A DURATION ANALYSIS OF FOOD SAFETY RECALL EVENTS IN THE UNITED STATES: JANUARY, 2000 TO OCTOBER, 2009

A Thesis

by

NATHANIEL ALLEN JOY

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2010

Major Subject: Agricultural Economics

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Approved by:

Chair of Committee,	Victoria Salin
Committee Members,	Desmond Ng
	Clifford Spiegelman
Head of Department,	John Nichols

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ABSTRACT

A Duration Analysis of Food Safety Recall Events in the United States:

January, 2000 to October, 2009. (December 2010)

Nathaniel Allen Joy, B.S. Economics, Texas A&M University

Chair of Advisory Committee: Dr. Victoria Salin

The safety of the food supply in the United States has become an issue of prominence in the minds of ordinary Americans. Several government agencies, including the United States Department of Agriculture and the Food and Drug Administration, are charged with the responsibility of preserving the safety of the food supply. Food is withdrawn from the market in a product recall when tainted or mislabeled and has the potential to harm the consumer in some manner. This research examines recall events issued by firms over the period of January, 2000 through October, 2009 in the United States. Utilizing economic and management theory to establish predictions, this study employs the Cox proportional hazard regression model to analyze the effects of firm size and branding on the risk of recall recurrence. The size of the firm was measured in both billions of dollars of sales and in thousands of employees. Branding by the firm was measured as a binary variable that expressed if a firm had a brand and as a count of the number of brands within a firm. This study also provides a descriptive statistical analysis and several findings based on the recall data

specifically relating to annual occurrences, geographical locations of the firms involved, types of products recalled, and reasons for recall. We hypothesized that the increasing firm size would be associated with increased relative risk of a recall event while branding and an increasing portfolio of brands would be associated with decreased relative risk of a recall event. However, it was found that increased firm size and branding by the firm are associated with an increased risk of recall occurrence. The results of this research can have implications on food safety standards in both the public and private sectors.

DEDICATION

I dedicate this work to my God, for without him, nothing is possible.

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I would like to thank my committee chair, Dr. Salin, for her wonderful support, encouragement, and leadership in this endeavor. Her assistance and persistence both channeled and motivated my research efforts. I would also like to thank my other committee members, Dr. Ng, and Dr. Spiegelman, for their support and guidance throughout the course of this research.

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Finally, thanks to my parents, family, and friends for their incredible encouragement and patience.

NOMENCLATURE

BYN	Binary Brand Variable indicating if a firn has a brand or not.
Diff_Date	Variable indicating the number of days between recall events.
MRE	Variable indicating the most recent number of employees observation of a firm in thousands of employees.
MRE^2	Squared term of the Most Recent Employees variable.
MRS	Variable indicating the most recent sales observation of a firm in millions of dollars.
MRS^2	Squared term of the Most Recent Sales variable.
NBS	Variable indicating the number of brands owned by a firm.

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1. INTRODUCTION

According to the acting United States Surgeon General, Rear Admiral Steven K. Galson (2009), "Americans still enjoy one of the safest food supplies in the world." This is despite apprehension with the nation's food supply and the fact that many Americans are left wondering what is safe to eat.

Due to several highly publicized food recall events, it is perceived that the general public has become less confident in the overall safety of the food supply. In the end, food scares across the country are becoming more publicized and as a result are triggering public concern for the overall safety of the food supply (Institute of Food Technologists/Food and Drug Administration 2009).

In recent years, food safety concerns have also intensified as a direct result of the September 11th, 2001 terrorist attacks. The potential susceptibility of food to deliberate contamination led President George W. Bush, in January 2004, to identify the United States food system as vulnerable to intentional acts of terrorism (Bush 2004). These concerns have raised pressure on those federal agencies in charge of the protection of the food supply in the United States.

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This thesis follows the style of *American Journal of Agricultural Economics.*

The safety of the food supply is of critical importance to all parties involved. In 2009, President Barack Obama (2009) expressed the feelings of many American parents,

> "In the end, food safety is something I take seriously, not just as your President, but as a parent. When I heard peanut products were being contaminated earlier this year, I immediately thought of my 7-year old daughter, Sasha, who has peanut butter sandwiches for lunch probably three times a week. No parent should have to worry that their child is going to get sick from their lunch."

Such feelings have intensified the sentiment that firms that produce contaminated products must strengthen prevention efforts for the welfare of the public.

It is generally perceived that a food recall event is an adverse occurrence for a firm that could lead to publicity problems, financial harm, and potential failure of the firm. Recall events are primarily voluntary practices that are the result of a risk assessment by the firm. A firm manager must decide whether to bring a product off of the shelf and experience direct financial loss or to jeopardize the consumer with the possibility of indirect financial damage.

The primary questions to be addressed with this study are:

(1) What factors influence the risk of recurrence of recall events for firms that have previously experienced at least one recall?

(2) How do these factors influence the risk of recurrence? Do they increase or decrease the relative risk of a subsequent recall event?

In this research, we will focus on firms that experience multiple recall events and will employ statistical methods to ascertain the risk of recurrence of these events. We will utilize economic and management theory to defend our presumptions and expectations. We will also present several interesting findings that we feel are valuable contributions to the current understanding of food safety.

We will present literature central to the food safety discussion. We will discuss the data used in this research. We will then discuss the statistical model that we will employ and our hypotheses. Finally, we will present our findings and conclusions.

2. LITERATURE REVIEW

We will begin by presenting information and past findings that we feel are important contributions to the discussion of food safety and the management processes involved with recall events. The Literature Review section is separated into four subsections: Regulatory Issues; Health Issues and Cost of Illnesses Due to Pathogens; Management Issues; and Recall Studies from Other Industries. The Regulatory Issues subsection looks at the food safety regulatory structure with a primary emphasis on the United States. The Health Issues and Cost of Illnesses Due to Pathogens subsection considers problems that have resulted in food safety events and the costs related to them. The Management Issues subsection discusses topics related to product traceability and decision making within the firm. Finally, the Recall Studies from Other Industries subsection considers recall events in other industries that have potential relevance to practices in the food sector.

2.1 Regulatory Issues

Two primary federal agencies, the United States Department of Agriculture (USDA) and the Food and Drug Administration (FDA), are charged with the task of overseeing and maintaining the food supply of the United States. The USDA has the authority to detain, seize, condemn, and destroy unsafe beef, poultry, and egg products under the Federal Meat Inspection Act, the Poultry Products Inspection Act, and the Egg Products Inspection Act. These conditions may be from food that is believed to be

adulterated, mislabeled, or contaminated in some manner. The USDA may force a production facility to shut down by either withdrawing meat or poultry inspectors or by removing the USDA "inspected and passed" label, both of which are mandatory (United States Government Accountability Office 2004b). It is estimated that the USDA is responsible for regulation of about 20 percent of the food supply (United States Government Accountability Office 2007a).

The FDA has the authority to seize, condemn, and destroy food and food related products that are not exclusively regulated by the USDA through the Federal Food, Drug, and Cosmetic Act. Under the Public Health Security and Bioterrorism Preparedness and Response Act of 2002, the FDA may detain food for up to 30 days without the need for a court order. This act also authorizes FDA to establish record-keeping requirements for food companies (United States Government Accountability Office 2004b). Along with its food related responsibilities, the FDA is in charge of ensuring the safety of a very broad range of products that also include animal drugs and feeds, human medicines and vaccines, radiation-emitting devices, medical devices, blood and blood products, and cosmetics (United States Government Accountability Office 2008). It is estimated that the FDA is responsible for regulation of about 80 percent of the food supply (United States Government Accountability Office 2007a).

The USDA and FDA employ a classification system for recalls based on the potential health risk that the food in question poses. Recalls range from Class I to Class

III, with Class I being the most serious. Class I recalls are designated for foods that may pose a serious adverse health consequence or death. These can include foods that are contaminated with *Escherichia coli O157:H7, Listeria, Salmonella,* or undeclared allergens such as peanuts and eggs. Class II recalls are designated for foods that pose a remote possibility of adverse health effects or may cause temporary or reversible health effects. Class III recalls are designated for foods that will not cause adverse health effects. These can include foods that contain added water that is not disclosed on the label and foods that contain mold or insects (United States Government Accountability Office 2004b).

Once a recall is issued, the USDA and FDA have separate but similar procedures for alerting the public and the parties involved in the recall event. The USDA will issue a press release for Class I and Class II recalls on their Recall Web website that describes the product, the reason for the recall, the risk involved with consuming the product, instructions on what to do with the product, and the contact information of the recalling firm. The FDA generally requires the company with the recall to issue a press release for all Class I recalls. The FDA provides a model for the firm to follow which covers the product, reason for recall, risk involved with consumption, instructions on what to do with the product, and contact information. The press releases are posted and archived on its Recall Enterprise System website (United States Government Accountability Office 2004b).

After the press release is given, both the USDA and FDA begin the process of directly alerting customers and providing them with instructions for return or disposal of the product. The USDA's and FDA's primary roles are to verify that firms and customers along the downstream supply chain are notified, the product is located, and the product is removed from the marketplace. For each case, depending on the health risk associated with the recall, a percentage of customers to be contacted and verified is determined. Once the product is recovered, USDA and FDA may require that inspectors be present to witness the destruction and final state of the recalled product (United States Government Accountability Office 2004b).

USDA and FDA do have a number of severe limitations to their respective authorities over food recall events. In the United States, the vast majority of food recalls are voluntary. Agencies do not have the authority to force companies to carry out recalls, with the exception that FDA may require a recall for infant formula (United States Government Accountability Office 2007a). They also do not generally have the authority to publically reveal retail stores that may be selling recalled food because it is considered to be confidential business information (United States Government Accountability Office 2004b). The agencies also have limited access to firms' records during a recall event and are sometimes required to gain access through state agencies that may have broader authority (United States Government Accountability Office 2008).

Other federal agencies and similar agencies in other countries have much broader recall authority over the products in their respective jurisdictions. In the United States, the Consumer Products Safety Commission has authority over a vast array of consumer products that range from toys to household chemicals. The National Highway Traffic Safety Administration covers motor vehicles, motor vehicle equipment, child safety seats, and tires. Both agencies may require a company to notify the agency of distribution of a potentially unsafe product, order a recall, establish recall requirements, and impose penalties, fines, and seek imprisonment if the firm violates the recall requirements. In Canada, the Canadian Food Inspection Agency has authority over all foods sold in Canada. It may issue a mandatory recall, establish recall requirements, and impose penalties, fines, and seek imprisonment (United States Government Accountability Office 2004b).

Jurisdictional hindrances between the USDA and FDA also lead to complications when conducting food recalls. These complications may stem from ingredients involved in the production process to packaging of the finished product. One example deals with frozen pizzas and their ingredients. If meat is used as a topping, the USDA is charged with inspection. If the pizza is vegetarian or cheese, FDA handles inspection. Another example deals with ham and cheese sandwiches and the method by which they are packaged. If the sandwich is packed with a slice of bread and is open-faced, the USDA inspects the manufacturer. If the sandwich has two slices of bread and is

closed-faced, then FDA conducts inspection (United States Government Accountability Office 2007a).

An additional comprehensive and central source of information pertaining to food safety issues has been the result of an intragovernmental collaboration between the FDA, USDA, the Environmental Protection Agency (EPA), and the Centers for Disease Control and Prevention (CDC). A website, www.foodsafety.gov, is designed to provide accurate and reliable information such as safety alerts, recalls, health warnings, and the latest news to a wide audience of consumers, producers, and food professionals (Galson 2009).

In order to give a brief insight to an actual recall event, a synopsis of a 2003-2004 recall related to positive Bovine spongiform encephalopathy (BSE) as presented by the United States Government Accountability Office (GAO) (2004a) will be provided. This particular recall had implications for both USDA and FDA.

In early December 2003, an infected cow, along with 22 other non-infected cows were slaughtered at a facility in Washington State. Due to the single cow's inability to walk, it was tested for BSE by USDA in accordance with USDA BSE surveillance policy (Nolen 2004). Fourteen days after slaughter, on December 23rd, test results returned as positive for BSE. Within the day, USDA field staff was on the scene at the company's slaughtering facility. Within hours, it was determined that the event would be classified as a Class II recall only pertaining to production on the day in

question, as the company's cleanup policies were sufficient not to warrant recall of additional days' production. A press release and Recall Notification Report were released to the media and the public.

The next day, USDA's Food Safety Inspection Service agency (FSIS) contacted the company's three primary customers and obtained secondary customer lists. In the following days, secondary and tertiary customers were contacted and notified of the recall event. Of these contacts, it was required that 100 percent of primary customers, 50 percent of secondary customers, and 20 percent of the known tertiary customers have onsite checks with every customer being contacted at least twice.

Repeated mixing of recalled beef and non-recalled beef at primary customers' facilities increased the number of carcasses in question from 23 to 43. By the 26th of December, it was determined that recalled beef had been shipped within Washington and to Oregon. On December 27th, the recall expanded to California and Nevada, and to Alaska, Hawaii, Idaho, Montana, and Guam on December 28th. On January 6th, Alaska, Hawaii, and Guam were released from the recall, as it was established that the possibly contaminated beef had not been shipped there.

In the end, it was determined that 713 customers that included processors, distributors, retailers, and storage facilities may have received the recalled beef, with 10,410 pounds of product being recalled. However, over 64,000 pounds of

beef were returned or destroyed by customers in order to conform to the recall and avoid possible contamination.

A second aspect of this event involved the FDA. It was determined that parts of the initial animal that tested positive for BSE were sent to two rendering plants where the processed materials had the potential to be used in many products that could include cosmetics and vaccines. The rendered products were not beef, poultry, or egg products for human consumption, and FDA, rather than USDA, had jurisdiction.

The FDA was notified about the event on December 23rd and sent an inspection team to the receiving renderers the following day. Both renderers voluntarily agreed to hold and destroy products that may have been contaminated. However, on January 7th, 2004, 15 containers of potentially contaminated materials were accidentally shipped from Seattle to Asia. Upon discovery, the material was returned to the United States and arrived on February 24th. It was disposed of on March 2nd. In all, an estimated 2,000 tons of rendered material were held and destroyed. In early March 2004, the USDA's Recall Management Division recommended termination of the recall and considered the event closed.

The federal government has a history of enacting legislation with the purpose of improving food safety. Following Upton Sinclair's portrayal of the meatpacking industry in his work *The Jungle* (1906), Congress passed the Meat Inspection Act of 1906 and the Pure Food and Drug Act of 1906. These were followed by additional regulations such as

the Federal Food, Drug, and Cosmetic Act of 1938, the Food Additives Amendment of 1958, and the Color Additives Amendment of 1960 (Miller (1993); Reed (2005)). One key price of legislation that was enacted with the purpose of improving food safety, especially in the meat and poultry sectors, was the Pathogen Reduction Hazard Analysis Critical Control Program (PR/HACCP) of 1996.

FSIS finalized the PR/HACCP rule on July 25th, 1996. It was completely phased in by January 31st, 2000 (Keener 2007). According to Ollinger (2008) PR/HACCP stated that:

> (1) All meat and poultry slaughter and processing plants must develop, implement, and take responsibility for Standard Sanitation Operating Procedures (SSOPs) and a HACCP process control program.
>
> (2) All slaughter plants had to conduct generic *E. coli* microbial tests to verify control over fecal contamination.
>
> (3) All slaughter and ground meat plants had to comply with *Salmonella* standards established by FSIS in a testing program conducted by FSIS.

For clarity, SSOPs are tasks that involve cleaning and sanitation that are implemented to augment pathogen control. These tasks may include requirements to control and monitor rodent and pest infestations, harmful contaminations, and dripping

condensation. HACCP programs monitor activities and actions if a critical control point deviates from an acceptable standard (Ollinger 2008).

To get a license to produce poultry and meat from FSIS, plants are required to meet the minimum standards set by the 1996 PR/HACCP rule. However, industry and consumer standards have forced some firms to surpass the minimum standards set by the PR/HACCP rule. Waldroup, et al. (1992) noted that an episode of the American television newsmagazine *60 Minutes* highlighting the risks of *Salmonella* contamination pushed poultry slaughtering plants to develop and install improved scalders, washes, chlorine rinses, and other pathogen reducing technologies. Ollinger and Mueller (2003) and Golan et al. (2004) noted that some major product purchasers, such as McDonalds and Jack-in-the-Box, mandated standards exceeding those required by FSIS. These included mandatory testing and installation of the most recent pathogen-control equipment.

A study by Ollinger, Moore, and Chandran (2004) looked at the compliance costs of the 1996 PR/HACCP rule. They examined the average costs for the highest and lowest quintiles with respect to plant size as measured in pounds of output and separated them as slaughtering and processing facilities. Ollinger (2008) interpreted that "if there were no economies of scale in the food safety process control, then the average cost per pound for plants in the top quintile would equal those costs in the lowest quintile." The results from the Ollinger, Moore, and Chandran (2004), given in

Table 1, suggest economies–of-scale exist, with higher costs per pound in the smallest size grouping.

Table 1. PR/HAACP Cost Increases with Plant Size

Percentile of Plant Size	Slaughter			Processing	
	Cattle	Hogs	Chicken	Cooked Meat	Raw Meat
Variable Costs			Dollars per Pound		
0-19	0.023	0.016	0.025	0.018	0.020
80-99	0.008	0.005	0.004	0.005	0.005
Mean	0.022	0.014	0.010	0.016	0.013
Fixed Costs			Dollars per Pound		
0-19	0.055	0.050	0.013	0.079	0.027
80-99	0.009	0.008	0.004	0.019	0.012
Mean	0.022	0.026	0.008	0.036	0.017
Number of Plants	135	96	58	198	139

Source: (Ollinger, Moore and Chandran, Meat and Poultry Plants' Food Safety Investments: Survey Findings 2004), Page 26.

Ollinger (2008) notes that the Ollinger, Moore and Chandran (2004) study suggests that the 1996 PR/HACCP rule favors large plants to small plants. This is a direct effect of economies-of-scale in variable and fixed costs in the meat and poultry industries. It is also noted that small multi-product plants are likely to have higher absolute costs than large single-product plants as a separate HACCP plan is required for each product.

Ollinger (2008) conducted a study and employed a least squares model to examine the direct and indirect costs of the 1996 PR/HACCP rule. In the model, food

safety costs were regressed on proxies for wages, indirect private actions (human and physical capital), direct private market actions, and direct and indirect regulatory effects.

Food safety costs were defined as the costs of complying with the 1996 PR/HACCP rule as a share of plant sales. Wages, $State\_Wage_i$, were defined as the average state wage for meat and poultry production workers in the state in which the plant was located. The human capital component of indirect private actions, $Experience\_QC_i$, consisted of an experience dummy variable that equaled one for plants that had formal food safety process controls in place prior to the 1996 PR/HACCP rule and zero otherwise. The physical capital component of indirect private actions, FS_Tech_i , consisted of a plant-level index of food safety technology that ranged from zero to one with more sophisticated equipment use indicated by a higher value. Direct private actions consisted of two variables: (1) a dummy variable, $Buyer_i$,that indicated the contractual agreements with buyers and was defined as one for plants with customers that specified more stringent safety requirements than those required by FSIS; (2) a dummy variable, $Process_i$,that indicated if a firm is vertically integrated. The indirect regulation component consisted of three variables: (1) a variable, $Employees_i$, that measured the number of employees per plant; (2) a dummy variable, $Multi_i$,that indicated if the plant was owned by a firm that owned more than one establishment; (3) a variable, Cap_Lab_i , that measured the capital-to-labor ratio. The direct regulation component consisted of

four variables: (1) a variable, $Plans\_Sale_i$, that measured the costs of developing the HACCP and SSOP plans as a share of plant sales; (2) a variable, $Tasks\_Emp_i$, that measured the number of SSOPs and HACCP tasks performed in 2001 in order to comply with the 1996 PR/HACCP rule divided by the total number of employees; (3) a variable, $Shar\_HACCP\_Task_i$, that distinguishes the costs of HACCP tasks from SSOP tasks; (4) a variable, PW_QC_i , that measures the ratio of production workers hired to comply with the 1996 PR/HACCP rule divided by the total number of production and quality control workers hired to comply. Additional details about the variables can be found in Ollinger (2008).

The model specified by Ollinger (2008) is presented as:

$$Shar_{HACCP\,i} = \beta_0 + \beta_1 State\ Wage_{\ i} + \beta_2 Experience\ QC_{\ i} + \beta_3 FSTech_i + \beta_4 Buyer_i + \beta_5 Process_i + \beta_6 Employees_i + \beta_7 Multi_i + \beta_8 Cap\ Lab_i + \beta_9 Plans\ Sale_i + \beta_{10} Tasks\ Emp_i + \beta_{11} SharHACCP\ Task_i + \beta_{12} PWQC_i + \varepsilon_i$$

Results of the empirical analysis concluded that economies-of-scale give a very large advantage to the largest plants over their smaller competitors in the implementation of food safety controls. The results can be found in Appendix I, Table 30.

