EFFECTS OF MEAT AND POULTRY RECALLS ON FIRMS' STOCK PRICES

by

VERONICA F. POZO

B.S., Pan-American Agricultural School Zamorano, 2006
M.S., Kansas State University, 2009

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2014

Abstract

Food recalls have been an issue of great concern in the food industry. Stakeholder responses to food safety scares can cause significant economic losses for food firms. Assessing the overall impact that may result from a food recall requires a thorough understanding of the costs incurred by firms. However, quantifying these costs is daunting if not impossible. A direct measurement of a firm's total costs and losses of revenue associated with a food recall requires firm-level data that is not available. The method utilized in this study overcomes this severe limitation. Using an event study, the impact of meat and poultry recalls is quantified by analyzing price reactions in financial markets, where it is expected that stock prices would reflect the overall economic impact of a recall. A unique contribution of this study is evaluating whether recall and firm specific characteristics are economic drivers of the magnitude of impact of meat and poultry recalls on stock prices.

Results indicate that on average shareholders' wealth is reduced by 1.15% within 5 days after a firm is implicated in a recall involving serious food safety hazards. However, when recalls involve less severe hazards, stock markets do not react negatively. Also, reductions in company valuations return to pre-recall levels after day 20. Firm size, firm's experience, media information and recall size are drivers of the economic impact of meat and poultry recalls. That is, firms recalling a larger amount of product perceive greater reductions in company valuations. Additionally, recalls issued by larger firms are less likely to present negative effects on stock prices, compared to smaller firms. Moreover, firms that have recently issued a recall are less harmed by a new recall compared to those firms issuing a recall for first time. Thus, suggesting that investors take into consideration the past performance of a company when dealing with food recalls. Furthermore, media information has a negative impact on shareholder's wealth. Findings

from this study provide essential information to the meat industry. In particular, understanding the likely impact of such “black swan” events is critical for firm’s investing in food safety technologies and protocols.

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Results indicate that on average shareholders' wealth is reduced by 1.15% within 5 days after a firm is implicated in a recall involving serious food safety hazards. However, when recalls involve less severe hazards, stock markets do not react negatively. Also, reductions in company valuations return to pre-recall levels after day 20. Firm size, firm's experience, media information and recall size are drivers of the economic impact of meat and poultry recalls. That is, firms recalling a larger amount of product perceive greater reductions in company valuations. Additionally, recalls issued by larger firms are less likely to present negative effects on stock prices, compared to smaller firms. Moreover, firms that have recently issued a recall are less harmed by a new recall compared to those firms issuing a recall for first time. Thus, suggesting that investors take into consideration the past performance of a company when dealing with food recalls. Furthermore, media information has a negative impact on shareholder's wealth. Findings

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Acknowledgements

My utmost thanks and sincere gratitude go to my major professor, Ted Schroeder for providing me with the opportunity, the guidance and the support to succeed, not only throughout the completion of this dissertation, but also at every stage of my Ph.D. program, and for having confidence in me. He has been an outstanding advisor and a role model; very generous with his time and academic insight. His encouragement was sometimes all that kept me going. Specially, during moments of self-doubt, he reinvigorated my enthusiasm tremendously. I am so fortunate to have such a caring and selfless individual as a mentor and dear friend.

I am deeply indebted to Dr. Lance Bachmeier for his invaluable contribution not only to this dissertation, but also to other research projects. He introduced me to the exciting field of time series econometrics and helped me develop my programming skills. His guidance and selfless time led me to improve substantially the quality of my research. I am also very thankful for his career advice and genuine interest in my professional and personal success.

I am very grateful to Dr. Glynn Tonsor for all the constructive feedback he has provided to this dissertation and other research studies over the years. Glynn has had an important academic and professional influence on me. I have learned a lot about how to do interesting and rigorous research through my collaboration with him. Also, I thank him for being always willing to review and comment on my work, and for his career advice and support.

