in turn will affect the efficiency and the effectiveness of a recall process. Preventive recall strategies have been associated with delays in recalls in prior studies as companies may have a tendency to delay recalls to prevent repercussions on their stock value, brand etc however we find that these results do not hold for meat and poultry recalls primarily because recalls associated with an illness are largely underreported (Johnson-Hall, 2012). However we find that a preventive recall strategy will be associated with a larger amount of product recovered as the occurrence of illnesses in the reactive recall scenario indicates downstream spread and consumption of the product thus hampering recovery efforts which is absent in this case.

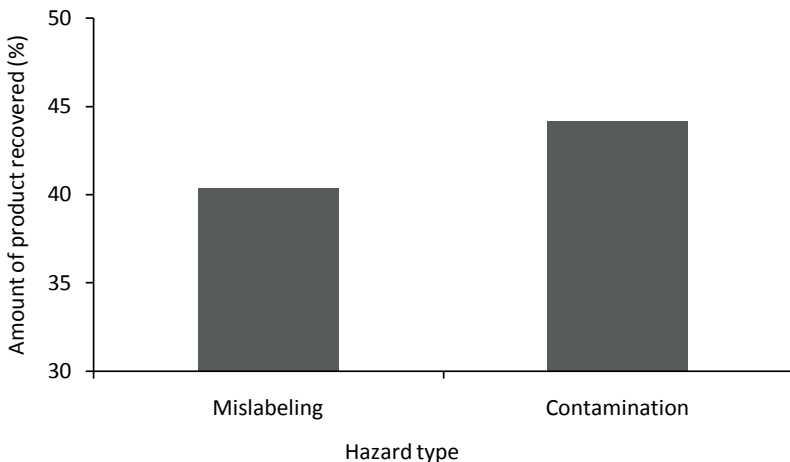


Fig. 6b: Bivariate relation between amount of product recovered and hazard type

It has been posited in literature that recalls detected by external entities (customers and regulatory agencies) indicate a lower recall detection competence of the supply chain entities and have a longer time to recall, on average, than recalls detected by internal entities (firms and their supply chain partners) which indicate a higher recall detection competence. Our results support this hypothesis and we further find that a supply chain's detection competency is an indicator of its visibility and tracking capabilities as detection by internal entities results in a larger amount of recovered product in contrast to detection by external supply chain entities.

Mislabeling is found to have a significant impact on the time to recall and the amount of product recovered. A hazard caused due to mislabeling is associated with a longer time to recall as well as smaller amount of recovered product. This may be primarily because of the inherent difficulties in detecting mislabeling through a testing or a foodborne illness.

As a part of ongoing work we hope to incorporate more independent variables such as shelf life, hazard class and position of the recalling entity in the supply chain (manufacturer, supplier etc) and incorporate control variables such as product type (poultry, pork, beef etc). Future research will also focus on the impact of supply chain structure and reverse logistics on the recall outcomes.

We also aim to comment on the potential impact of traceability (e.g., RFID) and condition monitoring (e.g., temperature sensors) on recall outcomes.

Further work will also include investigation of policy level differences between the functioning of different regulatory agencies such as the FDA and the USDA/FSIS to gain insights into the recall processes conducted by the respective agencies. From a methodology perspective we hope to analyze the data utilizing duration (survival) models.

Product Recalls in the Meat and Poultry Industry

	Estimate	Standard error	t-value	Pr(> t)
Preventive strategy	-0.6757	0.2302	-2.935	0.00353**
Internal detection	-0.4249	0.1487	-2.857	0.00451**
Mislabeling	1.2296	0.1343	9.154	<2e-16***
2005	0.6492	0.3411	1.903	0.05779
2006	0.4431	0.3125	1.418	0.15709
2007	0.3311	0.2938	1.127	0.26048
2008	0.5159	0.2929	1.761	0.7900
2009	0.3552	0.2880	1.233	0.21828
2010	0.6533	0.2876	2.272	0.02366*
2011	-0.0771	0.2838	-0.272	0.78603
2012	0.2646	0.2809	0.942	0.34678

Significance codes: *** 0.001 **0.01*0.05.0.1

Multiple R-squared: 0.2145

Adjusted R-squared: 0.1918

p-value: 4.684e-15

Tab. 3: OLS regression for time to recall

	Estimate	Standard error	t-value	Pr(> t)
Preventive strategy	23.124	6.7432	3.430	0.00067 ^{***}
Internal detection	12.1470	4.3562	2.788	0.00556 ^{**}
Mislabeling	-8.4330	3.9347	-2.143	0.03273 [*]
2005	-21.3065	9.9919	-2.132	0.03362 [*]
2006	-11.1395	9.1549	-1.217	0.22445
2007	0.4075	8.6063	0.047	0.96226
2008	-12.3778	8.5804	-1.443	0.14996
2009	-6.0482	8.4373	-0.717	0.47392
2010	-9.3172	8.4236	-1.112	0.26663
2011	-2.0570	8.3136	-0.247	0.80471
2012	-4.7964	8.2273	0.583	0.56025