2.2 Health Issues and Cost of Illnesses Due to Pathogens

In order to have an appropriate understanding of the food safety issues facing the United States, it is imperative to appreciate some of the most important motivations behind food recall events. We will now discuss several pathogens that result in recall events in the United States.

A 1994 report by the Council for Agriculture and Science Technology (CAST) found that microbial pathogens in food resulted in 6.5 million-33 million cases of human illness and up to 9,000 deaths in the United States each year (CAST 1994). These pathogens are microorganisms that cause disease and include fungi, bacteria, parasites, and viruses. A 1995 report by the Economic Research Service (ERS) division of the USDA estimated that seven foodborne pathogens resulted in between $5.6 billion and $9.4 billion in annual costs related to human illnesses. Of this, meat and poultry sources were between $4.5 billion and $7.5 billion (Federal Register 1995). However, these estimates undervalue the true costs as it is believed that there are over 40 foodborne pathogens that cause human illnesses (CAST 1994).

Bean et al., (1990) found that of the four pathogen types, over 90 percent of all confirmed illnesses and deaths reported to the CDC were ascribed to bacteria. There are some pathogens that are carried by animals and do not cause animal diseases but do cause human illnesses. One example is *E. coli O157:H7.* Even though it lives harmlessly in the intestinal tracts of cattle, humans who eat rare or undercooked

hamburger meat from infected cattle are at risk of developing bloody diarrhea and kidney failure. Most contamination of meat and poultry occurs at or after slaughter. A food scientist at Pennsylvania State University, Stephen Knabel, stated "only five percent of live poultry are contaminated with *Salmonella,* but after processing nearly half of the carcasses contain *Salmonella"* (Martz 1994-95). In poultry, cross contamination can occur at the defeathering , slaughtering, chilling, and processing stages. Widespread contamination of the packing line can occur due to accidental puncturing of the intestinal tract during slaughter. Improper pasteurization of raw milk may allow *Listeria* to survive and grow in refrigerated milk.

The three categories of human illnesses caused by microbial pathogens are: foodborne infections, foodborne toxicoinfections, and foodborne intoxications (CAST 1994).

When pathogens are eaten and are then established in the body, foodborne infections can occur. These pathogens multiply in the intestinal tract, irritate the lining of the intestines, and cause illness. Examples of these pathogens are *Listeria, Salmonella,* and *Campylobacter* (CAST 1994) .

When pathogens emit dangerous or lethal toxins while in the intestinal tracts, foodborne toxicoinfections can occur. The toxic byproducts, rather than the pathogens themselves, cause the illnesses. Examples of pathogens that can produce toxicoinfections are *Clostridium perfringens* and *E. coli O157:H7* (CAST 1994).

When food is consumed that contains mycotoxins produced by molds or toxins released during the growth stages of certain bacteria, foodborne intoxication can occur. *Staphylococcus aureus* is an example of such a pathogen. Illnesses tend to be sudden as they do not require establishment or a growth stage in the body (CAST 1994).

Most cases of foodborne illness are defined as acute but may result in chronic aftereffects. They tend to have rapid inception and are self-limiting where the body is able to damage and excrete the pathogen. Symptoms that are common include gastrointestinal difficulties and vomiting. A study by Archer and Kvenberg (1985) found that between two percent and three percent of acute cases develop into chronic, long-term aftereffects.

Buzby et al. (1996) conducted a comprehensive examination of the costs associated with food safety related illnesses. Here, we will provide a synopsis of their study with some additional information about several specific pathogens and their aftereffects.

Economic theory provides a precise framework that associates the benefits of risk reduction with the amount that people are willing to pay to achieve the reduction, and suggests methods of measuring those benefits (Just, Hueth and Schmitz 1982). There are two primary methods of benefit estimation that can be practically applied to human illnesses. The first method, willingness-to-pay (WTP), aims to estimate the value that individuals place on reductions in risk to identify the value to society of

publicly provided risk reduction. The second method, cost-of-illness (COI), measures the costs of an illness to an economy, via effects on current and future gross domestic product (GDP).

COI measures have been widely used for some time and the data utilized in the analyses are both meticulous and available. The COI method measures the sum of medical expenses, foregone earnings, and productivity losses (Buzby et al. 1996).

The COI method does have some potential shortcomings. It does not recognize the value of feeling healthy, avoiding pain, or usage of free time. It has been argued, that these, along with placing a low valuation on reducing the risk to the elderly and children, forces the COI to underestimate the genuine societal benefits from risk reduction (Buzby et al. 1996).

COI studies are capable of estimating separate values for foregone earnings for illnesses and deaths. COI methods may give conservative benefit measures for publicly provided risk reduction when compared to WTP methods.

The study by Buzby, et al. (1996) employed the COI method. We will now delve into four specific pathogens discussed in that work. The pathogens examined include *Salmonella, Campylobacter, E. coli O157:H7,* and *Listeria.*

Salmonella is the principle cause of documented foodborne illnesses in most developed countries (CAST 1994). The ten most common serotypes of *Salmonella* are

responsible for over 70 percent of human illnesses in the United States. The three most prevalent serotypes responsible for human illnesses are *S. typhimurium, S. enteritidis,* and *S. heidelberg. S. enteritidis* is frequent in poultry and eggs. *S. typhimurium* is common in beef products. *Salmonella* may also be found in contaminated vegetables, fruits, and even marijuana (Helmick et al. 1994).

The most common *Salmonella* triggered illness is gastroenteritis which is an inflammation in the lining of the stomach or intestines. It is known as salmonellosis and is often contracted after consuming contaminated food (Benenson 1990). Symptoms may include abdominal discomfort, diarrhea, dehydration, fever, headache, nausea, stomachache, and vomiting and usually last less than one day. Many people who contract salmonellosis believe that they have stomach flu (Tauxe 1987). Rarely, the bacteria can enter the bloodstream and result in bacteremia or septicemia (bacterial blood poisoning), both of which can be deadly. However, deaths are uncommon (Merck & Company, Inc. 1992). The elderly, very young, and those that are immunocompromised (e.g. those with cancer, sickle cell anemia, and AIDS) are the most susceptible to infection by *Salmonella.*

Buzby et al. (1996) used three sources to estimate the number of annual salmonellosis cases: surveillance data, outbreak data, and extrapolations from the surveillance and outbreak data. It was estimated that between 800,000 and 4 million cases of *Salmonella* occur annually in the United States. Of these, between 696,000

and 3,840,000 cases were from food sources. The estimated annual human illness costs of foodborne salmonellosis were estimated to be between $600 million and $3.5 billion. A detailed breakdown is provided in Table 2.

Table 2. Salmonellosis Cases and Costs

Disease Severity	Annual Number of Cases	Annual Costs of Disease
No Physician Visit	746,880 to 3,734,400	$276.8 million to $1.384 billion
Physician Visit Only	40,320 to 201,600	$32 million to $160 million
Hospitalized	12,000 to 60,000	$109 million to $545.2 million
Deaths	800 to 4,000	$7.3 million to $36.3 million

Source: (Buzby et al. 1996).

Of the species of *Campylobacter,* there are nine that are believed to be pathogenic to humans. *Campylobacter coli* and *Campylobacter jejuni* are the primary species associated with incidence of campylobacteriosis in humans (Tauxe et al. 1988). *C. coli* infections are principally related with consumption of pork and *C. jejuni* infections are primarily connected with consumption of poultry (Buzby et al. 1996).

Campylobacteriosis can result in symptoms that range from mild diarrhea and lethargy that lasts for as little as one day to severe diarrhea, abdominal pain, fever, and further complications that can last for several weeks (Park, Griffiths and Moreno 1991). Most cases are relatively mild and result in abdominal pain and diarrhea.

Campylobacteriosis has an incubation period that can last from one to ten days with most subjects experiencing illness between three and five days (Benenson 1990).

Prolonged illness and complications that last longer than one week are found to occur in up to 20 percent of campylobacteriosis cases (Blaser et al. 1979). These complications can include meningitis, cholecystitis (gall bladder inflammation), urinary tract infection, appendicitis, septicemia, and Reiter syndrome (bacterial induced arthritis) (Mossel (1988); University of Maryland Medical Center (2009)).

The largest source of cases of *Campylobacter coli/jejuni* in the United States can be traced to ingestion of chicken (Harris, Weiss and Nolan 1986). Up to 80 percent of poultry at the retail market have been found to be contaminated with *Campylobacter* (Skirrow and Blaser 1992). Other minor foodborne sources have included raw milk, raw clams, raw hamburger, turkey, cake icing, pork, and water (Benenson (1990); Blaser, Taylor, & Feldman (1983); Stern (1992); Tauxe et al. (1988); CAST (1994)). A surveillance study by the Seattle-King County Department of Public Health found that around 55 percent of *Campylobacter* cases are the result of consumption of food (Seattle-King County Department of Publc Health 1984). Buzby et al. (1996) estimated that the incidence was between 55 percent and 70 percent.

Following the surveillance work of Rosenberg et al. (1977); Blaser, Wells et al.(1983); Tauxe (1992); and Helmick et al. (1994), Buzby et al. (1996) estimated that the annual number of cases of campylobacteriosis were 2.5 million. Of these, between

1,375,000 and 1,750,000 were foodborne. Medical and productivity costs ranged from $600 million to $1 billion. A detailed breakdown is provided in Table 3.

Table 3. Campylobacteriosis Cases and Costs

Disease Severity	Annual Number of Cases	Annual Costs of Disease
No Physician Visit	2,351,770 to 2,352,300	$871.7 million to $871.9 million
Physician Visit Only	135,000	$107.2 million
Hospitalized	12,500	$113.6 million
Deaths	200 to 730	$77.1 million to $281.3 million

Source: (Buzby et al. 1996)

E. coli O157:H7 is a toxicoinfective microorganism as it causes illness through the toxins that it produces. The toxins adhere to kidney, intestine, and central nervous system receptors where they kill cells and prevent protein synthesis (CAST 1994).

Severity of illness associated with *E. coli O157:H7* ranges from mild cases of acute diarrhea lasting six to eight days to premature death (Centers for Disease Control and Prevention (1993), Buzby et al. (1996)). Acute illness symptoms include abdominal cramps, vomiting, diarrhea that is often bloody, and fever (Buzby et al. 1996). The commonly reported symptom of bloody diarrhea is instigated by the toxins and the partial destruction of the mucosal lining of the colon (United States Department of Agriculture: Animal and Plant Health Inspection Service 1994). A study conducted in

Washington State found that 95 percent of reported *E. coli O157:H7* disease had bloody diarrhea (Ostroff, Kobayashi and Lewis 1989).

More severe cases of *E. coli O157:H7* infections can result in hemmorhagic colitis (bloody inflammation of the colon) (Buzby, et al. 1996). Most hemmorhagic colitis cases fully recover within six to eight days of onset (Griffin and Tauxe 1991). Fewer than five percent of *E. coli O157:H7* cases will develop into the life-threatening illness, hemolytic uremic syndrome (HUS). HUS is commonly characterized by red blood cell destruction, kidney failure, and neurological complications such as strokes and seizures (McCarthy (1993), American Gastroenterological Association (1995)). Lifelong dialysis may be required for those that develop chronic kidney failure. Other complications can include nervous system deterioration, blindness, and partial paralysis (Merck & Company, Inc. 1992). As a result, many patients that develop HUS will die (Buzby, et al. 1996).

Bovine products are responsible for most foodborne cases of *E. coli O157:H7* in the United States. Contamination tends to occur upon slaughter. The microorganisms can live harmlessly in the gastrointestinal tracts of poultry and farm animals. Other products that have been linked to *E. coli O157:H7* contamination include mayonnaise, apple cider, vegetables, hot dogs, raw milk, raw potatoes, turkey, ranch dressing, pea salad, cantaloupe, and water (Griffin and Tauxe (1991), United States Department of

Agriculture: Animal and Plant Health Inspection Service (1994), American Gastroenterological Association (1995)).

Following research by MacDonald et al. (1988); Ostroff, Kobayashi and Lewis (1989); Martin et al. (1990); Griffin and Tauxe (1991); and American Gastroenterological Association (1995), Buzby et al. (1996) estimated that the annual number of cases of *E. coli O157:H7* disease were between 10,000 and 20,000. Of these, it was estimated that 80 percent were foodborne with costs ranging between $200 million and $600 million per year. A detailed breakdown is provided in Table 4.

Table 4. *E. coli O157:H7* Disease Cases and Costs

Disease Severity	Annual Number of Cases	Annual Costs of Disease
No Physician Visit	5,000 to 10,000	$900,000 to $1.8 million
Physician Visit Only	3,200 to 6,400	$1.6 million to $4.2 million
Hospitalized	1,600 to 3,100	$31.2 million to $62.4 million
Deaths	200 to 500	$241.7 million to $604.2 million

Source: (Buzby et al. 1996)

Undercooked hamburger consumption has been identified a risk factor for *E. coli O157:H7* infection (Slutsker et al. 1998). A study by Ralston et al. (2001) looked at the recommendation that individuals cook hamburgers thoroughly and order them to be cooked thoroughly in restaurants. They incorporated surveys to indicate how consumers cook and order hamburgers using doneness descriptive such as rare,

medium-rare, medium, medium-well, and well-done, as well as color descriptive such as red, pink, light brown, and dark brown. It is recommended that thermometers are used so that hamburgers are cooked to a temperature of 160 degrees Fahrenheit by FSIS, the FDA, and the CDC (USDA: FSIS 1998a). Color has been found to be an unreliable indicator of whether a hamburger has been thoroughly cooked in several studies (Mendenhall (1989), Berry & Stanfield (1993), USDA: FSIS (1998b), Killenger, et al. (2000)).

The study by Ralston et al. (2001) utilized the 1996 Hamburger and Egg Consumption Diary (HECD) and the Hamburger Preparation Quiz (HPQ), both conducted by the Market Research Corporation of America. The HECD was used to estimate the proportion of hamburgers consumed with a red or pink center. The HPQ was used to examine how cooking and ordering behaviors had changed over a five year period from 1991 to 1996, the risks associated with palatability characteristics (taste, texture, and juiciness) of hamburgers between demographics, and consumers' attitudes toward risk and hamburger characteristics in doneness choices.

Following the research of Marks et al. (1998), Ralston et al. (2001) calculated the probabilities of infection based on the doneness of a hamburger. Also calculated was the probability of a hamburger being cooked rare at home, rare at a restaurant, medium-rare at home, medium-rare at a restaurant, and the proportions of hamburgers cooked at home, at restaurants, and at other locations. As a result, it was

estimated that a reduction in the probability of illness of 4.6 percent may be attributed to diminution in medium-rare and rare hamburger consumption due to foodborne illness concern. This leads to an estimated annual medical and productivity savings of $7.4 million due to a risk reduction of *E. coli O175:H7.*

Listeria monocytogenes is the infectious bacterium that is responsible for the disease listeriosis (Buzby et al. 1996). Listeriosis is usually either mild or very severe (CAST 1994). Sudden fever, severe headache, vomiting, and other flu-like symptoms are characteristics of mild cases of listeriosis. More severe cases of listeriosis may develop into septicemia and/or meningoencephalitis (simultaneous inflammation or infection of the meninges and of the brain) that can result in delirium, coma, or death (Benenson (1990); University of Maryland Medical Center (2009)). Well-defined risk groups for listeriosis infection include pregnant women, newborn/fetal cases, the elderly, and the immunocropromised (Roberts and Pinner 1990). Listeriosis has an incubation period of between four days and several weeks and a duration period that may last from a few days to several weeks (CAST 1994).

Schuchat (1994) stated that roughly 85 percent to 95 percent of all listeriosis cases in the United States are foodborne. *Listeria* can grow under refrigeration and has been isolated in food products such as raw milk, vegetables, seafood, poultry, red meat, and liquid whole eggs, (CAST 1994). Pinner et al. (1992) found that *Listeria* can rapidly replicate in hot dogs, soft cheeses, and pâté.

Following the research of Roberts and Pinner (1990) and Gellin et al. (1987), Buzby et al. (1996) estimated that there were between 1,795 and 1,860 cases of acute listeriosis and 43 cases of chronic listeriosis in the United States annually. Under the assumption that 85 percent to 95 percent of listeriosis cases are foodborne, they estimated that a yearly cost ranging from $200 million to $300 million can be attributed to foodborne listeriosis in the United States.

In the next subsection, we would like to discuss a few issues from management literature and studies of recall events in other industries. The management topics will pertain to product traceability and decision making within the firm.

2.3 Management Issues

Product traceability has become a major issue in the face of food safety concerns. Regattieri, Gamberi and Manzini (2007) defined traceability as:

> "the history of a product in terms of the direct properties of that product and/or properties that are associated with that product once these products have been subject to particular value-adding processes using associated production means and in associated environmental conditions."

Complexities of the food sector rarely allow for full and transparent traceability to occur under the umbrella of a single enterprise. Few firms control all processes along the supply chain from farm to processor to retail. Therefore, development of tracking

and tracing capabilities requires coordination between many entities including producers, manufacturers, retailers, and regulators.

Ideally, traceability would allow for any product to be identified back to its initial source and forward to its final destination from any stage in the supply chain. These are the concepts of backward tracing and forward tracing. Along with the ability to identify the actual location of the product at any given time, backward and forward tracing are components of the greater idea of tracing capability (Porter 1985). According to Fritz and Schiefer (2009), the primary issue in a tracking and tracing methodology is the identification and isolation of units of production and trade and their movements through and between processes and firms from origin to destination.

However, it should be noted that in many circumstances the ideal traceability model is impossible to achieve at this time. One major hurdle in full traceability in the food sector occurs at the commodity level. In many instances, it is impractical to segregate bulk commodities that have arrived from the farm to storage or shipping facilities based on origin. There are possible solutions for these problems that are the direct result of recent technological advancements. One potential method suggests that radio-frequency identification (RFID) tracking devices might take the shape of individual cereal grains and become part of the production batch (Fritz and Schiefer 2009).

Another problem facing full traceability is the result of the "natural and increasing spatial distances between the rural areas of production and the urban areas of consumption." (Fritz and Schiefer 2009) Physical distances, globalization, and an increasing number of intermediaries in the production process escalate the complexities of recording and maintaining accurate information at each level.

A firm's strategy for dealing with a product problem and the perceptions that are involved with the formation of this strategy are complex issues. Firms may take a proactive and responsible recall strategy or a passive and defensive recall strategy (Siomkos and Kurzbard 1994). One idea implies that a proactive approach may result in positive consumer perceptions while the other implies that the same strategy may instigate negative investor perceptions (Chen, Ganesan and Liu 2009). Both parties, consumers and investors, are extremely important to the firm and will be influential in the strategic decision making process.

The firm typically controls the greatest amount of private information about a product involved in the recall process. It knows the nature of the hazard and potential stock market consequences. This knowledge is due to the firm's consumer proximity, knowledge of the production process, and regular communication with regulators (Chen, Ganesan and Liu 2009).

A proactive firm is likely to issue a voluntary recall of a product even if a potential hazard is identified internally and is not the result of a regulatory discovery.

One example of such an event is the February 15, 2007 recall of 500,000 toys by the Fisher-Price arm of Mattel, Inc. The firm issued the recall as the result of internal testing's indication that the products may prove to be a choking hazard even though no incidents of injuries had been reported by consumers (Chen, Ganesan and Liu 2009).

A passive firm is likely to delay the recall process or attempt to force responsibility onto other entities. One example of this strategy is Playskool's recall of 255,000 toys. This recall occurred only after the death of two toddlers when the possible hazards were known by the firm beforehand (Chen, Ganesan and Liu 2009).

It seems that positive consumer perceptions are a result of proactive recall strategies. Siegel and Vitaliano (2007) found that firms were perceived as being of higher quality if they acted in a socially responsible manner. Siomkos and Kurzbard (1994) found consumers' perceptions of a firm and their future purchase intentions were fostered by a more active firm response to a product problem. Chen, Ganesan and Liu (2009) note that trustworthiness and positive customer care can be indicated by a proactive strategy.

On the other hand, investors and the stock market may interpret a proactive strategy as "a signal of severe product hazard and financial damage" (Chen, Ganesan and Liu 2009). Investors' primary concern is the firm's ability to maintain positive and vibrant cash flow in the short-run. Their study consistently found that negative returns are associated with proactive recall strategies. Therefore, they interpret a firm's quick

actions as an indicator of the severity of the possible financial consequences of a crisis event and that there were no other choices available but to issue a proactive recall.