This dissertation also benefited from the valuable comments and suggestions provided by my other committee members, Dr. Mykel Taylor and Dr. Kelly Getty, from their respective areas of expertise. Additionally, I am very thankful for their editorial assistance with my dissertation manuscript. The insightful comments provided by Dr. John Crespi during the preparation of my dissertation proposal, and the econometric assistance from Dr. Nathan Hendricks in the last stage of my dissertation, are greatly appreciated. The assistance provided by Kassie Curran, Shelby Hill and Ian Goding during the data collection process was imperative for the on time completion of this dissertation and deserve a special acknowledgement.

Financial support from the department of Agricultural Economics and the Agriculture and Food Research Initiative at the U.S. Department of Agriculture (USDA) is gratefully acknowledged. Special thanks go to Ilene Arnold, senior staff officer at the USDA Food Safety and Inspection Service (FSIS), for facilitating the coordination of my visit to the FSIS headquarters in Washington DC. I gathered valuable insights and information about meat and poultry recalls and FSIS protocols during this visit. In particular, I am grateful to Regina Tan, Soumaya Tohamy, Victoria Levine, Todd Furey and Rasika Tripathy, for meeting with me.

I would also like to thank my two dearest friends and colleagues, Elizabeth Canales and Graciela Andrango, for their unconditional support. I will cherish forever all the great memories we have shared together. My sincere appreciation go to Dorivar Ruiz Diaz, Mary Copple, Yasmin Diaz, Mario Ortez, Deana Foster, Amanda Erichsen and Ted’s family (Karen, Taylor and Mariah), for making my life at Kansas State even more enjoyable.

I would not have been able to get this far without the constant and unwavering support of my parents, Edwin and Mercedes. They have shaped me into the person I am today and always encouraged me to pursue my dreams, even when these took me far away from home. The moral, ethical and intellectual education I received from them, contributed tremendously to my success in achieving this Ph.D. degree. A very special thanks go to my brother Martin, my sister Gabriela, my nephew Camilo and my grandfather Angel, for being my most enthusiastic cheerleaders and for giving me countless reasons to smile.

No words can express how fortunate and grateful I am for having my wonderful husband and best friend, Vladimir, right by my side at every step of this exciting, yet sometimes daunting journey. He has been immensely supportive, loving and understanding throughout the ups and downs of the entire Ph.D. process. With his dedication and unique sense of humor, he raised my spirits and inspired me every day. Thanks to him, I was able to accomplish this dream.

Dedication

To my parents Edwin Pozo and Mercedes Gordillo, and my beloved husband Vladimir. Having you in my life is the greatest blessing.

Chapter 1 - Introduction

Food recalls have been an issue of great concern in the food industry. In recent years the number of identified and reported incidents of contaminated food products has dramatically increased as has public awareness of food safety breaches, thus elevating consumers' concerns about the safety of our food. On the supply side, stakeholder responses to food safety scares can cause significant economic losses for food firms. As a preventive measure, firms invest substantial resources into minimizing food safety hazards. However, optimal investment is elusive because food contamination incidents are difficult to predict and even more, their probable economic impact is unknown. In addition to economic repercussions related to the reduction in product demand, triggered by a decline in consumer or customer confidence, firms involved in food-related outbreaks incur expenses of recovering, disposing of, or reconditioning food products already in the market pipeline (Thomsen and McKenzie, 2001).

Depending on the severity of the threat and its potential effects on the wellbeing of consumers, firms may also face product liability costs which can permanently damage a firm's reputation and even force the firm to exit the market. For example, in 1997, Hudson Foods Co. recalled 25 million pounds of ground beef (one of the largest recalls of food in the U.S.) due to foodborne contamination that caused several illnesses. This particular event resulted in the company's acquisition by Tyson Foods, after losing its largest customer, Burger King (Belluck, 1997). Food contamination incidents may also influence the decisions of food company investors. That is, product recalls negatively affect the firm's stock prices because of the adverse effect on current and future profitability of the firm involved (Salin and Hooker, 2001; Thomsen and McKenzie, 2001; Wang et al., 2002).