Significance codes: *** 0.001 **0.01*0.05.0.1

Multiple R-squared: 0.07591

Adjusted R-squared: 0.04916

p-value: 0.001395

Tab 4: OLS regression for amount of product recovered

References

- Akkerman, R., Farahani, P., Grunow, M., 2010. Quality, safety and sustainability in food distribution: a review of quantitative operations management approaches and challenges. *OR Spectrum*, 32, 863–904.
- Berman, B., 1999. Planning for the inevitable product recall. *Business Horizons*, 42 (March/April), 69–78.
- Chen, Y., Ganesan, S., Liu, Y., 2009. Does a firm's product-recall strategy affect its financial value? An examination of strategic alternatives during product-harm crises. *Journal of Marketing*, 73 (November), 214–226.
- Dawar, N., Pillutla, M., 2000. The impact of product-harm crises on brand equity: the moderating role of consumer expectations. *Journal of Marketing Research* (May), 216–226.
- Dyckman, L.J., Lansburgh, E.J., 2004. Food safety: USDA and FDA need to better ensure prompt and complete recalls of potentially unsafe food. United States Government Accountability Office report to Congressional requesters. GAO-05-51.
- Hora, M., Bapuji, H., Roth, A.V., 2011. Safety hazard and time to recall: The role of recall strategy, product defect type, and supply chain player in the U.S. toy industry. *Journal of Operations Management* 29, 766–777.
- Johnson-Hall, T.D., 2012. Essays on product recall strategies and effectiveness in the FDA-regulated food sector, Dissertation. Clemson University, 2012.
- Jonge, J.D., Trijp, H.V., Renes, R.J., Frewer, L., 2007. Understanding consumer confidence in the safety of food: Its two-dimensional structure and determinants. *Risk Analysis*, Volume 27, No. 3.
- Kramer, M.N., Coto, D., Weidner, J.D., 2005. The science of recalls, *Meat Science*, 71, 158–163
- Lyles, M.A., Flynn, B.B., and Frohlich, M.T., 2008. All supply chains don't flow through: Understanding supply chain issues in product recalls. *Management and Organization Review*, Volume 4. Issue 2.
- Roth, A.V., Tsay, A.A., Pullman, M.E., Gray, J.V., 2008. Unraveling the food supply chain: strategic insights from China and the 2007 recalls. *Journal of Supply Chain Management*, 44 (1), 22–39.
- Marsh, T.L., Schroeder, T.C., Minert, J., 2004. Impacts of meat product recalls on consumer demand in the USA. *Applied Economics*, 36:9.
- Peirson, M., 2005. FSIS submitted for the record Statement before the subcommittee on the federal workforce and agency organization.
- Salin, V., Hooker, N.H., 2001. Stock market reaction to food recalls. *Review of Agricultural Economics*, 23 (1), 33–46.

- Skees, J., Botts, A., Zeuli, K., 2001. The potential for recall insurance to improve food safety. *International Food and Agribusiness Management Review*, 4, 99-111.
- Smith, C.N., Thomas, R.J., Quelch, J.A., 1996. A strategic approach to managing product recall. *Harvard Business Review* 74, 102-112.
- Teratanavat, R., Salin, V., Hooker, N.H., 2005. Recall event timing: Measures of managerial performance in U.S. meat the poultry plants. *Agribusiness, An International Journal*, 21 (3), pp. 351-373.
- Tromp, S., Franz, E., Rijgersberg, H., Van Asselt, E., Van Der Fels-Klerx, I., 2010. A model for setting performance objectives for salmonella in the broiler supply chain. *Risk Analysis*, 30, 945-951.
- Weiser, A.A., Gross, S., Schielke, A., Wigger, J.F., Ernert, A., Adolphs, J., Fetsch, A., Muller-Graf, C., Kashbohrer, A., Mosbach-Schulz, B., Apple, B., Greiner, M., 2013. Trace-back and trace-forward tools developed ad hoc and used during the STEC O104: H4 outbreak 2011 in Germany and generic concepts for future outbreak situations. *Foodborne pathogens and disease*, 10.3, 263-269.
- <http://www.cdc.gov/foodsafety/facts.html>, 2011.
- <http://www.fsis.usda.gov/wps/portal/fsis/topics/recalls-and-public-health-alerts>, 2014.