It seems that firms' recall strategies are influenced in a number of ways. Depending on management's level of accountability to investors, a firm may be inclined to position the desires of investors as a priority over the safety of consumers.

Salin and Hooker (2001) examined the reactions of shareholder returns due to food safety incidents. Their study focused on microbiological contamination events with market reaction quantified by shareholders' investment in common stock of publically traded food processing firms. Their study concentrated on four recall events representing firms of various size and business practices. One event was linked to *Listeria* contamination at Sara Lee Food's Bil-Mar Foods packaged meats subsidiary. Two events were linked to *E.coli O175:H7* contamination of ground beef at IBP, Inc. The final recall examined was also associated with *E.coli O157:H7,* but was contaminated apple juice produced by Odwalla, Inc.

Salin and Hooker (2001) conducted an event study to measure the impact of these recall events on the value of the respective firms. This was accomplished by estimating the "normal return" of the stock and then comparing it to the actual return over a period surrounding the recall event. Abnormal returns were estimated as the difference between the predicted return and the actual return.

The study found that for the smallest firm, Odwalla, returns to shareholders fell immediately after the recall event. However, large reductions in returns were not consistently associated with recalls by the larger firms. They proposed that this consequence may be the result of other factors such as outside business diversification, intensity of press coverage, or timeliness of the recall event.

2.4 Recall Studies from Other Industries

The case studies on recall events deal with issues in the pharmaceutical and automotive industries. A paper by McGhan and Block (1987) studied the implications of the size of pharmaceutical companies and the number of drug recall events per firm. The variable used to relate the size of the firm was sales. Their study classified pharmaceutical firms into two groups: (1) generally smaller, nonresearch-oriented firms, and (2) larger, research-oriented firms. The premise of the research was to determine if the smaller, nonresearch-oriented firms produced drugs that were equal in quality to those produced by the larger, research-oriented firms. It was understood that lower quality drugs were indicative of recall events. Their study examined 3,720 recall events and court actions over a period from 1970-1979.

Like food safety recall events, most recalls in the McGahn and Block study were voluntarily issued by the firms upon identification of a problem. If an involuntary recall was required, the FDA could initiate a court action that could result in seizures,

injunctions, and prosecutions. Over the period of the study, only 299 of the 3,720 events were the consequence of FDA court actions.

McGahn and Block estimated the number of recalls, the average number of units per recall, the average cost per unit recalled, the total units recalled, and the total cost of recalls for nonresearch-oriented and research-oriented firms. This information is provided in Table 5.

Table 5. Pharmaceutical Recalls by Firm Size (1970-1978)

	Nonresearch-Oriented Firms	Research-Oriented Firms
Number of Recall Events	2,970	451
Average Number of Units Recalled	794,106	1,044,613
Average Cost Per Unit Recalled	$0.34	$0.65
Total Units Recalled	2,358 million	471 million
Total Cost of Recalls	$803 million	$305 million

Source: Drug Recalls and Court Actions: A Comparison of Research-Intensive and Nonresearch-Intensive Pharmaceutical Firms, McGahn and Block, 1987, (p. 187).

McGahn and Block found a significant difference in the average number of recalls and citations per firm between research-intensive and nonresearch-intensive firms. They found that there was a positive correlation between sales volume and the number of recalls and citations. They also found that larger firms generally had a lower percentage of their product involved in a recall.

A study by Rupp (2004) considered the effects of recall events in the automotive industry. Specifically, the study looked at the adjusted percentage cumulative abnormal return (CAR) in the stock price of a firm that could not be explained by the overall movement of the automotive industry following a recall event. A wide range of defective components, recall characteristics, and company characteristics were considered as possible explanatory variables for the CAR. The defective components ranged from air bags and brakes to engines and seat belts. Recall characteristics included the age of the automobile model, if the recall was the first for the model, and if the government initiated the recall, among others. Company characteristics considered if the company had a AAA bond rating and a variable that measured market capitalization. For this study, the market capitalization was selected as a firm size measurement variable as other measurements may have been unavailable. Market capitalization was defined as the stock price multiplied by the number of outstanding shares.

The study by Rupp (2004) collected data for cars and trucks in the United States over a period from 1973 to 1998. The data was obtained from the Wall Street Journal Index of Automotive Recall Announcements and contained records of the six largest automobile manufacturers in the United States. The data used to calculate the market capitalization variable was collected from the Center for Research in Security Prices at the University of Chicago. During the twenty-six year sample period, 592 safety recall announcements were published. These involved an estimated 138 million vehicles

produced by the six manufacturers. The events ranged widely in size from a recall of 39 Buick Reattas with faulty air bag sensors to a 7.9 million vehicle recall due to defective ignition switches by the Ford Motor Company.

Rupp (2004) conducted twelve models with varying fixed and random effects of manufacturers and years. Two of the models that included fixed year effects to capture changes over time during the sample period and excluded fixed manufacturer effects found significance in the natural log of the market capitalization variable. This indicated that firm size had an effect on the CAR under a product recall for these two models. It was concluded that firms with larger $\ln(market\ capitalization)$ have smaller losses in the stock market following recall announcements.

In this literature review, we have discussed key topics related to food safety recall events. These have included the regulatory structure of the food system in the United States, several primary causes of recall events, management issues that relate to recalls, and recalls stemming in other industries. This assessment will support the framework of our analysis and examination of food safety recalls that have occurred in the United States in the past several years. We will now transition into the description of the data to be used in our analysis with the principal target of providing a broad prospective prior to developing the model and our hypotheses.

3. DATA DESCRIPTION

The data to be utilized in this examination have been acquired from several sources. Numerous individuals have worked on the collection and organization of the data. With the aid of data management and analysis software such as Microsoft Excel and Statistical Analysis System (SAS), the task has been facilitated. In this section, we will first describe the datasets and information contained therein. We will then discuss the process by which they were organized and combined.

The datasets can be classified into three categories:

(1) Individual recall events;

(2) Corporate financial and details about the recall events; and

(3) Corporate family information.

Datasets of the first category, relating to individual recall events, were collected from press releases issued by the FDA and FSIS. The information collected from FDA was gathered from its Archive for Recalls, Market Withdrawals and Safety Alerts website (United States Food and Drug Administration 2009). The information from FSIS was collected via its Recall Case Archive website (United States Department of Agriculture: Food Safety Inspection Service 2009). The recall events span a period from January, 2000 through October, 2009. We believe that the recall data contain most every recall event issued by the FDA and FSIS over that period and that it is one of the most comprehensive datasets located outside of the federal government regarding

food safety recalls. From the recall dataset, observations contain comprehensive information on: date of the recall event; firm; city and state of the firm involved; type of firm involved as manufacturer, retailer, or a combination of the two; recall problem; how the problem was discovered; and contact information. Additional information, albeit not as exhaustive, is available on recall class as a measure of recall severity, illnesses reported, total pounds recalled, and the number of states to which the product was distributed. We should mention that both FDA and FSIS only report information on firms that have experienced recall events. In this original dataset, there were 2,443 recall events reported.

The second dataset category relates to corporate financial information and details about the recall events. There were five original datasets of this type. The information was collected from the Hoover's Company Information Database (2009). The information contained in these firm datasets provide sales figures, number of employees, percentage of sales growth, percentage of employee growth, a binary variable equal to one if a firm has a brand and zero otherwise, and the number of brands per firm. It should be noted that if we were unable to observe if a firm had a brand and subsequently the number of brands that the firm had, we assumed that the firm did not have a brand. Therefore, we coded both the binary variable and the brand count variable for such firms as zero. It should also be noted that firm level sales and employment numbers data are spaced across several years. While most of the data are in terms of 2008 figures, the Hoover's database also contained 2007 and 2009 figures.

The data on sales and employment numbers were pooled over dates into two new variables: most recent sales (MRS) and most recent employees (MRE). MRS and MRE contain the most recently available information that was obtainable for the individual firms. There are a total of 1,143 firm level observations in these datasets.

The final category of datasets contains information on the corporate structure of the final parent companies of the firms. Two datasets contain information from the Food Business Review Database (2009), the Funding Universe Database (2010), and MintGlobal (Bureau van Dijk 2009) relating corporate parents to their subsidiaries. In this research, we feel that the best representation of the overall safety of the firm and the implication of recall events can be viewed at the corporate level. These datasets contain a total of 2,273 observations.

The organization and combination of the data into one useable and functional dataset was a tedious project. The first step was to combine the five corporate and technical information datasets into a single dataset. The same procedure was completed to combine the parent-subsidiary datasets into a single dataset. At this point, there were three datasets, one for each dataset category. Next, a corporate level code was created. The code provided a unique number for each corporate parent company and assigned the same number to each of the company's subsidiaries. The next step was to delve into the corporate information and recall datasets and match the correct parent company code to the firms given in these datasets. This procedure

had to be conducted on an observation by observation basis due to discrepancies in the firm names. Once this process was complete, the recall dataset and the financial and technical dataset were merged into one by the company code. This dataset is the primary dataset that will be used in the analysis and contains 1125 observations.

A final key variable had to be constructed for the model analysis to be conducted. This variable, known as Dif_date, provides the number of days between recall recurrences for a firm. For example, if the first recall event for firm XYZ occurred on October 21st, 2003 and the second recall event occurred on December 2nd, 2003, then the Dif_date would equal 42. There were 42 days between the first and second recall events for firm XYZ.

4. METHODOLOGY, DISCUSSION OF VARIABLES, & HYPOTHESES

In this analysis, we will utilize survival analysis techniques. Survival analysis procedures have been employed extensively in demographic and medical research. The methods have been well established in Cox (1972), Anderson & Gill (1982), Elandt-Johnson & Johnson (1999), Lee & Wang (2003), Der & Everitt (2009), and others. This study will utilize similar approaches used in these works and apply them to the food recall data. For an individual firm, multiple recall events and the periods of time between them are easily observed. In our study, survival is equivalent to risk of recurrence and we may be able to say something about proactive indicators of the next recall event.

In this analysis, the event will be defined as the occurrence of a food safety recall by an individual firm. It is quite possible that for a firm, the event may be recurrent. The statistical procedures to handle recurrences will be considered later in the study, once the basic methodology is explained.

In order to employ survival analysis procedures for this investigation, first the unit of analysis needs to be defined. The corporate firm in question will be the unit of analysis and the individual firms in the recall database will be traced back to the ultimate corporate parent. This will allow for an enhanced depiction of the corporate management influence over the overall firm and its subsidiaries.

4.1 Survival and Hazard Functions

Following the methods of Der and Everitt (2009), we will define the survival and hazard functions to be used in our model.

Defining T as the survival time, the survival function $S(t)$, is the probability that an individual (or firm in our case) survives longer than t without a failure (recall) event. In our analysis, T is defined as the duration without a recall event.

(1) $$S(t) = \Pr(T > t)$$

The graph of $S(t)$ against t, known as the survival curve, can then be obtained. The Kaplan-Meier estimator, $\hat{S}(t)$, will be used to obtain an estimate of $S(t)$ (Kaplan and Meier 1958). Survival curves provide information on the chance that subjects do not experience the recall. Hence, longer survival is positive in terms of food safety performance.

The hazard function, $h(t)$, will be defined as the probability that a firm experiences the event in a small time interval s, given that the firm has survived up to the start of this interval.

(2) $$h(t) = \lim_{s \to 0} \Pr \frac{(event\ in\ (t,t+s) | survival\ up\ to\ t)}{s}$$

This is also known as the instantaneous failure rate or in medical and demographic analysis, as the age-specific failure rate. For our analysis, it will be a measure of the risk

of recurrence of a recall event. The hazard function can then be calculated by defining it as an operation of the cumulative distribution and the probability density function of survival time (Der and Everitt 2009).

(3) $$h(t) = \frac{f(t)}{1-F(t)} = \frac{f(t)}{S(t)}.$$

By employing the Kaplan-Meier estimator of the survival function, we can obtain an estimator of the hazard function as:

(4) $$\hat{h}(t) = \frac{f(t)}{\hat{S}(t)}.$$

4.2 Cox's Regression

In our analysis, we will employ Cox's proportional hazard model to determine the relationship of the response to our explanatory variables. We need Cox's regression because the response variable is a potentially censored survival time. The Cox regression is semi-parametric as it does not require the probability distribution for the survival time to be specified. The hazard function is used as an instrument for modeling as it does not necessitate the cumulative history of events. Care must be taken not to model the hazard function as linear with respect to the explanatory variables as the hazard function is strictly positive (Der and Everitt 2009). Since it may be the case that the hazards may increase or decrease with time, the model suggested by Cox (1972) is preferred. The Cox model allows for the form of dependence of $h(t)$ on t to remain unspecified as given by:

(5) $\log h(t) = \log[h_0(t)] + \boldsymbol{\beta}'\boldsymbol{x}$

$\boldsymbol{\beta}$ is defined as a vector of the regression parameters and $\boldsymbol{x}$ is a vector of covariate values. The function $h_0(t)$ is known as the baseline hazard function. If the vector $\boldsymbol{x} = \mathbf{0}$, then the baseline becomes the hazard function. The Cox regression model can be rewritten as:

(6) $h(t) = h_0(t)\exp(\boldsymbol{\beta}'\boldsymbol{x})$.

From here, the regression parameters, $\boldsymbol{\beta}$, can now be estimated by maximizing the partial likelihood function. From the estimated regression parameters, we can calculate hazard ratios associated with each covariate. The hazard ratios are calculated as:

(7) $HZ_i = \exp(\hat{\beta}_i)$.

The hazard ratios can be interpreted as follows:

(1) An increase in a continuous explanatory variable by n unit(s) will result in $|1n - (HZ)^n|$ percent increase in the hazard rate if the $HZ > 1$ (SAS Institute Inc. 2009). Therefore a hazard ratio greater than one is associated with an increase in the hazard rate or the relative risk of a recall event. Hazard ratios greater than one indicate a positive association of that variable with recall risk.

(2) An increase in a continuous explanatory variable by n unit(s) will result in $|1n\ -(HZ)^n|$ percent decrease in the hazard rate if the $HZ < 1$. Therefore a hazard ratio less than one is associated with a decrease in the hazard rate or the relative risk of a recall event. Hazard ratios less than one indicate a negative association of that variable with recall risk.

The Cox model assumes that the hazard functions are proportional over time and for strata of particular choices of the explanatory variables (Elandt-Johnson and Johnson 1999). Therefore, it assumes that ratio of hazard functions for observations do not depend on time (StatSoft, Inc. 2010).

4.3 Discussion of Variables

In the execution of the proportional hazards model we must identify several factors that we would like to test. We will look into economic and management theory in an attempt to uncover what may be viable links to the risk that recall events occur over a period of time.

We will first examine the work considering the nature of the firm by Coase (1937). His work considers the theoretical grounding of what a firm is. He states,

"A firm becomes larger as additional transactions (which could be exchange transactions co-ordinated through the price mechanism) are organized by the

> entrepreneur and becomes smaller as he abandons the organization of such transactions."

Fundamentally, the size of the firm, as Coase explains it, can be interpreted as volume or sales.

Coase (1937) argues that efficiency within the firm tends to decrease as the firm becomes larger. As a firm gets larger, the entrepreneur or management must organize an increasing number of transactions, both monetary and physical. These transactions will also become more spatially distributed and dissimilar in kind. The costs of organizing these transactions will eventually force the firm to reach a point where the costs of organizing an additional transaction within the firm are equal to the costs of carrying out the transaction in the open market. In other words, it becomes optimal for the firm to outsource. At this point the firm will cease physical expansion. Coase (1937) explains this as the "diminishing returns to management." Consider a firm that initially produces a single good and employs a set of workers and technology for its production. As the firm expands either vertically or horizontally, additional employment of workers or technology will be required. However, as production levels and/or goods become more diverse, upper management will face a mounting problem of organization and supervision.

This concept is known as bounded rationality. According to Simon (1957) and cited by Williamson (1981), "boundedly rational agents experience limits in formulating

and solving complex problems and in processing (receiving, sorting, retrieving, transmitting) information." Therefore, as the size of the firm increases, at some point, complexities within the firm limit management's ability to organize, supervise, and implement employees, structure, and standards on an increasing quantity and variety of products and processes.

In the case of the food sector, this supervision constraint is a primary concern. Firms that are vertically integrated must insure that stages along the production path maintain quality and integrity. Firms that are horizontally integrated or produce multiple products must preserve safety over a widening variety of processes that may be very dissimilar. Hence, there are limits to the employer's authority and his or her ability to monitor an increasing number of integrated units and processes. Therefore, in this paper we contend that the growing size of a firm will not lead to safer and more stringent food safety practices and therefore will increase the risk of recurrence of recall events.

Next we will delve into management and information theory and specifically the principal-agent model and signaling theory. The basic idea for the principal-agent signaling model has its roots in the asymmetric information model by Spence (1973). In his hypothetical example, there are two types of employees also known as agents: a good employee with high productivity and a bad employee with low productivity. There is also an employer also known as the principal who has the desire to hire the

good candidate. The employer is willing to compensate the good employee through a higher wage but initially cannot distinguish between the employee types. The good employee recognizes that he or she must offer the employer some manner of signal that will indicate his or her type as a high productivity worker. This could be given by some sort of education or discernment where the good employee must forgo an opportunity cost in order to signal his or her type.

In comparison, consider the agents as firms; one with a high quality, safe product, and one with a low quality, less safe product. We could think of the principal as the customer who has an incentive to distinguish between the two goods and therefore the two agents that produce for it, but initially cannot tell them apart. The higher quality producer has an incentive to characterize its product as distinct from the lower quality product. One method to create this distinctive image is through branding and the subsequent advertising and goodwill opportunity costs that accompany it.

Branding at its essence can be thought of as a principal-agent signaling device where the producing firm is the agent conveying meaningful information to the principal or consumer of the product. In the case of the food sector, the conveyance mechanism is brand reputation and the meaningful information is safety and quality of the product.

As a complement to the principal-agent explanations for branding, we will explore a subject heavily studied in sociology and social psychology known as

impression management and apply it to our rationale. According to Leary and Kowalski (1990), impression management is "the process by which people control the impressions others form of them." Zadek et al. (1997), suggest that a firm's reputation depends on "what people *think* is true and *feel* is important." Branding is a good example of how a firm attempts to control the impressions that consumers form about a product. This is especially relevant with experience goods where consumers cannot easily observe some product characteristics such as quality. Milgrom and Roberts (1986) note that:

> "It is clear that if high quality brands advertise more and if advertising expenditures are observable (even if not perfectly so), then rational informed consumers will respond positively to advertising, even if the ads cannot and do not have much informational content."

Many goods in the food sector can be thought of as experience goods. Packaging often renders it impossible to determine the definite quality of the product contained. Pathogen concentration and contamination of fresh fruit, vegetables, dairy products, and meats are often undetectable to the naked eye.

Branding may involve corporate level, umbrella branding where a single name marks a wide variety of products and/or product-specific branding. Both management strategies are implemented as methods to convince and signal customers of quality and integrity of the product. Research has found that umbrella branding generates savings

resulting from marketing and brand development (Erdem and Sun 2002). However, the long term increased expenditures and opportunity costs of multiple product branding may be an increased signal of quality across products. Branding and the number of brands that a firm owns are not necessarily related to the size of the firm. Small firms can have a large portfolio of brands while large firms can be single branded.

For these reasons, branding of products and number of brands appear to be very reasonable explanatory factors when considering food safety. Here, we expect that both product branding and an increasingly large portfolio of brands will decrease the risk of recurrence of future recall events with the likelihood that branding is a signal of higher quality, safer products.

Before we move on, we will admit that it may be that the predictions made by the Coase and brand-management arguments are inconsistent. It may be perceived that a growing portfolio of brands will lead to complexities within the firm. Therefore Coasian theory would content that the growing number of brands would be associated with less safe and less stringent food safety practices and therefore will increase the risk of recurrence of recall events. We recognize this conflict but feel that for the branding variables the brand-management theoretical framework presented is the favorable approach.