1.1 Motivation

Assessing the overall impact that may result from a food recall requires a thorough understanding of the costs incurred by firms. However, quantifying these costs is daunting if not impossible. A direct measurement of a firm's total costs and losses of revenue associated with a food safety outbreak requires firm-level data that are not available, and often, not even the firm involved has the data necessary to undertake an economic assessment. To overcome this severe limitation, previous work has quantified the impacts of food recalls by analyzing price reactions in retail, futures and financial markets during the periods surrounding the recall announcement. Of particular interest in this study is the assessment of price reactions in financial markets, since it is expected that stock prices would reflect the overall economic impact of a recall through the expected impact on the future profitability of the firm involved.

Food recalls do not cause the same adverse effects in all companies. Thomsen and McKenzie (2001) found significant shareholder losses when publicly traded food companies were implicated in a recall involving serious food safety hazards (e.g., foodborne disease outbreaks), indicating that reductions in company valuations are contingent on the overall human health risk associated with the consumption of adulterated or misbranded products. Moreover, the amount of product that is implicated in a food safety problem determines the size of a recall. It may not be accurate to assume that firms recalling a small amount of product would be affected in the same manner as firms recalling millions of pounds of product. Therefore, recall size has the potential to influence firms' valuations during a food safety incident.

Furthermore, previous literature shows that media information accompanying a food safety scare has the potential to decrease consumer demand for the implicated product (Piggott and Marsh, 2004; Schlenker and Villas-Boas, 2009). However, while some food recalls have received widespread media coverage, others have barely made it to the news. Thus, raising the question of whether the effects of media information impacting consumer perceptions regarding the safety of a product and the firm producing the product, are translated into financial markets.

Different types of publicly traded firms are responsible for food safety. These firms have different sizes and differ according to their scale of operations and levels of diversification. This distinction is important for the analysis of stock market reactions to food safety scares because investors are suspected to include into their stock valuations risk perceptions about firms. That is, larger firms, likely to operate numerous plants or produce an array of different products that are not affected by the recall, are expected to have smaller economic impact, all else constant. Additionally, a firm's past experience managing recalls can influence the outcome from contamination incidents on the market value of firms (Salin and Hooker, 2001; Wang et al., 2002). That is, firms undertaking an effective food safety crisis management strategy have the potential to minimize the stock market reaction.

Altogether, this evidence indicates that the impact of a food recall on the value of a firm is likely to depend on factors associated with the specific recall and the firm issuing the recall. However, previous work has not assessed how the magnitude of stock market price reactions to recalls is determined by a broader set of important factors. This study is designed to directly address this important gap in information.

1.2 Objectives

The objectives of this study are twofold. The first one is to quantify the impact of meat and poultry recalls on related financial markets. More specifically, reductions in food company valuations that result from meat and poultry recalls are calculated using an event study approach based on daily stock prices. Assuming the impact of a recall will be reflected in adverse stock price movements, this approach allows comparing observed stock prices with those that would have been expected to occur in the absence of a recall.

The second objective is to determine how specific factors associated with meat and poultry recalls and the firms involved, explain the magnitude of stock prices reactions. In particular, the focus of this study is on factors such as: severity of the health threat, size of the recall, firm size, firm structure (e.g. level of diversification), firm's experience, media information surrounding the recall and important meat industry events.

1.3 Meat and Poultry Recalls

Recalls of meat, poultry and processed egg food products are carried out under the supervision of the United States Department of Agriculture Food Safety and Inspection Service (FSIS). Typically, meat and poultry products that have already been shipped and distributed into the market and are suspected of being potentially hazardous to public health, are voluntarily recalled by firms either by their own initiative or by the request of FSIS. When a product is recalled, FSIS issues a recall release to the media in the affected area, sends it to public health partners and stakeholders and posts it on the FSIS website. However, FSIS will not issue a recall release when the company is able to regain control over adulterated product distributed solely to the wholesale level. A recall can occur for many different reasons. Among these are foodborne illness outbreaks, undeclared allergens, contamination with foreign materials (e.g., plastic, glass and metals), mislabeling, and underprocessing or undercooking. The most severe type of recalls involve meat products contaminated with foodborne bacteria such as *Escherichia coli* O157:H7 (*E. coli*), *Listeria monocytogenes* or *Salmonella*.

There are several ways a firm may learn about a potential recall situation. These include: through FSIS, firm's customers, consumer complaints, its own laboratory analysis reports, or through reports from the Food and Drug Administration (FDA), the Centers for Disease Control and Prevention (CDC) or from other federal agencies. When the establishment believes that adulterated or misbranded product has been shipped into the market, it must notify FSIS within 24 hours. Then, a recall committee will assess whether it is necessary to recommend a recall based on a series of protocols, which includes the evaluation of the severity of the recall based on potential health risk. Once this committee determines that the establishment must undertake a recall, FSIS issues a recall release. If an establishment refuses to conduct a recall, FSIS personnel have the right to detain any product found in commerce that would have been subject to a recall (FSIS Directive, 2014). A recall is terminated after FSIS determines that all reasonable efforts have been made to recover the product in question.

Despite firms' efforts to adopt preventive measures and invest in food safety enhancing technologies, firms may encounter food safety threats during production, processing or packaging of food products. Human errors and limitations of food safety technologies make zero food safety tolerance impossible. In the last two decades, FSIS has reported almost 1,300 meat and poultry recalls, representing nearly 638 million pounds of product, from January 1, 1994, through December 31, 2013. Of the total, almost three-fourths corresponded to the most severe class of recalls (FSIS, 2014).[1] These recalls come at the expense of the firm directly involved and can create substantial losses.

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[1] Class I recalls are the most serious and involve a "situation where there is a reasonable probability that the use of the product will cause serious, adverse health consequences or death." Class II recalls involve a "situation where there is a remote probability of adverse health consequences from the use of the product." Class III recalls involve a "situation where the use of the product will not cause adverse health consequences."

1.4 Importance of Study

Results from this study provide essential information to the meat industry. Particularly, understanding how food safety recalls impact a firm's value is necessary for firms to evaluate strategies of adopting and investing in new, often expensive, food safety technology and protocols. In addition, results will demonstrate how a variety of factors influence the economic impact of a meat recall event. This information is valuable to managers as they assess potential costs or revenue losses associated with specific characteristics of a food safety recall. Furthermore, results also benefit investors as they may find it valuable to have information related to the duration of the effects of meat recalls on stock prices. Lastly, understanding the likely impact of meat recalls events is critical for policy makers to establish and evaluate food safety regulations.

Chapter 2 - Literature Review

This section provides an overview of relevant literature related to food recalls and other food safety scares. The first subsection presents a discussion of how financial markets have been impacted by food safety incidents. The second subsection focuses on reviewing studies assessing consumer responses to food recall announcements and other food safety scares. The third subsection summarizes main findings regarding food safety scares in the futures markets literature. Finally, studies related to food safety regulations and recall management are reviewed in the fourth subsection.

2.1 Financial Market Reactions to Food Recalls and Other Food Safety Scares

The study of financial market reactions to food recalls provides important information to firms and the industry in general. That is, the magnitude of a stock market reaction can be compared to the direct costs incurred by the implicated firms. Consequently, this magnitude can be used to assess the benefits of implementing new technologies or food safety protocols, and even further, the adoption of an industry level food safety management system (Salin and Hooker, 2001).