4.4 *Hypotheses*

As stated earlier, we contend that the growing size of a firm will not lead to safer and more stringent food safety practices and therefore will increase the risk of recurrence of recall events. We expect that, controlling for firm branding, an increase in the size of a firm will increase the risk of recurrence of recall events and therefore the hazard ratios for the firm size variables (HZ_{FS}) will be greater than one (FS denotes firm size). That is:

(1) $H_1: HZ_{FS} \geq 1,$

$H_{A1}: HZ_{FS} < 1.$

Also, we contend that both product branding and a growing portfolio of brands will decrease the risk of recurrence of recall events with the likelihood that branding is a signal of higher quality, safer products. We expect that, controlling for firm size, branding and an increasing portfolio of brands will decrease the risk of recurrence of recall events and therefore the hazard ratios for the branding variables (HZ_B) will be less than one (B denotes brand). That is:

(2) $H_2: HZ_B \leq 1,$

$H_{A2}: HZ_B > 1.$

In closing, we believe that the Cox proportional hazard model extending from duration analysis is an appropriate model for examining the risk of recurrence of recall

events for firms. From business and economic foundations, we have determined that firm size measured in sales and number of employees and branding by a firm are proper explanatory factors with regard to food safety. We have come to the conjecture that escalating firm size will increase the risk of recurrence and branding will decrease the risk. We will now test our hypotheses and present the results of our examination.

5. RESULTS

The results section is divided up into two major sections. The first portion presents the results of the survival analysis models presented in the previous section. The second portion presents summary statistics and interesting findings from the data.

5.1 Discussion of Models

We will begin by defining the explanatory variables that will be included in the Cox proportional hazard models. Based on economic and management reasoning provided in previous sections, we have collected firm sales and employee data as indicators of firm size. We have also collected data on branding by the firms and the number of brands that a firm owns. The binary variable BYN indicates a firm that has a brand with a one and a firm that does not have a brand with a zero. The variable NBS indicates the number of brands within a firm, ranging from 0-50 in our data.

An issue that we would like to address is the possible problem of confounding between the two firm size variables. We suspect that the two variables will be highly correlated. It is logical that a firm with more employees will have higher sales and vice versa. We will test the hypothesis:

(1) $H_0: \rho_{MRE,MRS} = 0$

$H_A: \rho_{MRE,MRS} \neq 0.$

The symbol $\rho_{MRE,MRS}$ denotes the correlation coefficient of the most recent firm sales (MRS) and number of employees of the population (MRE). The null hypothesis states that there is no correlation between the two variables. Next, we calculate the Pearson correlation coefficient $(\hat{\rho})$and find that $\hat{\rho} = 0.84562$ at a significance level, $p < 0.0001$. Therefore, we reject the null hypothesis that there is no linear relationship between the two variables. We find that the correlation between the two variables is actually very high which confirms our thoughts.

We will consider also the possibility that the firm size variables and the branding variables are correlated. For this procedure, we will test four hypotheses. The first (2) will test the correlation between the sales variable and the binary brand variable, where $\rho_{MRS,BYN}$ denotes the correlation coefficient. The second (3) will test the correlation between the employees variable and the brand binary variable, where $\rho_{MRE,BYN}$ denotes the correlation coefficient. The third (4) will test the correlation between the sales variable and the number of brands count variable with $\rho_{MRS,NBS}$ denoting the correlation. Finally, the fourth hypothesis (5) will test the correlation of the employees variable and the number of brands count variable, where $\rho_{MRE,NBS}$ denotes the correlation coefficient. The hypotheses are presented as:

(2) $H_0 : \rho_{MRS,BYN} = 0$

$H_A : \rho_{MRS,BYN} \neq 0$

(3) $H_0 : \rho_{MRE,BYN} = 0$

$H_A : \rho_{MRE,BYN} \neq 0$

(4) $H_0 : \rho_{MRS,NBS} = 0$

$H_A : \rho_{MRS,NBS} \neq 0$

(5) $H_0 : \rho_{MRE,NBS} = 0$

$H_A : \rho_{MRE,NBS} \neq 0$

The results are presented in Table 6.

Table 6. Correlation Coefficients between Regression Variables

Correlation	Significance Value
$\hat{\rho}_{MRS,BYN} = 0.47293$	$p < 0.0001$
$\hat{\rho}_{MRE,BYN} = 0.46074$	$p < 0.0001$
$\hat{\rho}_{MRS,NBS} = 0.28763$	$p < 0.0001$
$\hat{\rho}_{MRE,NBS} = 0.45462$	$p < 0.0001$

The null hypotheses state that there are correlations between the two respective variables. As we can see, there is in fact a significant positive correlation between each respective pair. According to Devore (2004), a reasonable rule of thumb is that the correlation is weak if $0 \leq |\rho| \leq 0.5$, moderate if $0.5 \leq |\rho| \leq 0.8$, and strong if

$0.8 \leq |\rho| \leq 1$. From this understanding, we can classify all four as having weak positive correlations. At this point we will note that it may be useful to include interaction terms between the firm size variables and the branding variables in our models. However, for the Cox proportional hazard regression the coefficients of these terms may not be interpretable and therefore we will continue without the interaction terms with the knowledge that weak positive correlation does exist.

Based on our finding concerning the high correlation between the two firm size variables and the weak correlations between the firm size and branding variables, we feel that the best way to proceed from this point is to estimate four separate models. The first model will contain variables that measure the most recent firm sales in billions of dollars (MRS) and BYN. The second model will contain variables that measure the most recent employee in thousands of employees (MRE) along with BYN. The third model will contain MRS and the variable that measures the number of brands (NBS). The fourth model will contain MRE and NBS. The fourth model will contain MRE and NBS.

5.2 Model 1

In our first model, we will estimate the regression parameters for MRS and BYN. The model is presented as:

(1) $h(t) = \log h_0(t) + \beta_1 MRS + \beta_2 BYN$

Here, $h(t)$ is the risk of the second recall given that the firm has already had one recall.

The maximum likelihood estimates for the parameter estimates, the hazard ratios rounded to three decimal places, and the Chi square significance values from the Cox proportional hazard model are provided in Table 7.

Table 7. Cox Proportional Hazard Model for Covariates: MRS and BYN

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRS	0.00952	<0.0001	1.010	157
BYN	0.81547	<0.0001	2.260	

The effects of both explanatory variables are significant. However, before we can interpret and conclude the validity of the results, we must confirm that the assumption of proportionality is satisfied. We will follow the procedures provided by UCLA Academic Technology Services (2007). We will check this assumption by including time-dependent covariates in the model. The time-dependent covariates are interactions of the explanatory variables with the time differential independent variable used to calculate the hazard function in our model. This independent variable is the difference in days between first and second recall event and is given noted as Dif_date . We will use the suggested and commonly used $\log(time)$, or in our case, $\log(Dif\_date)$ function of our time variable to interact with the covariates. It should be noted that

any function of time would be appropriate. Our model to test the proportionality assumption is given by:

(2) $$h(t) = \log h_0(t) + \beta_1 MRS + \beta_2 BYN + \beta_3 MRS * \log(Dif\_date) + \beta_4 BYN * \log(Dif\_date).$$

According to UCLA Academic Technology Services (2007), a significant coefficient on the respective interaction variable indicates that there is a violation of the proportionality assumption for the specified variable. The analysis of the maximum likelihood estimates is presented in Table 8.

Table 8. Cox Proportional Hazard Model for Covariates: MRS, BYN, $MRS * \log(Dif\_date)$, and $BYN * \log(Dif\_date)$

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	n
MRS	0.00596	0.1091	1.006	157
BYN	0.2750	0.3058	1.317	
$MRS * \log(Dif\_date)$	0.00107	0.1714	1.001	
$BYN * \log(Dif\_date)$	0.11353	0.0329	1.120	

It is obvious that the time-dependent covariate for the binary brands variable BYN is significant. Before we conclude that BYN is non-proportional, we can consider a final option presented by UCLA Academic Technology Services (2007). We can check if the variable truly violates the assumption by taking the supposed non-proportional predictor and stratifying by it. If we estimate our model by strata and find that the estimate for the other parameter is similar to those found prior to the stratifications, then, we can believe that the variable in question should be included in our model as a proportional predictor and stratification is not necessary.

We will test the brand variable by stratifying it into two categories: those with a brand and those without a brand. The summary of the stratifications and the maximum likelihood estimate of the sales variable are provided in Table 9 and Table 10, respectively.

Table 9. BYN Stratification Summary for Model 1

Stratum	BYN	Total Observations
1	0	577
2	1	373
Total		950

Table 10. Cox Proportional Hazard Model for Covariates MRS with Stratified BYN

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio
MRS	0.01006	<0.0001	1.010

As we can see, both the parameter estimate and hazard ratio for the sales variable are very close to that found in the non-stratified regression found in Table 7. Therefore, we can safely conclude that the brand variable is actually proportional and should be included in the model without stratification.

We can now turn back to the results in Table 6 and provide interpretations. The parameter estimates are rather difficult to interpret due to the functional form of the model. However, we can easily interpret the hazard ratios (HZ) that are directly calculated from the parameter estimates. We will follow the guide provided by SAS Institute Inc. (2009). An increase in a continuous explanatory variable by k unit(s) will result in $|1-(HZ)^k|$ percent increase in the hazard rate if the $HZ > 1$. For a binary variable, inclusion of an indicator equal to one will result in a $|1-(HZ)|$ percent increase in the hazard rate if the $HZ > 1$. The hazard rate is defined as risk of recurrence of a recall event.

Our final results for this model conclude:

(1) Given that one recall event has occurred and controlling for if a firm has a brand or not, an increase in sales of $1 billion is associated with a 1.0 percent increase in the risk of recurrence of a recall event;

(2) Given that one recall event has occurred and controlling for sales of the firm in billions of dollars, the fact that a firm has a brand is associated with a 126.0 percent increase in the risk of recurrence of a recall event.

We can also examine firms that have recall events subsequent to the 2nd event, 3rd event, 4th event and so forth. To do this, we will create further subsets of recall events that contain the required information on sales and branding. To clarify, we will define the information contained within a subset as pertaining to the recall event given by the subset number and the next successive recall event. Therefore, subset 02 considers the times between events two and three, given a firm has experienced one recall event. Subset 03 considers the times between events three and four, given that a firm has experienced events one and two. The interpretations of the regression results are the same as previously stated. We will conduct this examination for nine additional subsets. The results are given in Table 11.

Table 11. Cox Proportional Hazard Models for Subset 02 through Subset 10 for Model 1

Subset	Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	n
02	MRS	0.01053	<0.0001	1.012	79
	BYN	1.17341	<0.0001	3.233	
03	MRS	0.01303	<0.0001	1.03	51
	BYN	1.46927	<0.0001	4.346	
04	MRS	0.01385	<0.0001	1.014	36
	BYN	1.76536	<0.0001	5.844	
05	MRS	0.01470	<0.0001	1.015	28
	BYN	1.96112	<0.0001	7.107	
06	MRS	0.01553	<0.0001	1.016	24
	BYN	2.11706	<0.0001	8.307	
07	MRS	0.01611	<0.0001	1.016	19
	BYN	2.28889	<0.0001	9.864	
08	MRS	0.01700	<0.0001	1.017	17
	BYN	2.35885	<0.0001	10.579	
09	MRS	0.01731	<0.0001	1.017	15
	BYN	2.52807	<0.0001	12.529	
10	MRS	0.01777	<0.0001	1.018	13
	BYN	2.88820	<0.0001	17.961	

As an example, for subset number two the information considers the time between events two and three. The Dif_date is calculated as the number of days between the second and third recall events. Given that a firm has initiated two recall events and controlling for firm branding, an increase in sales of $1 billion is associated with a 1.2 percent increase in the risk of recurrence of a recall event. Given that a firm has initiated two recall events and controlling for firm size measured in billions of dollars, the fact that a firm has a brand is associated with a 223.3 percent increase in the risk of recurrence of a recall event. As we can see, with significance, the risk of

recurrence of a recall event continues to increase for both a firm branding its products and for larger firms.

The information for firm size and firm branding from Table 11 are presented in Figure 1 and Figure 2, respectively.

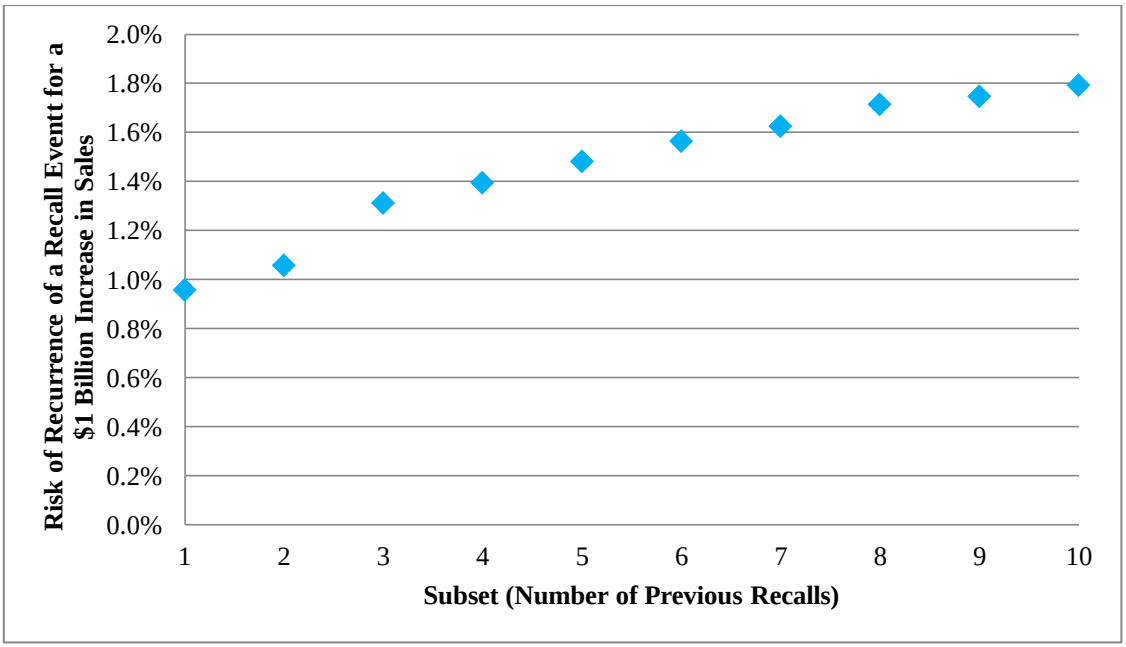

Figure 1. Trend of the risk of recurrence of recall events by firm size measured in sales for Model 1

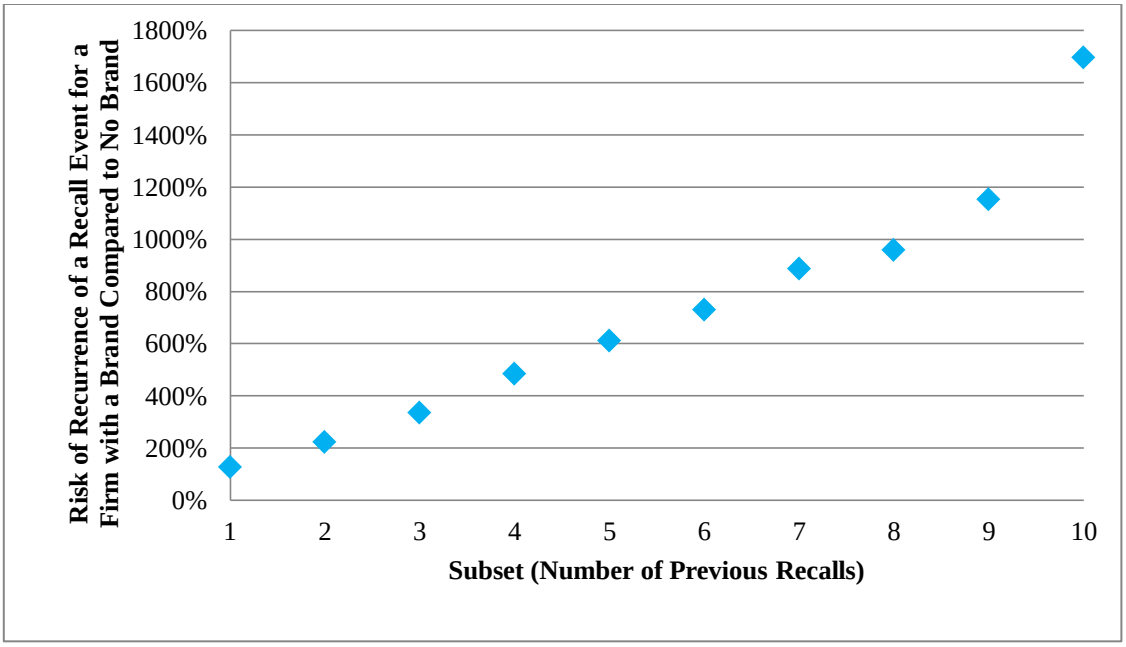

Figure 2. Trend of the risk of recurrence of recall events by branding for Model 1

Before moving on the next model, we will conclude that the branding binary variable has a very large effect on the relative risk of a recall event when compared to the effect of increased sales.

5.3 Model 2

In our second model, we will estimate the regression parameters for firm size as measured by thousands of employees (MRE) and our binary brand variable (BYN). Due to the high correlation between firm sales and the number of employees that we observed earlier, we expect to see very similar results from this model as compared to the first model. The model is given as:

(3) $$h(t) = \log h_0(t) + \beta_1 MRE + \beta_2 BYN.$$

The maximum likelihood estimates of the parameters and hazard ratios along with their respective significance indicators are presented in Table 12.

Table 12. Cox Proportional Hazard Model for Covariates MRE and BYN

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRE	0.00343	<0.0001	1.003	188
BYN	0.83212	<0.0001	2.298	

As before, we must check the proportionality assumption using the method provided by UCLA Academic Technology Services (2007). We must create a time-dependent interaction for each of our two parameters, MRE and BYN. Again, we will use the suggested and commonly used $\log(Dif\_date)$ function of our time variable to interact with the covariates. Our model is given as:

(4) $$h(t) = \log h_0(t) + \beta_1 MRS + \beta_2 BYN + \beta_3 MRE * \log(Dif\_date) + \beta_4 BYN * \log(Dif\_date).$$

The results of the maximum likelihood estimates are provided in Table 13:

Table 13. Cox Proportional Hazard Model for Covariates MRE, BYN, $MRE * \log(Dif\_date)$, and $BYN * \log(Dif\_date)$

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRE	0.00307	0.0121	1.003	188
BYN	0.30506	0.2071	1.357	
$MRE * \log(Dif\_date)$	0.00016	0.5210	1.000	
$BYN * \log(Dif\_date)$	0.10791	0.0233	1.114	

As stated earlier, a significant time-dependent interaction suggests that there may be a violation of the proportionality assumption for the variable that is interacted with. Therefore, the binary brand variable, BYN, is a potential problem. Using the second procedure suggested by UCLA Academic Technology Services (2007), we will stratify the binary variable into two categories. These two categories will include firms with a brand and firms without a brand. We will then regress again. The results of the stratification and the likelihood estimates are provided in Table 14 and Table 15, respectively.

Table 14. BYN Stratification Summary for Model 2

Stratum	BYN	Total Observations
1	0	612
2	1	491
Total		1103

Table 15. Cox Proportional Hazard Model for Covariates MRS with Stratified BYN

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio
MRS	0.01006	<0.0001	1.010

The parameter estimate and hazard ratio for MRE in Table 15 are very similar to those found in our original model estimates in Table 12. Therefore, we can conclude that the binary brand variable does not require stratification and satisfies the proportionality assumption.

We will interpret the results using the guide provide by the SAS Institute Inc. (2009). From Table 12 and the hazard ratios, we conclude that:

(1) Given that one recall has occurred and controlling for branding by the firm, an increases in the number of employees by 1,000 is associated with a 0.3 percent increase in the risk of recurrence of a recall event;

(2) Given that one recall event has occurred and controlling for the firm size measured in thousands of employees, the fact that a firm has a brand is

associated with an 129.8 percent increase in the risk of recurrence of a recall event.

Again, we can also examine firms that have subsequent recall events beyond the second event. We will follow the procedure described earlier and will examine nine additional subsets created from the branding and firm size with regard to employment numbers. The results are given in Table 16.

Table 16. Cox Proportional Hazard Models for Subset 02 through Subset 10 for Model 2

Subset	Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
02	MRE	0.00425	<0.0001	1.004	95
	BYN	1.21544	<0.0001	3.372	
03	MRE	0.00474	<0.0001	1.005	60
	BYN	1.54535	<0.0001	4.690	
04	MRE	0.00506	<0.0001	1.005	44
	BYN	1.84100	<0.0001	6.303	
05	MRE	0.00541	<0.0001	1.005	34
	BYN	2.03648	<0.0001	7.664	
06	MRE	0.00573	<0.0001	1.006	28
	BYN	2.18493	<0.0001	8.890	
07	MRE	0.00592	<0.0001	1.006	22
	BYN	2.37305	<0.0001	10.730	
08	MRE	0.00615	<0.0001	1.006	20
	BYN	2.46926	<0.0001	11.814	
09	MRE	0.00615	<0.0001	1.006	18
	BYN	2.65184	<0.0001	14.180	
10	MRE	0.00629	<0.0001	1.006	15
	BYN	3.01798	<0.0001	20.450	

In Figure 3 and Figure 4 we can see that, with significance, the risk of recurrence of a recall event continues to increase with subsequent events, in association with

branding and increases in firm size as measured in thousands of employees. For example, given that a firm has initiated five recall events and controlling for firm branding, an increase in 1,000 employees is associated with a 0.5 percent increase in the risk of recurrence of a recall event. Given that a firm has initiated five recall events and controlling for firm size measured in thousands of employees, the fact that a firm has a brand is associated with a 666.4 percent increase in the risk of recurrence of a recall event.

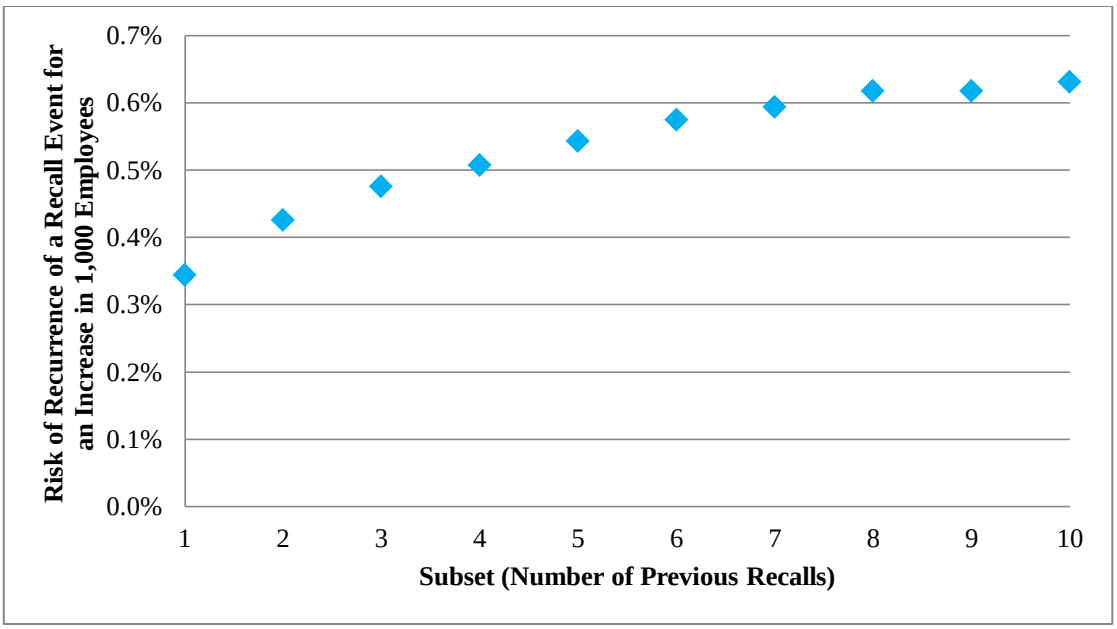

Figure 3. Trend of the risk of recurrence of recall events by firm size measured in employees for Model 2

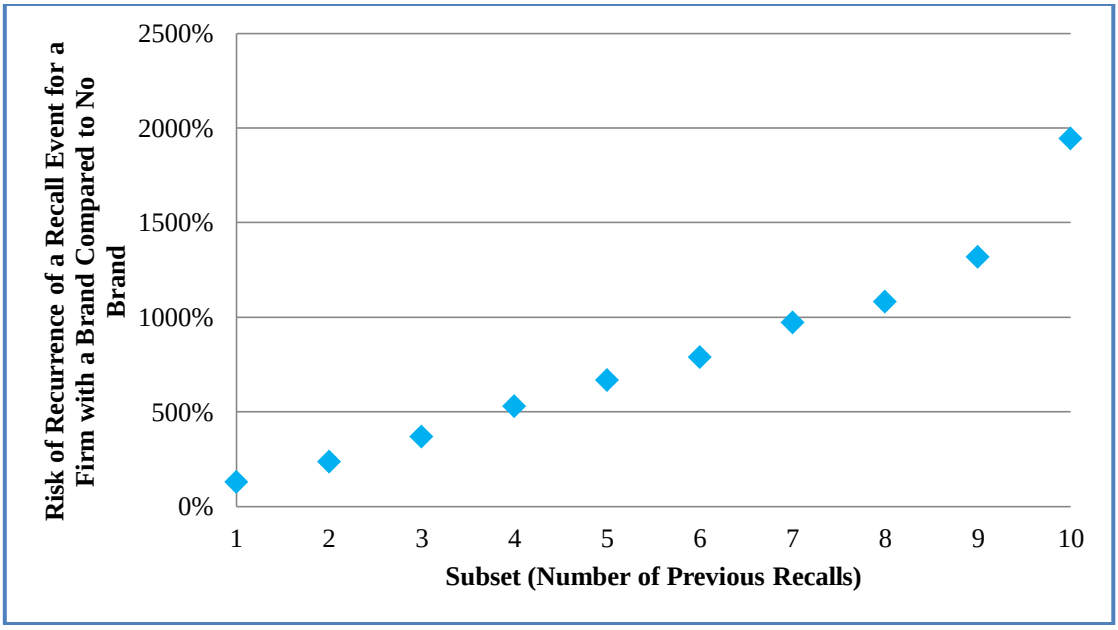

Figure 4. Trend of the risk of recurrence of events by branding for Model 2

5.4 Model 3

In our third model, we will estimate the regression parameters for firm size as measured in billions of dollars (MRS) and the number of brands variable (NBS). The model is given as:

(5) $$h(t) = \log h_0(t) + \beta_1 MRS + \beta_2 NBS.$$

The maximum likelihood estimates of the parameters, hazard ratios, and significance values are presented in Table 17.

Table 17. Cox Proportional Hazard Model for covariates and *MRS* and *NBS*

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRS	0.01191	<0.0001	1.012	135
NBS	0.01802	<0.0001	1.018	

We will check the proportionality assumption using the method provided by UCLA Academic Technology Services (2007) by creating time-dependent interaction for each of our two parameters, MRS and NBS. As before, we will use the suggested and commonly used $\log(Dif\_date)$ function of our time variable to interact with the covariates. Our model is given as:

(6) $$h(t) = \log h_0(t) + \beta_1 MRS + \beta_2 NBS + \beta_3 MRS * \log(Dif\_date) + \beta_4 NBS * \log(Dif\_date).$$

The maximum likelihood estimates are provided in Table 18.

Table 18. Cox Proportional Hazard Model for Covariates: MRS, NBS, $MRS * \log(Dif\_date)$, and $NBS * \log(Dif\_date)$

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRS	0.00475	0.2733	1.005	135
NBS	0.00347	0.7702	1.003	
$MRS * \log(Dif\_date)$	0.00203	0.0844	1.002	
$NBS * \log(Dif\_date)$	0.00249	0.1161	1.003	

A significant time-dependent interaction suggests that there may be a violation of the proportionality assumption for the variable that is interacted with. All of the time-dependent variables are not significant individually. Therefore, we conclude that the proportionality of both the sales and brand parameters are valid and consequently, the original model, parameter estimates, and hazard ratios are valid.

Therefore, from Table 17 and the hazard ratios, we conclude that:

(1) Given that one recall has occurred and controlling for the number of brands that a firm has, an increases in sales of $1 billion is associated with a 1.3 percent increase in the risk of recurrence of a recall event;

(2) Given that one recall event has occurred and controlling for the firm size measured in billions of dollars, an increase in the number of brands that a firm holds by one is associated with a 1.4 percent increase in the risk of recurrence of a recall event.

We will examine firms that have subsequent recall events beyond the second event. We will follow the procedure described earlier and will examine eight additional subsets created from the number of brands and firm size with regard to sale. The results are given in Table 19.

Table 19. Cox Proportional Hazard Models for Subset 02 through Subset 10 for Model 3

Subset	Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
02	MRS	0.01613	<0.0001	1.016	61
	NBS	0.02257	<0.0001	1.023	
03	MRS	0.01934	<0.0001	1.020	37
	NBS	0.02552	<0.0001	1.026	
04	MRS	0.02198	<0.0001	1.022	22
	NBS	0.02781	<0.0001	1.028	
05	MRS	0.02382	<0.0001	1.024	16
	NBS	0.02938	<0.0001	1.030	
06	MRS	0.02550	<0.0001	1.026	14
	NBS	0.03021	<0.0001	1.031	
07	MRS	0.02678	<0.0001	1.027	10
	NBS	0.03023	<0.0001	1.031	
08	MRS	0.02826	<0.0001	1.029	10
	NBS	0.03043	<0.0001	1.031	
09	MRS	0.02985	<0.0001	1.030	9
	NBS	0.03067	<0.0001	1.031	
10	MRS	0.03250	<0.0001	1.033	8
	NBS	0.03069	0.0001	1.031	

Figure 5 and Figure 6 illustrate that, with significance, the risk of recurrence of a future recall event continues to increase in association with both an increase in the number of brands that a firm has and an increase in firm size as measured in billions of dollars of sales.

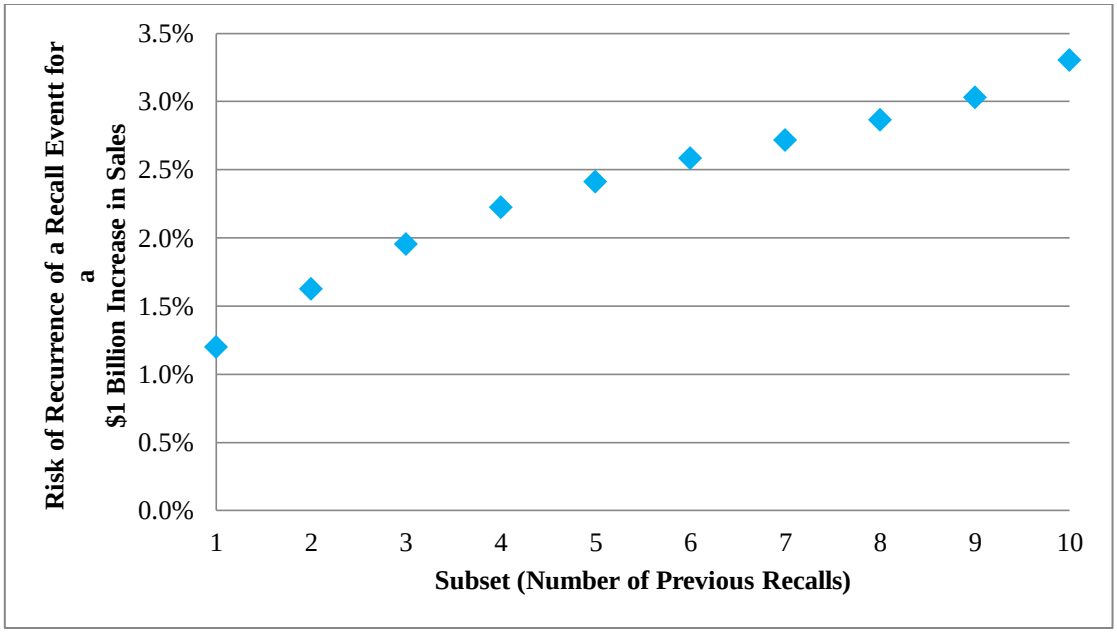

Figure 5. Trend of the risk of recurrence of events by firm size measured in sales for Model 3

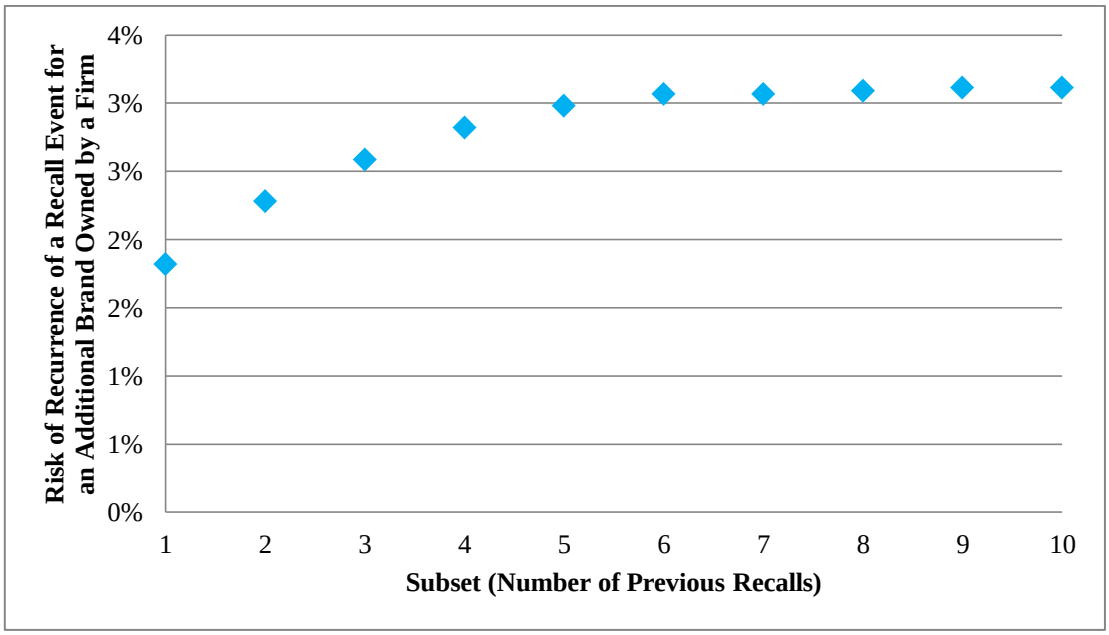

Figure 6. Trend of the risk of recurrence of events by number of brands for Model 3

5.5 *Model 4*

In our fourth model, we will estimate the regression parameters for firm size as measured in thousands of employees (MRE) and the number of brands variable (NBS). The model is given as:

(7) $$h(t) = \log h_0(t) + \beta_1 MRE + \beta_2 NBS.$$

The maximum likelihood estimates of the parameters, hazard ratios, and significance values are presented in Table 20.

Table 20. Cox Proportional Hazard Model for Covariates MRE and NBS

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRE	0.00446	<0.0001	1.004	162
NBS	0.01786	<0.0001	1.018	

We will check the proportionality assumption using the method provided by UCLA Academic Technology Services (2007) by creating time-dependent interaction for each of our two parameters, MRE and NBS. As previously, we will use the suggested and commonly used $\log(Dif\_date)$ function of our time variable to interact with the covariates. Our model is given as:

(8) $$h(t) = \log h_0(t) + \beta_1 MRE + \beta_2 NBS + \beta_3 MRE * \log(Dif\_date) + \beta_4 NBS * \log(Dif\_date).$$

The maximum likelihood estimates are provided in Table 21.

Table 21. Cox Proportional Hazard Model for Covariates: MRE, NBS, $MRE * \log(Dif\_date)$, and $NBS * \log(Dif\_date)$

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
MRE	0.00131	0.5520	1.001	162
NBS	0.00793	0.4811	1.008	
$MRE * \log(Dif\_date)$	0.00080	0.0771	1.001	
$NBS * \log(Dif\_date)$	0.00237	0.3096	1.002	

Again, a significant time-dependent interaction suggests that there may be a violation of the proportionality assumption for the variable that is interacted with. All of the time-dependent variables are not significant individually. Therefore, we conclude that the proportionality of both the employment and brand parameters are valid and consequently, the original model, parameter estimates, and hazard ratios are valid.

Therefore, from Table 20 and the hazard ratios, we conclude that:

(1) Given that one recall has occurred and controlling for the number of brands that a firm has, an increase in employees by 1,000 is associated with a 0.4 percent increase in the risk of recurrence of a recall event;

(2) Given that one recall event has occurred and controlling for the firm size measured in thousands of employees, an increase in the number of brands that a firm holds by one is associated with a 1.8 percent increase in the risk of recurrence of a recall event.

We will examine firms that have subsequent recall events beyond the second event. We will follow the procedure described earlier and will examine nine additional subsets created from the number of brands and firm size with regard to employment. The results are presented in Table 22.

Table 22. Cox Proportional Hazard Models for Subset 02 through Subset 10 for Model 4

Subset	Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	N
02	MRE	0.00589	<0.0001	1.006	75
	NBS	0.02135	<0.0001	1.022	
03	MRE	0.0067	<0.0001	1.007	44
	NBS	0.02407	<0.0001	1.024	
04	MRE	0.00729	<0.0001	1.007	30
	NBS	0.02667	<0.0001	1.027	
05	MRE	0.00772	<0.0001	1.008	22
	NBS	0.02863	<0.0001	1.029	
06	MRE	0.00811	<0.0001	1.008	18
	NBS	0.02912	<0.0001	1.030	
07	MRE	0.00827	<0.0001	1.008	13
	NBS	0.02957	<0.0001	1.030	
08	MRE	0.00822	<0.0001	1.008	13
	NBS	0.03169	0.0001	1.032	
09	MRE	0.00798	<0.0001	1.008	12
	NBS	0.03381	0.0002	1.034	
10	MRE	0.00811	<0.0001	1.008	10
	NBS	0.03504	0.0004	1.036	

Figure 7 and Figure 8 illustrate that, with significance, the risk of recurrence of a future recall event continues to increase in association with both an increase in the number of brands that a firm has and an increase in firm size as measured in thousands of employees.

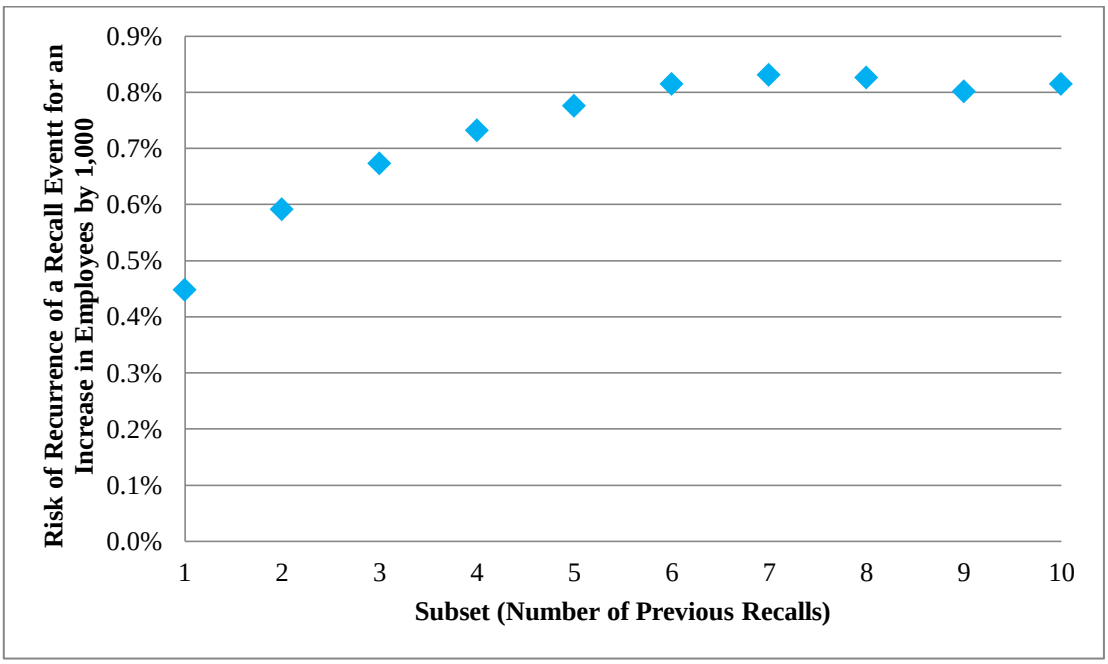

Figure 7. Trend of the risk of recurrence of events by firm size measured in employees for Model 4

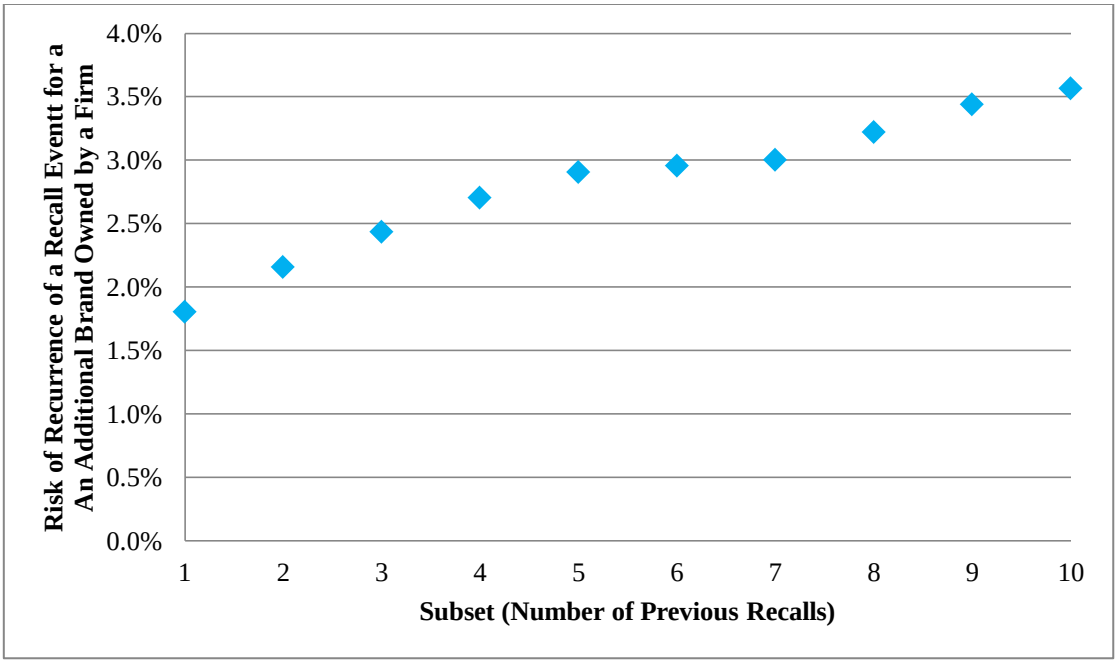

Figure 8. Trend of the risk of recurrence of events by number of brands for Model 4

5.6 Reexamination of Models One-Four with Quadratic Functions of Continuous Explanatory Variables

In this subsection we will reexamine the previous models by including quadratic functions of the continuous explanatory variables. We will perform this procedure to capture the marginal effects of increments in these explanatory variables on the relative risk of a recall. It will also be feasible to determine a threshold point. The threshold or turning point is of merit as it will provide an introspective into the risk of a recall event based on the magnitude of the variable in question. For this analysis, it may be that there is actually a change in the slope of the relationship between the risk

and the explanatory variables for largest and smallest firms or between the firms with the greatest number and least number of brands.