2.1.1 Effects of Meat and Poultry Recalls on Financial Markets

Several studies have assessed the impact of meat and poultry recalls in financial markets. Using an event study approach, Thomsen and McKenzie (2001) examined reductions in food company valuations that resulted from meat and poultry recalls supervised by FSIS. Significant shareholder losses were found when companies were implicated in a recall that caused serious threats to consumer health (1.5-3 percent reduction in stock returns). Here, the most adverse reactions occurred within 6 trading days after the recall announcement. On the contrary, recalls that involved less severe food safety hazards, had no negative impact on stock markets. This finding indicates that the magnitude of impact of meat and poultry recalls depends on the recall class. The present study extends Thomsen and McKenzie' (2001) analysis to evaluate what factors (other than recall class) related to the meat recall, as well as the firm involved, help explaining the magnitude of stock markets' reactions. This study also addressed the issue of clustering among recalls using a test of significance that accounts for the cross-sectional correlation of returns, instead of removing important observations out of the sample. In addition, since their study was conducted in 2001, important conclusions can be drawn from updating and comparing results.

Salin and Hooker (2001), evaluated stock markets' reactions to food recalls caused by microbiological contamination using a partial event study approach. Their main focus was on four different recalls: Odwalla apple juice contaminated with *E. coli* O157:H7 in 1996, two IBP recalls involving ground beef also contaminated with *E. coli* O157:H7 bacteria in 1998 (6 months between each other), and Sara Lee hot dogs contaminated with *Listeria monocytogenes* in 1998. Stock returns fell immediately after the recall for the smaller firms in the study (Odwalla and first IBP recall), but recalls by the larger firm (Sara Lee) were not consistently associated with large reductions in stock returns. The second IBP recall did not have a significant negative impact in stock returns as did the first one, suggesting that the market had learned from the earlier recall. The authors argued that perhaps IBP sent a good signal to investors after handling the first recall, indicating that contamination incidents did not have long-term impacts on shareholders' wealth.

In a similar study, Wang et al. (2002) evaluated stock market responses to five meat recalls from two different companies (Sara Lee and IBP), using a Generalized Autoregressive Conditional

Heteroskedasticity (GARCH) framework. The first recall from each company, had significant negative effects on stock returns, whereas the subsequent recalls did not affect stock returns. The authors also found volatility spillovers across firms, suggesting that recalls caused by bacterial contamination can potentially have widespread effects on the industry. Findings from both studies suggest that other factors that could potentially influence the magnitude of the effects of food recalls are the size of the firm, the firm's experience and whether or not the recall was caused by a foodborne pathogen.

2.1.2 Effects of the Bovine Spongiform Encephalopathy (BSE) Outbreak on Financial Markets

The first case of BSE reported in the U.S. in December 2003, had a substantial impact in the livestock and meat industries. Following its discovery, some countries closed their doors to U.S. products, costing beef export markets over $3 billion in 2002 (Unnevehr, 2004). Jin and Kim (2008) studied the BSE outbreak and its effects on the security values of U.S. agribusiness and food processing firms, using an event study approach. Looking at 23 different securities, results showed that security values of firms in the category of "mixed meats" were negatively affected, whereas firms in the category of "other meats" were positively affected. Also, some firms in the "farm machinery and equipment" sector were negatively affected because of its positive relationship with farm income. Furthermore, the authors argued that the response of U.S. consumers to this outbreak was not prominent, whereas the response by shareholders of U.S. firms in the meat and poultry industry was significant. A possible explanation for this finding is that the ban imposed on U.S. products by major importing countries impacted investors decisions.

2.2 Consumer and Retail Market Reactions to Food Safety Scares

A product recall alters investors' expectations about future earnings. Since these expectations are estimated based on the firm's revenue, reductions in revenue and increases in costs attributed to the recall, result in lower expected earnings per share and, consequently, lower share prices. Consumers directly affect the firm's revenue by changing their purchasing patterns. Therefore, it is important to understand how consumers and the retail market react to food safety scares.

2.2.1 Consumer Reactions to Food Safety Scares

Numerous studies have addressed how consumers' purchasing patterns are affected by food recalls. For example, Marsh, Schroeder and Mintert (2004) analyzed the impact of meat recalls on aggregate demand for beef, pork and poultry products using a Rotterdam demand model. Including recall indices as demand shifters, findings revealed that recalls caused small but statistically significant responses. Own and cross-effects indicated that meat recalls induce a reallocation of expenditure both within the meats group and across meat and non-meat groups. Using disaggregated data Thomsen, Shiptsova and Hamm (2006) estimated sales losses experienced by food processing companies following a recall caused by *Listeria monocytogenes*. This study used branded frankfurter products to assess substitution effects associated with a food scare that can be directly linked to one or more brands. Product sales of affected brands decreased by 22-23% after the outbreak. On the contrary, non-recalled brands experienced an increase of sales when a competing brand was involved in a recall.

In a similar study, Bakhtavoryan, Capps and Salin (2012) evaluated spillover effects among peanut butter brands, initiated by the 2007 Peter Pan recall, using Nielsen Homescan data. Changes in own-price and cross-price relationships among peanut butter brands following the recall, suggested that the recall caused a structural change in the demand for peanut butter. However, after 27 weeks Peter Pan recovered from this food safety crisis.

Furthermore, Arnade, Calvin and Kuchler (2009) employed a two-stage almost ideal demand system (AIDS) model and weekly scanner data to investigate the impact of an *E. coli* O157:H7 outbreak linked to spinach. Consumers substituted spinach with lettuce, and moved away from bagged salads that did not contain spinach, indicating a negative spillover effect on other leafy greens. However, retail expenditure for all leafy greens only declined 1 percent after 68 weeks, whereas for bagged spinach it decreased 20%. All these findings reveal consumers change their purchasing patterns after a recall by reallocating their budget on what they believe are unaffected products (substitutes). However, in some cases, uninvolved brands (or products) also suffer from sales losses, although it appears this effect is short-lived.

2.2.2 Influence of Media Coverage on Consumer Reactions towards Food Recalls

The news media has long been a primary source of consumer information relating to food safety. Today, consumers receive instant information through the use of technology and social media. Thus, immediately influencing their perception and reaction towards a recalled product and the company involved. Several studies have addressed the impacts of food safety information on consumer demand.

Smith, van Ravenswaay and Thompson (1988) estimated sales loss following a food safety incident involving fresh fluid milk contaminated with pesticide in Hawaii, in 1982. They modeled consumer responses to a contamination incident in function of their information about the quality of the product. Assuming consumers' primary source of information is the media coverage of the incident, they built a media index based on newspaper articles. These articles were coded either as positive or negative depending on the type of information presented and when an article contained both types of information, each sentence was assigned a value and the sum of values determined the code given to the article. In addition, these articles were weighted using a scale from 0 to 5 depending on their location in the newspaper (e.g., front page of a section, etc.). A total of 41.7 million pounds of milk was not sold because of this incident, and after receiving compensations, sales losses amounted to $26,000 per producer. Additionally, negative media coverage had a larger effect on consumers' perceptions compared to positive media coverage. Although government officials assured the safety of the remaining milk after the contaminated product was removed out of the shelves, consumers did not respond immediately. This article was among one the first empirical studies that compared the impact of positive and negative media information.

Similarly, Richards and Patterson (1999) used an equilibrium displacement approach to calculate the effects of negative or positive news regarding a disease outbreak on the profits of strawberries growers. Positive and negative media articles had the expected effects on price, but negative reports had a greater effect on price than positive reports.

In a more recent study, Piggott and Marsh (2004) developed a theoretical and empirical framework of consumer response to publicized food safety information on meat and poultry demand. Including food safety indices constructed based on newspaper articles, the empirical analysis showed the average demand response to food safety events was economically small, except in periods of a significant food safety outbreak. In addition, adverse publicity concerning the safety of a product depressed its demand. However, this impact was small and short-lived.