5.7 Model 5

We will begin by reexamining Model 1 from earlier in Section 5. We will denote this model as Model 5. In this model we will estimate the regression parameters for sales measured in billions of dollars, a quadratic function of this sales variable, and the binary brand variable. This model is presented as:

$$h(t) = \log h_o(t) + \beta_1 MRS + \beta_2 MRS^2 + \beta_3 BYN \quad (9)$$

Here, $h(t)$ is the risk of the second recall given that the firm has already experienced one recall event.

The maximum likelihood estimates for the parameter estimates, the hazard ratios rounded to three decimal places, and the Chi-square significance values form the Cox proportional hazard model are provided in Table 23.

Table 23. Cox Proportional Hazard Model for Covariates: MRS, MRS^2, and BYN

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	n
MRS	0.02638	<0.0001	1.027	157
MRS^2	-0.00016	0.0003	1.000	
BYN	0.71115	<0.0001	2.036	

The effects of all explanatory variables are significant. We will assume that all variables are proportional based on our findings in the initial model in Section 5.

At this time, we will examine the threshold point for our sales variable. Again, the threshold is the value where the marginal effect on the relative risk associated with an incremental change in sales is zero. We will begin by focusing on the hazard rate and the parameter estimates for sales. The hazard rate associated with sales is presented as:

(10) $h(t) = 0.02638 * MRS - 0.00016 * MRS^2$

To locate the threshold value, we must find the point where the slope of the hazard function is equivalent to zero. To do this, we will differentiate this hazard function with respect to the independent variable MRS. Therefore,

(11) $h'(t) = 0.02638 - 2 * (0.00016) * MRS$

By setting the first derivative equal to zero and solving for the independent variable, we can calculate the threshold value.

(12) $MRS = \frac{0.02638}{2*0.00016} = 82.4375$

As sales are measured in billions of dollars, the threshold for sales is 82.4375 billion dollars. However, before we proceed, we should identify this point as a

maximum or minimum value of our quadratic function. We accomplish this by taking the second derivative of our hazard function.

(13) $h''(t) = -2 * 0.00016 = -0.00032$

The second derivative is negative and therefore we have a maximum value at the threshold point for sales of 82.4375 billion dollars. As the hazard rate is defined as the risk of a second recall given that a firm has experienced one recall event, this risk continues to increase at a diminishing rate for a firm up to 82.4375 billion dollars in sales. At the threshold, the risk is the highest and beyond this point, the risk begins to decline.

We should mention that the threshold point of 82.4375 billion dollars in sales is at the higher end of the sales figures for the firms in this analysis where the average is 12.301 billion dollars. There are only two recall events in this model that have sales greater than the threshold point. Therefore, the quadratic function is concave down with only very few observations beyond the turning point.

We will now focus on the hazard ratios from our parameter estimates with guidance provided by SAS Institute Inc. (2009). The hazard ratio for the binary brand variable is calculated from our parameter estimate. It is the exponential function of the parameter estimate for the brand binary variable.

(14) $HZ_B = \exp(0.71115) = 2.036$

As we can see, there are separate hazard ratios calculated for the coefficients on both the linear and quadratic terms of the sales variable. We can calculate a hazard ratio for the collective terms. This hazard ratio for the sales variable is a little more difficult to calculate considering the parameter estimate of the quadratic variable. We proceed taking the exponential function of the additive parameter estimates for the linear and quadratic variables (SAS Institute, 2010).

(15) $HZ_{Sales} = \exp(0.02638 - 0.00016) = 1.02657$

From here, we can calculate the increase in the relative risk of a second recall event associated with a 1 billion dollar increase in sales. This figure is calculated as the absolute value of one minus the hazard ratio and will be denoted as RR_{Sales}.

(16) $RR_{Sales} = |1 - HZ_{Sales}| = 0.02657$

We can also do a final check to make sure that we calculated the hazard ratio correctly. We will calculate the individual hazard ratios for the two sales parameter estimates, from there the respective increases or decreases in the relative risk of a second recall event, and then add these individual relative risk influences to find the overall association of the sales variables to the relative risk of a second recall event.

The first step is to calculate the individual hazard ratios for the sales variables by hand.

(17) $HZ_{MRS} = \exp(0.02638) = 1.02673$

(18) $HZ_{MRS^2} = \exp(-0.00016) = 0.99984$

The second step is to calculate the respective increases or decreases in the relative risk of a second recall event. As the hazard ratio for the MRS term is greater than one, there will be an increase in the relative risk. As the hazard ratio for the MRS^2 term is less than one, there will be a decrease in the relative risk. These are calculated as provided earlier in Section 5 by taking the absolute value of the difference between one and the respective hazard ratio. Here we will denote the relative risk associated with the MRS term as RR_{MRS} and the relative risk associated with the MRS^2 term as R_{MRS^2} .

(19) $RR_{MRS} = |1 - 1.02673| = 0.02673$

(20) $RR_{MRS^2} = |1 - 0.99984| = 0.00016$

We must remember that the relative risk associated with the MRS term is increasing and that the relative risk associated with the MRS^2 term is decreasing. Therefore, to calculate the cumulative effect in relative risk associated with sales we will subtract the relative risk associated with MRS^2 from the relative risk associated with MRS.

(21) $RR_{MRS} - RR_{MRS^2} = 0.02673 - 0.00016 = 0.02657$

This is the same value that we found in equation (7), an overall increase in the relative risk associated with an increase of 1 billion dollars in sales.

We will now offer the interpretations of the hazard ratios for the sales and binary brand variables as we have in the previous section according to the guidance of SAS Institute Inc. (2009).

(1) Given that one recall event has occurred and controlling for if a firm has a brand or not, an increase in sales of $1 billion is associated with a 2.7 percent increase in the risk of recurrence of a recall event when considering the decreasing marginal effects of an increase in sales. However, this effect is modestly diminishing after the threshold value for the largest firms.

(2) Given that one recall event has occurred and controlling for sales of the firm in billions of dollars, the fact that a firm has a brand is associated with a 103.6 percent increase in the risk of recurrence of a recall event.

For the reexaminations of Model 2, Model 3, and Model 4, to be noted as Models 6,7, and 8 respectively, we will not present the detailed background that we have for Model 5. Instead, we will focus on the results of the examinations on the following pages.

5.8 Model 6

In this model we will estimate the regression parameters for employees measured in thousands, a quadratic function of this employees variable, and the binary brand variable. This model is presented as:

$$(22) \qquad h(t) = \log h_o(t) + \beta_1 MRE + \beta_2 MRE^2 + \beta_3 BYN$$

The maximum likelihood estimates for the parameter estimates, the hazard ratios rounded to three decimal places, and the Chi-square significance values form the Cox proportional hazard model are provided in Table 24.

Table 24. Cox Proportional Hazard Model for Covariates: MRE, MRE^2, and BYN

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	n
MRE	0.00982	<0.0001	1.010	188
MRE^2	-0.00002	<0.0001	1.000	
BYN	0.75511	<0.0001	2.128	

The threshold point for the hazard function associated with employment numbers is calculated as before and has a value of 254,500 employees and is a maximum point. It should be noted that we found the average number of employees to be 32,422 in Table 24. Therefore, the threshold value is on the high end of our firm data. There are two recall events associated with a number of employees greater than the threshold value. Again, the threshold is the point at which the risk of a second recall event occurring given that one recall event has occurred is the greatest. Beyond this point, the risk begins to diminish.

The cumulative hazard ratio for the employment term is calculated as 1.00986. The hazard ratio for the brand binary variable is given in Table 24 as 2.128. Therefore the hazard ratios for this model are interpreted as:

(1) Given that one recall event has occurred and controlling for if a firm has a brand or not, an increase in employees by 1,000 is associated with a 0.1 percent increase in the risk of recurrence of a recall event when considering the decreasing marginal effects of an increase in employees. Beyond the threshold point for employees, the effect is diminishing.

(2) Given that one recall event has occurred and controlling for number of employees in thousands, the fact that a firm has a brand is associated with a 112.8 percent increase in the risk of recurrence of a recall event.

5.9 Model 7

In the seventh model we will estimate the regression parameters for sales measured in billions of dollars, a quadratic function of this sales variable, the number of brands variable, and a quadratic function of the number of brands variable. This model is presented as:

(23) $$h(t) = \log h_o(t) + \beta_1 MRS + \beta_2 MRS^2 + \beta_3 NBS + NBS^2$$

The maximum likelihood estimates for the parameter estimates, the hazard ratios rounded to three decimal places, and the Chi-square significance values from the Cox proportional hazard model are provided in Table 25.

Table 25. Cox Proportional Hazard Model for Covariates: MRS, MRS^2, NBS, and NBS^2

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	n
MRS	0.03499	<0.0001	1.036	135
MRS^2	-0.00020	<0.0004	1.000	
NBS	0.02939	0.0864	1.030	
NBS^2	-0.00037	0.2664	1.000	

The parameter estimates for the sales variables are both significant, where those for the number of brands are not. For our analysis, we will consider the number of brands term to be linear and will not consider the quadratic term due to its very high p-value.

Again we will calculate the threshold value for the sales term. It has a value of 87.547 billion dollars which is comparable to the figure that we found in Model 5. Again, we mention that most of the firms fall well below this figure. There were two recall associated with sales values above the threshold value.

We calculate the cumulative hazard ratio for the sales term as 1.0356 and note that the hazard ratio from the number of brands variable in Table 25 is 1.030. Therefore:

(1) Given that one recall event has occurred and controlling for the number of brands controlled by a firm, an increase in sales of 1 billion dollars is associated with a 3.6 percent increase in the risk of recurrence of a recall event when considering the decreasing marginal effects of an increase in sales. This relative risk begins to diminishes beyond the threshold point.

(2) Given that one recall event has occurred and controlling for sales in billions of dollars, an increase in the number of brands that a firm holds by one is associated with a 3.0 percent increase in the risk of recurrence of a recall event.

5.10 Model 8

In our final model we will consider the number of employees, a quadratic function of this term, the number of brands, and a quadratic function of the number of brands. The model is presented as:

(24) $$h(t) = \log h_0(t) + \beta_1 MRE + \beta_2 MRE^2 + \beta_3 NBS + \beta_4 NBS^2$$

The hazard ratios, parameter estimates of the maximum likelihood functions, and the Chi-square significance values are provided in Table 26**.**

Table 26. Cox Proportional Hazard Model for Covariates: MRE, MRE^2, NBS, and NBS^2

Variable	Parameter Estimate	Pr > Chi Sq	Hazard Ratio	n
MRE	0.01528	<0.0001	1.014	162
MRE^2	-0.00005	<0.0001	1.000	
NBS	0.05368	<0.0001	1.055	
NBS^2	-0.00071	0.0080	0.999	

It is obvious that all of the parameter estimates and therefore the hazard ratios for explanatory variables are significant.

The threshold value for the employment parameters has a value of 152,800 employees and the threshold value for the number of brands is 37.80. Both of these figures are on the higher end of the values in the data. There are five recall associated with firms having sales values greater than the threshold value and three events associated with firms having a greater number of brands than the threshold for brands. In fact, the most brands controlled by a single firm in our dataset are fifty.

The value of the cumulative hazard ratio for the employee term is 1.0154 and the value of the cumulative hazard ratio for the number of brands term is 1.0544. Therefore:

(1) Given that one recall event has occurred and controlling for the number of brands a firm has, an increase in 1,000 employees is associated with a 1.4

percent increase in the risk of recurrence of a recall event when considering the decreasing marginal effects of an increase in employees. The relative risk associated with an increase in the number of employees diminishes after the threshold value for the firms with the greatest number of employees.

(2) Given that one recall event has occurred and controlling for the number of employees measured in thousands, an increase in the number of brands that a firm holds by one is associated with a 5.5 percent increase in the risk of recurrence of a recall event when considering the diminishing marginal of an increase in the number of brands. This relative risk diminishes after the threshold for the firms holding the largest number of brands.

5.11 Summary Statistics and Findings

At this point, we would like to discuss some summary statistics and interesting findings that are not directly related to the models that were analyzed. We will begin by discussing the most recent sales (MRS) and most recent employees (MRE) variables that were created to represent firm size. The results are reported in Table 27 and Table 28, respectively. From the original corporate information data, we can see that the mean sales were $12.302 billion with a minimum observation of only $100,000 and a maximum observation of $120.439 billion. We were able to collect 909 MRS observations. The mean value MRE was 32,422 employees with a minimum observation of one employee and a maximum observation of 351,000 employees. Good

Karma Food Technologies had only one employee and the Target Corporation had 351,000. We should also comment on the fact that the threshold values for sales found in Models 05 and 07 are much greater than the median shown in Table 27. This gives a depiction of the very slow and gradual curvature of the quadratic function where the majority of firms have sales below the turning point. The same is found with respect to the threshold values of the employment terms found in Models 06 and 08. With a median value of 1,135 employees and a threshold ranging from 150,000 to 250,000, we can get a picture that most of the firms are located well below this threshold value.

Table 27. Most Recent Sales $(\boldsymbol{MRS})$ Descriptive Statistics

Number of Observations	909
Mean	$12.302 Billion
Standard Deviation	$27.230 Billion
Minimum Value	$100,000
Maximum Value	$120.439 Billion
25^{th} Percentile	$6 Million
Median	$180 Million
75^{th} Percentile	$7.586 Billion

Table 28. Most Recent Employees (MRE) Descriptive Statistics

Number of Observations	1,066
Mean	32,421.606
Standard Deviation	69,692.543
Minimum Value	1
Maximum Value	351,000
25^{th} Percentile	45
Median	1,235
75^{th} Percentile	25,820

The next data that we would like to mention are from the original recall dataset. Figure 9 and Figure 10 capture the types of products recalled. Figure 9 shows the types of goods as percentages of total goods recalled over the January, 2000 through October, 2009 time span. Figure 10 compares the groups by the actual number of recall events. Confectionary goods topped the results with 483 recall events. Many of these events are due to in-store bakeries of retail supermarkets, having problems connected with mislabeling and ingredients that may be potential allergens.

Figure 11 and Figure 12 capture the problems associated with the product recall events over the January, 2000 to October, 2009 period. Figure 11 captures the problems associated with the recall events as percentages of the total recalls. Figure 12 compares the problem types by the actual number associated with each. As we can see, most of the recalls were the result of salmonella contamination and mislabeled ingredients.

Figure 13 compares the frequency of recall occurrence due to specific pathogens that include *Salmonella, E. coli,* and *Listeria.* As we can see, the frequencies tend to move together and there were large spikes in all three in 2009. The sharp increases in Salmonella cases in 2009 were due to two specific events. The first was triggered a bulk recall of peanut butter by the Peanut Corporation of America. This recall affected many other secondary manufacturers that used peanut butter as an ingredient in their goods. The second was triggered by a large recall of pistachios by Setton Pistachios of California.

Figure 14 and Figure 15 capture the percentage of recall events occurring by year and the trend in the number of recall events issued, respectively. The trend is rather steady throughout the 2000 to 2008 period ranging from 123 to 216 recalls with a moderate spike in 2002 with 283 recalls. However, there is a considerable spike in 2009 with 742 events reported through October of that year.

Figure 16 captures the state of origin for the product recalling firm. Firms in several states have issued over 100 recalls. In fact, New York led with 400, followed by California with 330, New Jersey with 120, Michigan with 114, and Illinois with 107. There were no firms that issued a recall from the state of Wyoming.

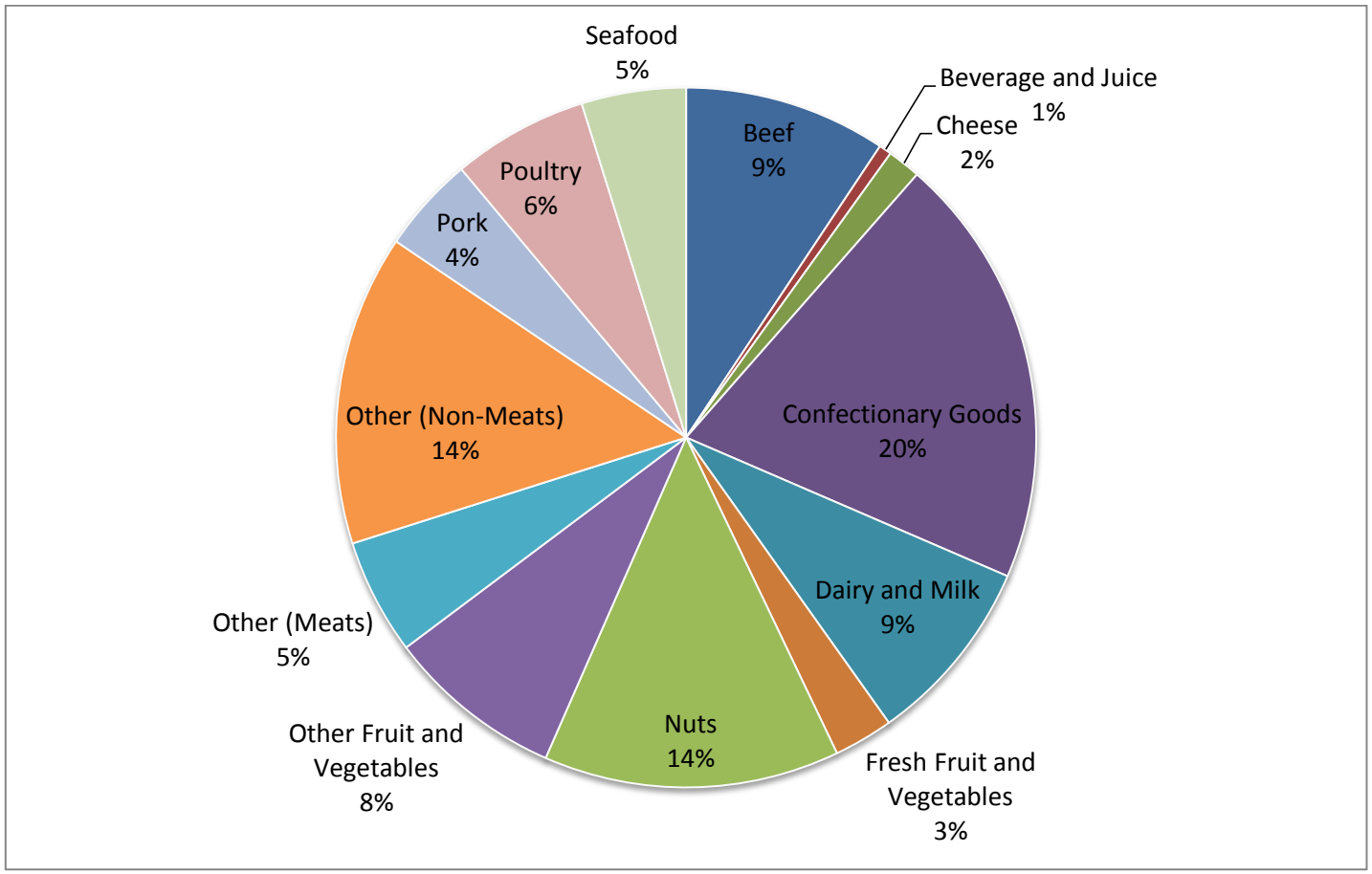

Figure 9. Products recalled by type (January 2000-October 2009)

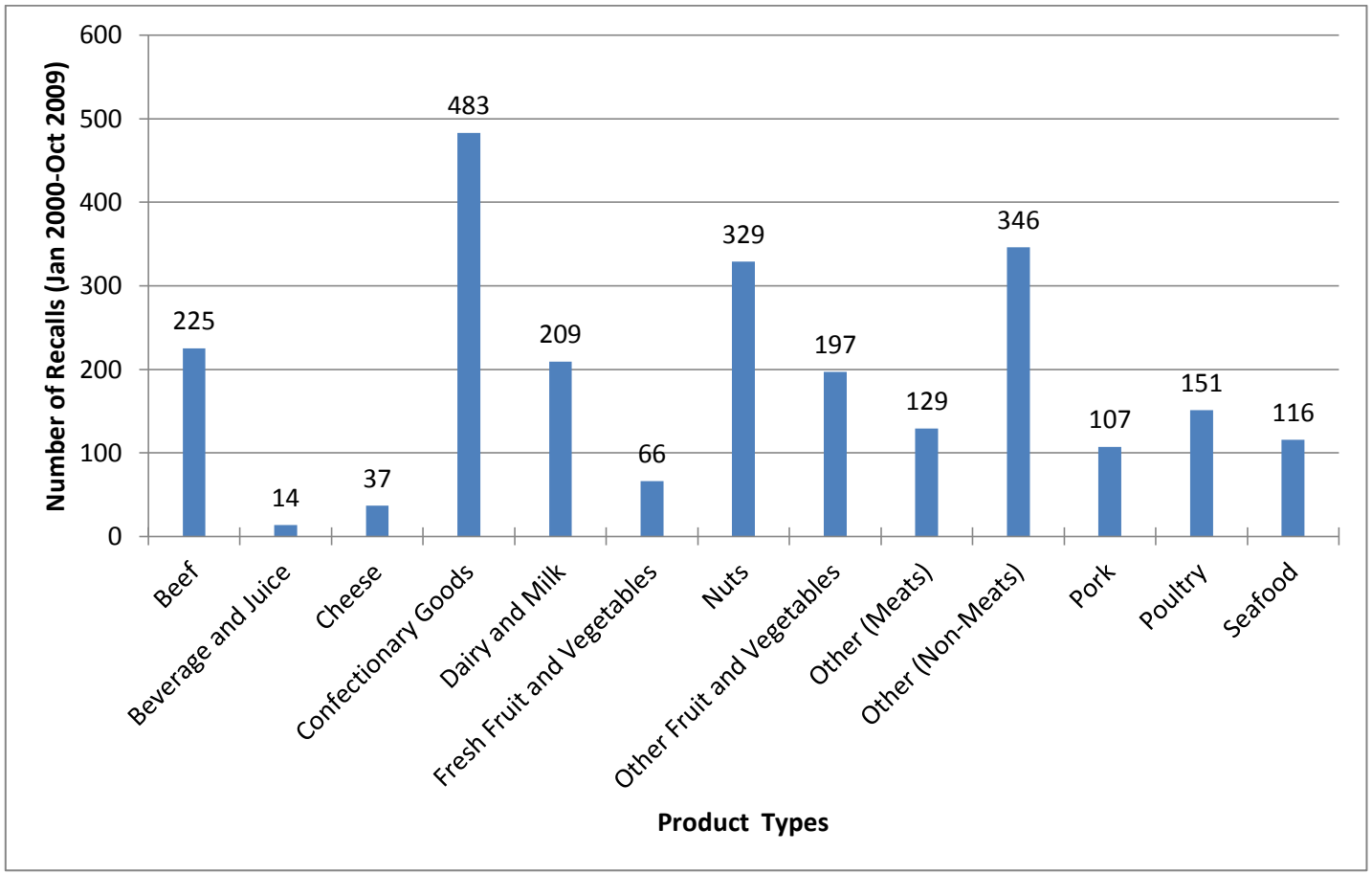

Figure 10: Frequency of products recalled by product type (January 2000-October 2009)

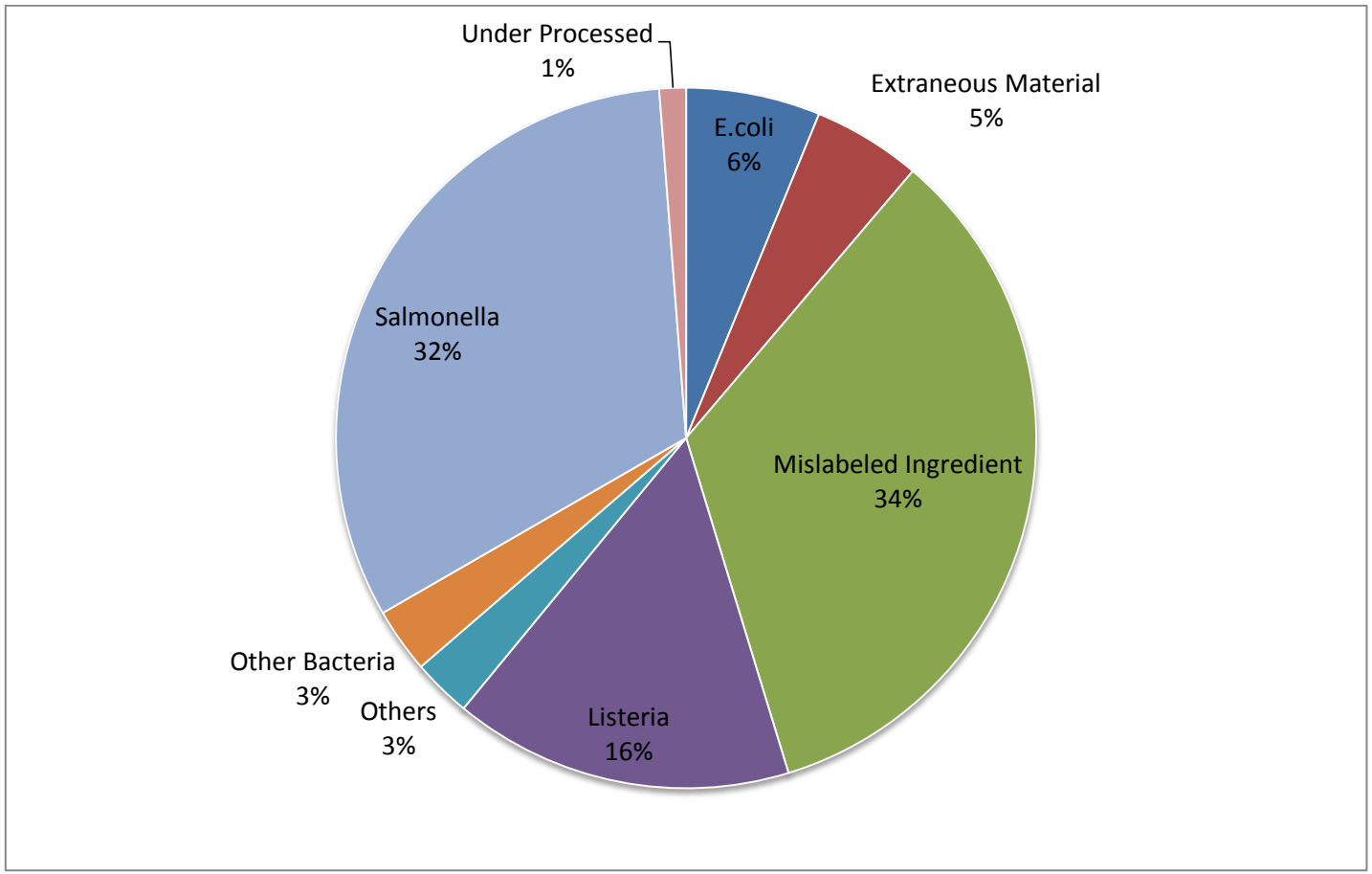

Figure 11. Problems associated with recall events (January 2000-October 2009)

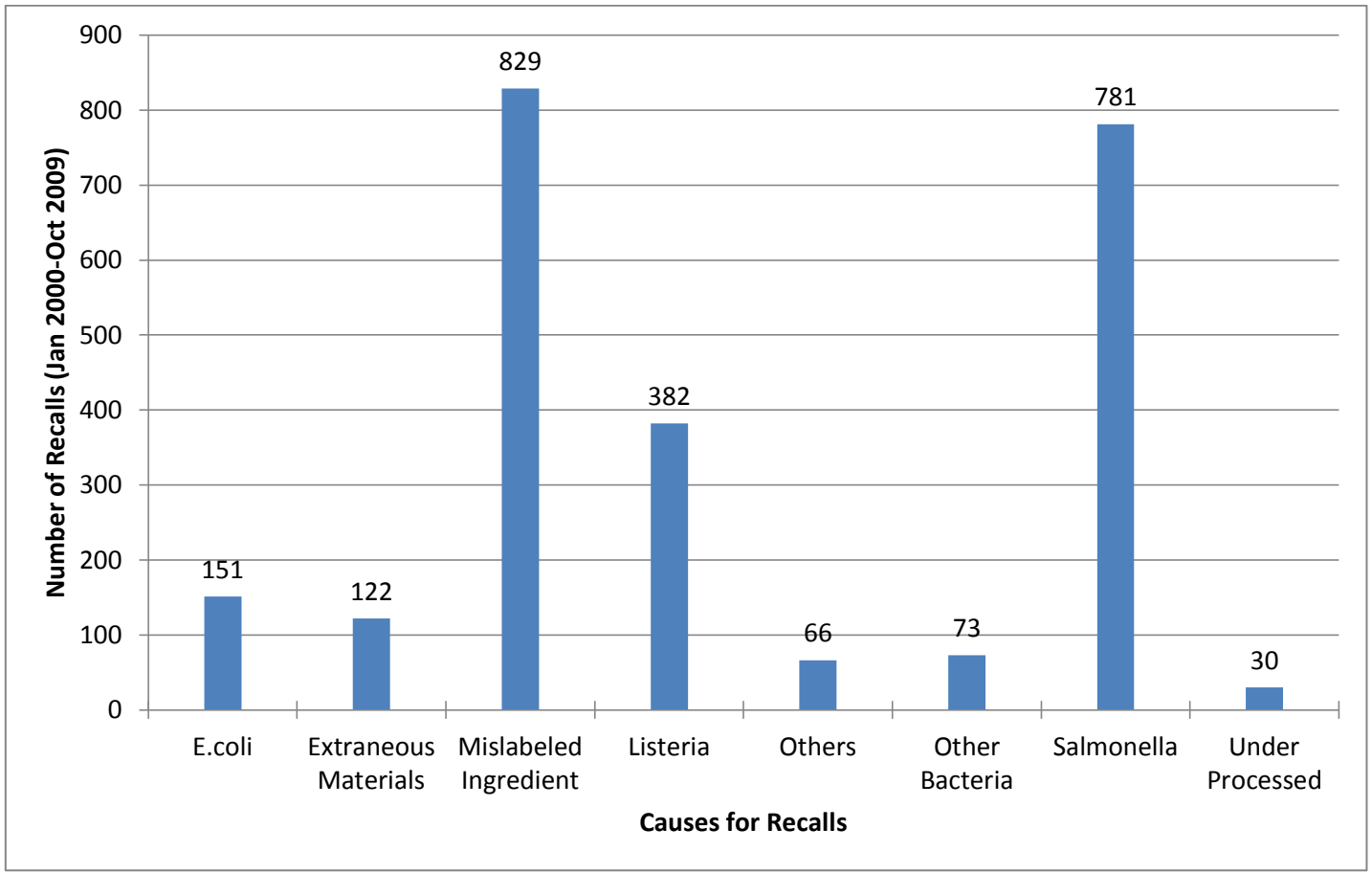

Figure 12. Frequency of problems associated with recall events (January 2000-October 2009)

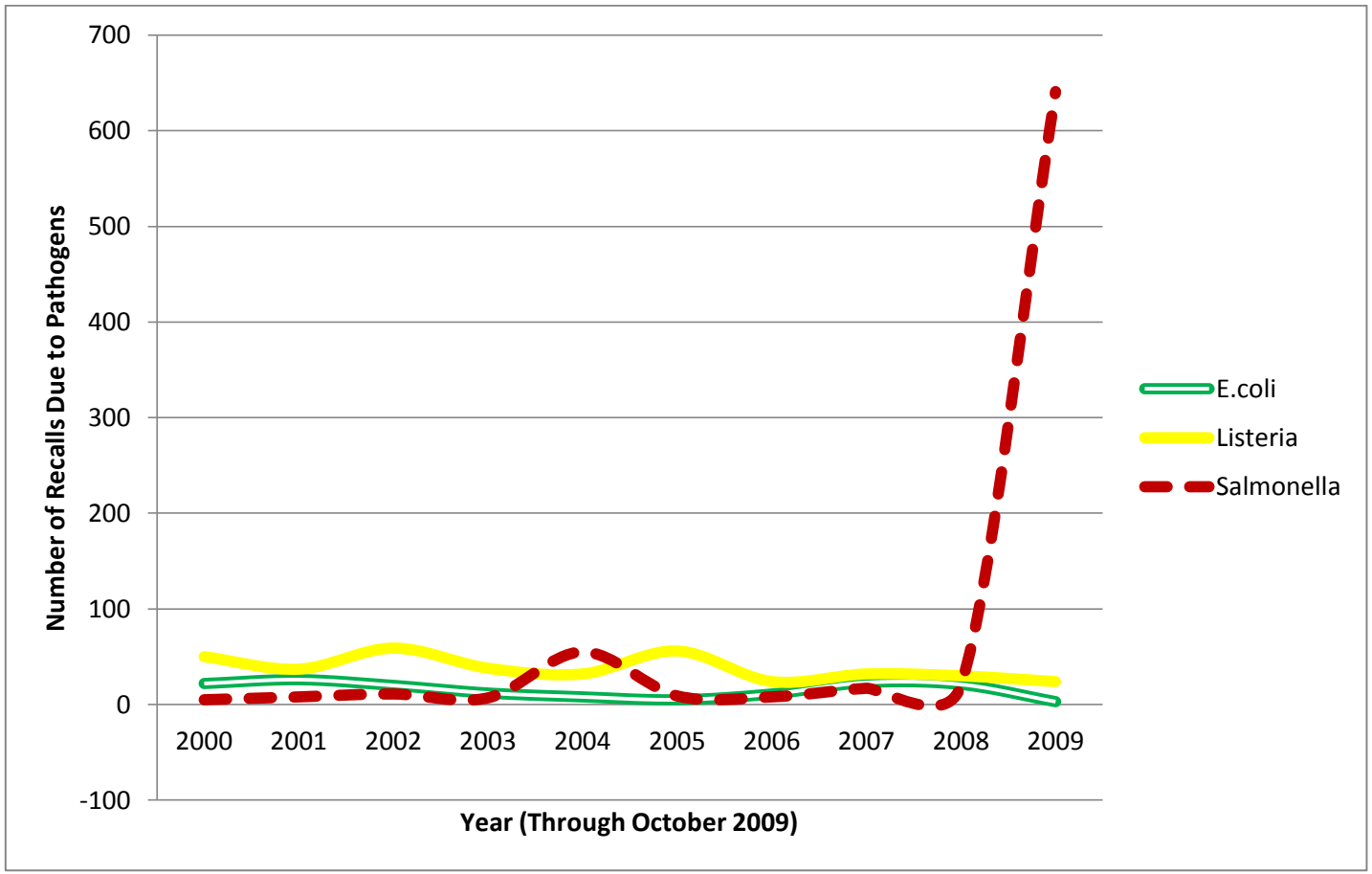

Figure 13. Frequencies of recall occurrence due to specific pathogens (January 2000-October 2009)

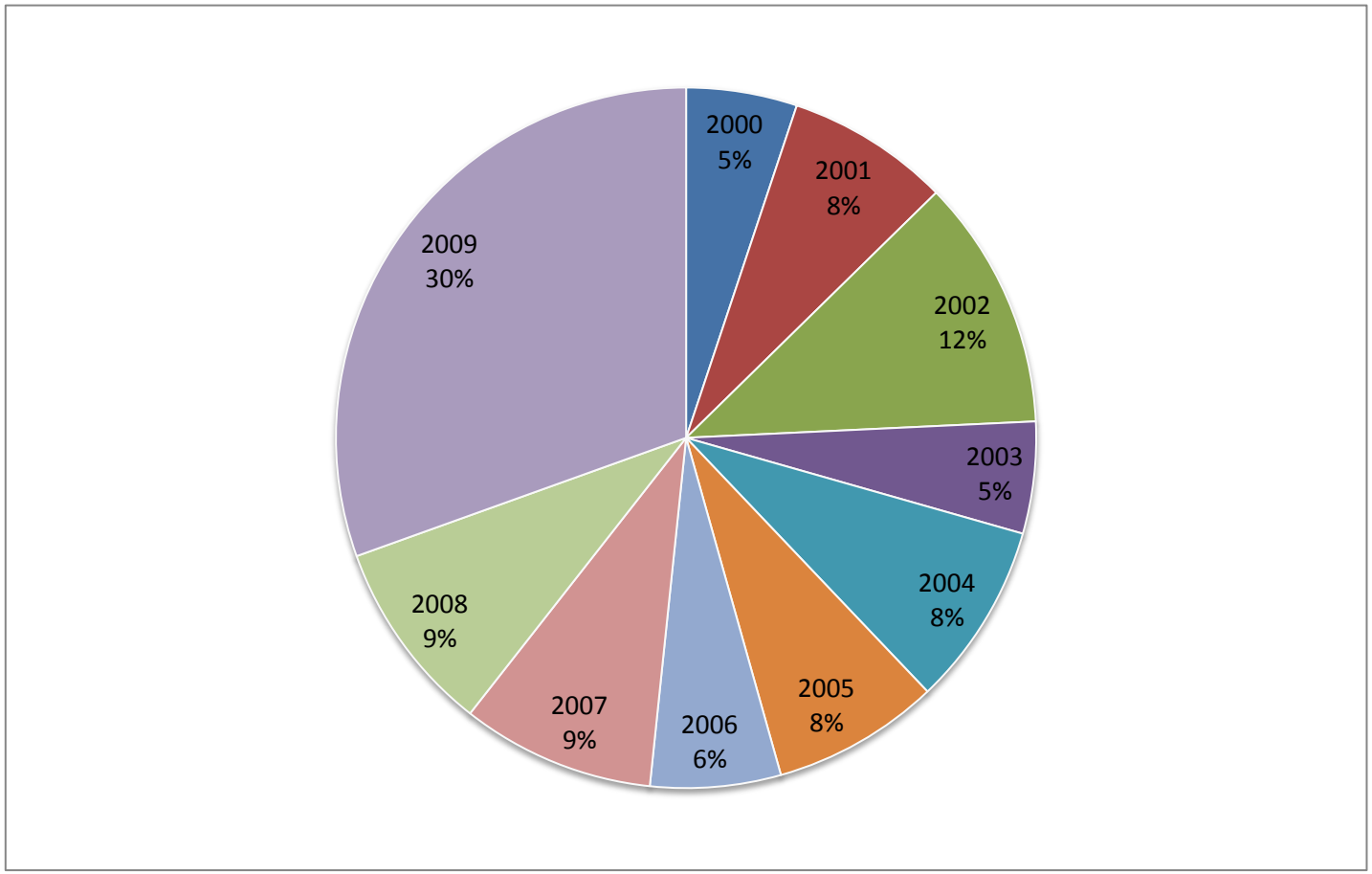

Figure 14. Occurrences of recall events by year (January, 2000-October, 2009)

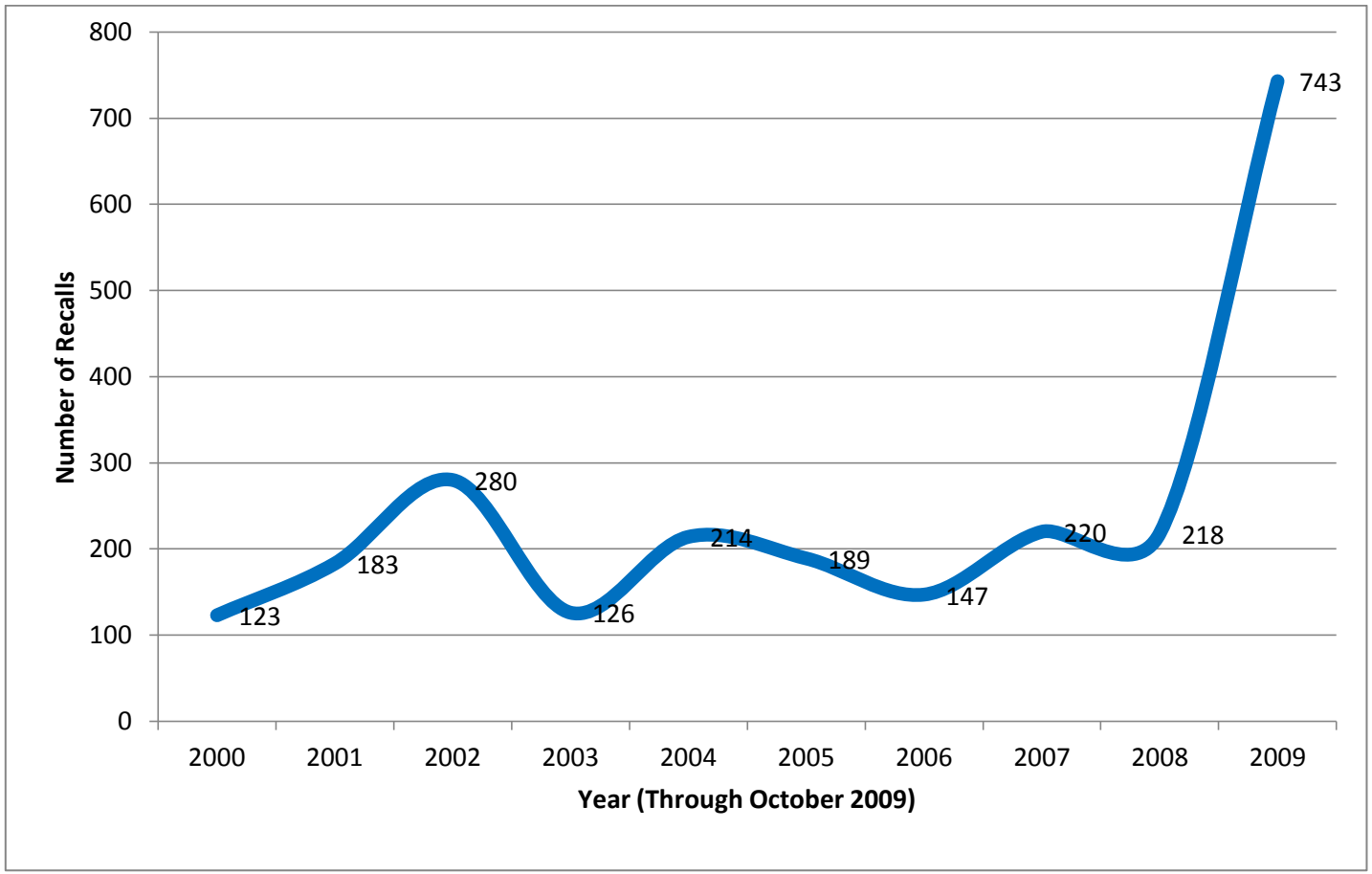

Figure 15. Trend of recall events by year (January 2000-October 2009)

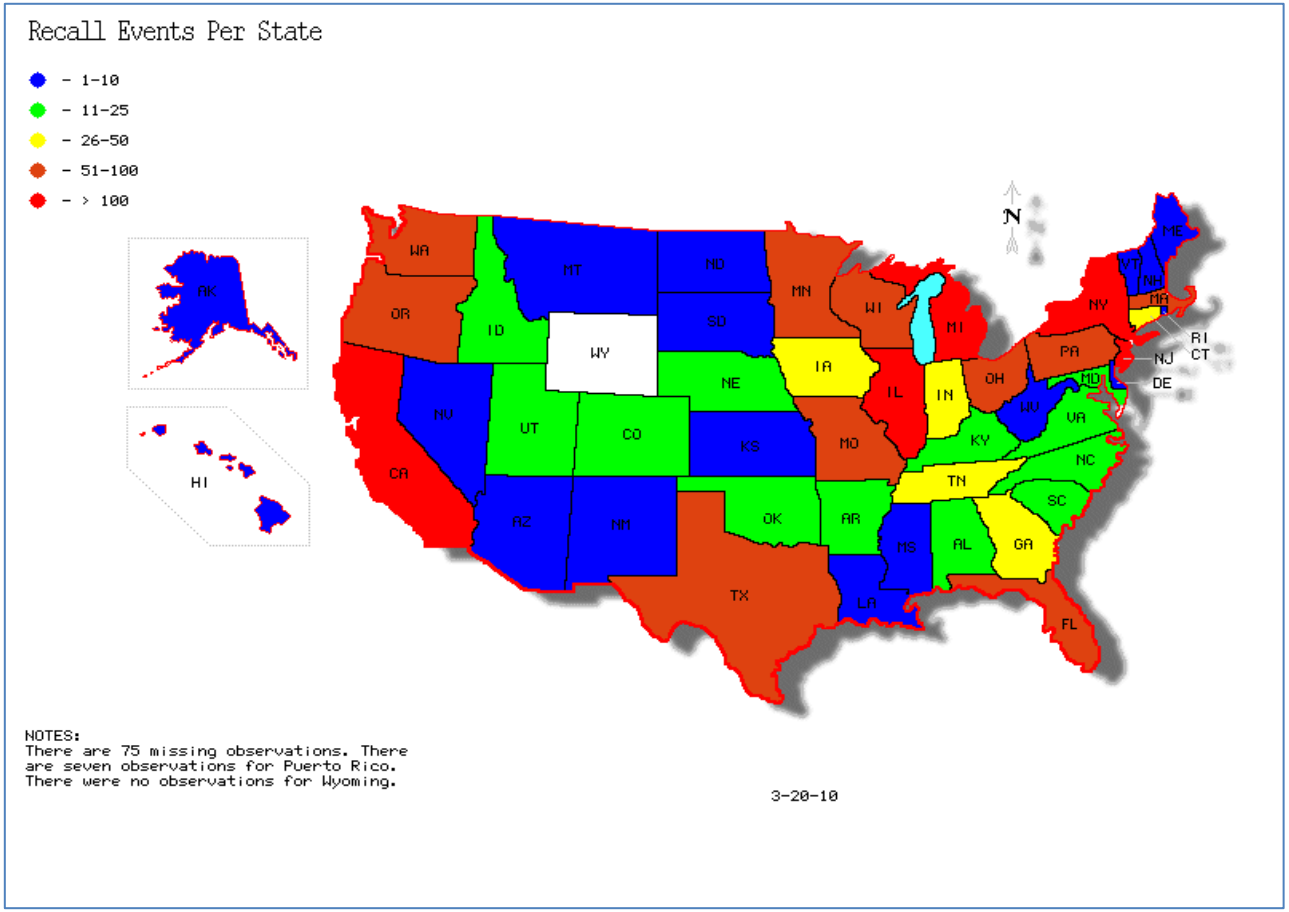

Figure 16. Recall events per state (January 2000-October 2009)

There are several firms that are noteworthy based on the high frequency of recall events per firm. Some of these firms are presented in Table 28 along with a brief description of their primary business activities, whether the company is public or private, the number of recall events occurring between January, 2000 and October, 2009, and the sales for the firm. Information for their business activities was collected from their respective corporate websites. While the vast majority of firms have only a few recall events, it is interesting that some firms have as many as 18, 19, or 20 recall events over an approximate ten year period.

Table 29. Noteworthy Examples of Firms with Multiple Recalls

Firm	Business Activities	Public/Private	Recall Events	Sales (Billions)
Cargill, Inc.	Food, Agricultural, Financial and Industrial Products and Services	Private	20	$120.439
ConAgra Foods	Consumer Foods and Commercial Products	Public	19	$12.731
Harry and David Holdings, Inc.	Direct Marketing and E-Commerce	Private	19	$0.541
Kellogg Company	Cereals and Convenience Foods	Public	15	$12.822
Kraft Foods, Inc.	Food Products	Public	18	$42.201
Nestlé S.A.	Nutrition, Health and Wellness Products	Public	18	$104.061
The Kroger Company	Grocery, Department Stores, Jewelry Stores	Public	19	$76.000
Tyson Foods, Inc.	Chicken, Beef, and Pork Food Products	Public	14	$26.862
Whole Foods Market, Inc.	Natural and Organic Foods	Public	18	$7.954

Sources: Cargill, Inc. (2010); ConAgra Foods (2010); Giant Food, Inc. (2010); Harry and David (2010); The Kellogg Company (2010); Kraft Foods, Inc. (2010); Nestlé (2010); Tyson Foods, Inc. (2010); Whole Foods Market, Inc. (2010).

6. CONCLUSIONS

In conclusion, we will first examine our initial hypotheses and the results of our analyses. Then we will consider further food safety work that may be of interest and could be realized as accompaniments to this initial research.

Based upon economic and management theories presented in Section 4, we made two hypotheses. The first hypothesis contended that, controlling for firm branding, an increase in the size of a firm will increase the risk of recurrence of recall events. Therefore, we expected the hazard ratios for the firm size variables to be greater than one. This hypothesis was based on our belief that the larger firm is expected to face bounded rationality constraints and be less able to manage effectively across production.

In our analysis, we failed to reject our hypothesis as we found consistently significant hazard ratios greater than one for the firm size measures of sales in billions of dollars and thousands of employees in all three models. The results conform to the economic theories proposed by Coase (1937) and Simon (1957) on bounded rationality within the firm. As the size of the firm increases, growing complexities within the firm limit management's ability to organize, supervise, and implement employees, structure, and standards on an increasing quantity and variety of products and services. The hazard ratios for firm size were small and increased with the number of food recalls. A

threshold in the growth rate of risk increasing was found at size increases of 82.4375 billion dollars in sales and at 254,500 employees.

The second hypothesis contended that, controlling for firm size, branding by the firm and an increasing portfolio of brands within the firm will decrease the risk of recurrence of recall events. Therefore, we expected the hazard ratios for branding by the firm and the number of brands within the firm to be less than one. This hypothesis was based on our belief that branding is a signal of higher quality, safer products.

In our analysis, we rejected our hypothesis as we found consistently significant hazard ratios greater than one. This occurred for branding by the firm in Model 1 and Model 2, and for the number of brands within the firm in Model 3 and Model 4. The hazard ratios for brands were very large and they increased with the number of occurrences of food recalls.

It is imperative that we offer several alternative plausible explanations for our findings that the relative risk of recall events increases as both firm size measured in sales and employees and branding by a firm increase. We will first begin by considering the firm size.

It may be the case that larger firms control larger volumes of product that is at risk of a problem occurring. The association of increased relative risk of recall to firm size may actually be an attribute of the volume of product processed by the firm. The likelihood of a rare event occurring that could trigger the need for a recall would lead to

more recalls for firms that process higher volumes. If it is possible to gather accurate information about the product volumes of firms in the food industry, the understanding of this influence on the firm size indicators of risk could be enhanced. The data we have available is for values of sales, not volume, and is not used in a normalization of the risk.

A second alternative plausible explanation with regard to the increase in relative risk of larger firm size may be due to the possibility that larger firms process riskier products. For example, many meat and poultry processors are very large and process, handle, and ship millions of pounds of product over a relatively short period of time. The risk of contamination for these products from pathogens such as *E. coli* and *Salmonella* is higher than for most other products. This is partly due to the fact that the animals to be processed usually enter the facilities with the pathogen present on their bodies. This could be studied by utilizing information on the type of problem associated with each individual recall event and level of severity such as the recall classification system used by FDA and FSIS.

A third alternative plausible explanation for the increased relative risk of a recall for a larger firm may be partly explained by the experience and education levels of employees. It is widely believed that many large production operations in the food sector employ unskilled and inexperienced workers on production lines. This is transparent in the produce and meatpacking industries where seasonal and migrant

workforces are essential requirements for cost reduction in a competitive environment. If workers do not understand food safety practices and do not recognize the potential consequences of failures, then it is possible that they will not uphold food safety as a priority. Information such as indicators of employee age, relevant work experience in the food sector, education levels, and provisions of food safety training may assist in painting a clearer picture of influence of experience and education on the association of firm size to relative risk of a recall event.

A final plausible explanation for the increased relative risk of recalls associated with firm size may relate to short-term pressures from shareholders. Many larger firms are publicly traded. Pressures to increase sales, revenues, and profits may encourage management to forgo some costly quality and safety practices. Dr. Frank Dooley (2010), professor of agricultural economics at Purdue University suggested that stock prices and other financial indicators for publically traded firms could be a starting point for this analysis. This information is readily available and accessible, but incorporating it into this model may prove to be difficult. Data pertaining to the many small private companies would not be available and therefore a separate analysis considering only publically traded firms could be performed.

Now we will shift focus to providing several alternative plausible explanations for the increased relative risk associated with branding.

The first alternative plausible explanation that we will suggest may be that consumers' higher expectations of the quality of branded products pressures firms to maintain this expectation through voluntary and preventative recall announcements that might not otherwise be necessary from a health perspective. For example, the Kellogg Company (2010), the worlds' largest cereal manufacturer, recently announced a recall of 28 million boxes of Apple Jacks, Corn Pops, Fruit Loops, and Honey Smacks branded cereals. The recall was due to an unusual odor originating from the packages' plastic linings. The company noted that the potential for health problems associated with the problem was low and that the recalled products did not meet the company's quality standards. This is an example of a very large and expensive recall with the express purpose of proactively protecting a brand image and upholding consumers' expectations. Measuring these types of recalls would be very challenging but a breakdown of recalls due to these types of actions could assist with determination of this impact on the relative risk of recall due to branding.

A second and related alternative plausible explanation for the increased relative risk of recalls due to banding may come from pressure to voluntarily recall products as the result of media coverage. Branded firms and products are clearly more visible to the everyday food consumer. Through marketing, firms have made many of their products household names synonymous with the intended use of the product. With this familiarity, media and consumer activist scrutiny has propagated. The media tends to focus on stories that appeal and relate to most people and food safety issues

involving well known branded items and firms are no exception. This is especially relevant when the product in question is potentially harmful to those members of society who are the most vulnerable, such as children and the elderly. Positive press coverage of a proactive firm may be much less damaging to long term brand reputation than negative coverage of a reactive firm. This would be difficult to measure. Information on type of recall as being proactive or reactive and a quantitative examination of respective press coverage and audience might shed some light on the influence to relative risk of a recall associated with branding.

Another alternate plausible explanation could be due to firms' need to offset risk by creating additional brands. If a firm feels that certain products are riskier that others within its portfolio, the firm may create a brand with little investment in brand equity and incorporate these riskier products into that new brand. This will allow the firm to offset negative publicity and effects on the brand image that the firm feels are more vital. Peter Thor (2010), owner of Bellissimo Foods, a major Italian foods distributor in the United States, commented that his firm has started rebranding its products that are imported from China to something other than the primary Bellissimo brand. This is in response to the higher potential of a food safety event occurring with the Chinese products. It is an effort to prevent a disaster that could ruin the company's principal brand with the possibility of bankrupting the firm. Information concerning the country of origin of products supplied under a brand name is difficult to obtain at this time due to confidentiality concerns but could be very beneficial.

We feel that an additional possible explanation may be found in the idea that management may be focusing on the short-run. Swinbank (1993) considered that "if the short-run profits of supplying shoddy goods now outweigh the long-run benefits of protecting the brand, it would be rational for the profit-maximizing firm to deceive customers and supply faulty products." This proposal may be most credible for small firms that develop brands that are not widely recognized and that did not require a great deal of investment. These firms can simply develop another brand to replace the one experiencing a recall. A final explanation may be found in the notion that large firms that brand their products do so as an investment in goodwill as a form of insurance against problematic events. These firms may attempt to convince customers of the quality of the product through branding, just as we suggested. However, this investment is offset by an actual decrease in quality after a long period of high quality. Here, the firm relies greatly on consumer loyalty to the brand and must be willing to expend resources for development and protection of the brand.

Further, we examined several interesting findings concerning the frequencies of recall events based on the product type, problem associated with the recall, specific pathogens, annual recall events, and geographic location of the firms associated with the events.

We feel that further analysis and examination of the recall and corporate information databases that have been assembled is of interest. One possible research

endeavor may focus on recall events that are due only to pathogen contamination as these are the events that receive the highest level of public attention and are linked to public health. Another could expand the corporate level information to include more recent and comprehensive data on sales, employment numbers, and brands. A final possible undertaking could examine a case study of one very significant recall event that involved the Peanut Corporation of America. This event encompassed a large group of firms that produced a variety of products. These are just a few examples of future research that may be embarked on with the information that is currently available.

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APPENDIX 1

Table A1. Direct Regulation, Buyer Requirements, and Food Safety Technology Impacts on the Costs of Complying with PR/HACCP

	Slaughter			Processing	
Variables	Cattle	Hogs	Chicken	Cooked	Raw
Intercept	-0.002	-0.033	0.009	0.002	-0.037^{+}
	(-0.13)	(-2.03)	(0.58)	(0.10)	(-1.31)
Wages					
State_Wage	-0.001***	0.001***	-0.0008	-0.0010**	-0.0004^{+}
	(-2.68)	(4.21)	(-1.90)	(-2.38)	(-1.41)
Private Actions					
Indirect					
Human Capital	-0.009^{+}	-0.007^{+}	0.0008	-0.013^{+}	0.006
Experience_QC	(-1.48)	(-1.33)	(0.28)	(-1.45)	(1.21)
Physical Capital	0.042**	0.046**	0.014	0.038*	0.056***
FS_Tech	(2.64)	(2.51)	(1.28)	(1.65)	(3.99)
Direct					
Buyer	0.013**	0.012**	0.009*	-0.0004	0.007^{+}
	(2.28)	(2.19)	(1.67)	(-0.05)	(1.48)
Process	-0.006	-0.005	-0.0001	-0.010	0.0002
	(-0.60)	(-0.95)	(-0.02)	(-1.20)	(0.03)
Regulation Effects					
Indirect					
Employees	-0.0036	-0.0049	-0.008***	-0.006	-0.031***
	(-0.97)	(-0.75)	(-0.31)	(-0.31)	(2.50)
Multi	-0.002	-0.011^{+}	0.0004	0.002	0.003
	(-0.27)	(-1.50)	(0.06)	(0.25)	(0.51)
Cap_Lab	-0.00004	-0.0002*	0.00002	0.000002	-0.00001
	(-0.27)	(-1.90)	(0.16)	(0.01)	(-0.06)
Direct					
Plan_Sales	0.865^{+}	-0.105	9.23***	6.97***	3.32***
	(1.58)	(0.13)	(2.23)	(5.31)	(3.99)
Tasks_EMP	0.0002**	0.0003***	-0.0003	0.0002**	0.00034***
	(1.96)	(4.55)	(-0.77)	(2.27)	(2.97)
Shar_HACCP_Task	0.018	-0.00008	0.005	0.029	0.015
	(0.69)	(0.00)	(0.27)	(0.90)	(0.45)
PW_QC	0.012*	0.012*	-0.004	0.017*	0.014**
	(1.90)	(2.00)	(-0.96)	(1.70)	(2.35)
R^2	0.36	0.50	0.16	0.28	0.39
Observations	81	82	64	191	109

Source: (Ollinger, The Direct and Indirect Costs of Food Safety Regulation CES 08-31 2008), Page 27 t-statistics in parentheses. +,*,**,***: 80, 90,95,99 percent levels of significance.

VITA

Name: Nathaniel Allen Joy

Address: Department of Agricultural Economics
Texas A&M University
2124 TAMU
College Station, Texas 77843-2124

Email Address: NAJoy@ag.tamu.edu

Education: B.S., Economics, Texas A&M University, May 2007
M.S., Agricultural Economics, Texas A&M University, December 2010