Laestadius et al. (2012) analyzed the content of newspaper articles covering the 2010 Iowa egg recall caused by a *Salmonella* outbreak. The main focus of this analysis was to evaluate the media impact on public support for food safety policy reforms needed to prevent future outbreaks.

Articles were categorized according to several parameters including: focus of coverage (e.g., egg recall, politics and food safety), causal factors (e.g., poor production practices, lack of government oversight) and possible solutions (e.g., consumer actions, alternative eggs, policy actions, etc.) among others. Although media coverage conveyed the policy relevance of the recall, it failed to contextualize the issue within the food safety policy agenda of that time.

Focusing on a different type of media coverage, Schlenker and Villas-Boas (2009) used an event study approach to examine how U.S. consumers reacted to two highly publicized warnings about bovine spongiform encephalopathy (BSE): the first discovery of an infected cow in December 2003 and an Oprah Winfrey show that aired in 1996. Large and significant drops in beef sales followed both episodes. Particularly, implications are that receiving coverage in one of America's most-watched television programs can impact markets in a sizeable way compared to government warnings combined with continued general news coverage. They concluded, printed media is not the only source of information able to alter consumer demand patterns. Although other alternatives have been proposed to the inclusion of media indices in consumer demand analysis (Mazzocchi, 2006), these articles demonstrate that media coverage play a crucial role in determining market response to a food scare. Hence, the inclusion of media indices in this study.

2.3 Futures Market Reactions to Food Safety Scares

While food recalls and other food safety scares have the potential to adversely affect consumer demand and retail market responses, they are also expected to cause a downward movement in futures prices as traders react to potential declines in derived demand triggered by negative consumer responses. Several studies have analyzed futures markets' reactions to food recalls and other food safety scares. For example, McKenzie and Thomsen (2001) examined the impact of *E. coli* O157:H7 meat and poultry recalls (supervised by FSIS) on farm and wholesale level beef prices, using an event study. The farm prices used were live cattle cash price and settlement prices for nearby live cattle futures contracts, and the wholesale prices used were the 90 percent lean boneless beef price index and the USDA's boxed beef cutout price for choice carcasses. Although wholesale prices of boneless beef were negatively affected by recalls, farm and wholesale prices of boxed beef showed either insignificant or very limited response to the recalls.

Lusk and Schroeder (2002) analyzed the effect of beef and pork recalls on live cattle and lean hogs futures markets using an event study approach. Particular focus was given to test whether size and severity of meat recalls statistically affected daily futures prices. Medium-sized beef and large-sized pork recalls with serious health concerns had a marginally negative impact on the nearby cattle and lean hogs futures market prices. Although the authors did not find significant effects of recall size on futures prices, it raises the question of whether stock prices are influenced by this recall characteristic. Furthermore, Moghadam, Schmidt and Grier (2013) investigated the effect of meat and poultry recalls (supervised by FSIS) caused by *E. coli* O157:H7 on nearby cattle futures prices, using an event study. Recalls had an adverse impact on cattle futures prices. However, this impact was short-lived. These findings contradict those from McKenzie and Thomsen (2001), indicating that recalls had no impact on cattle futures prices.

Focusing on a widespread food contamination event, Carter and Smith (2007) assessed market responses to the food-corn supply contamination by a genetically modified corn variety called StarLink that was not approved for human consumption. On September, 2000 the *Washington Post* reported the detection of traces of StarLink in taco shells in the U.S. which led to food recalls of approximately 300 food products and eventually, a decrease of U.S. corn exports to Japan (the largest single importer of U.S. corn at that time) of about 8 percent. To estimate the price effect of this event on the U.S. corn market, the authors developed a new approach called the relative price of a substitute (RPS) method, which exploits the equilibrium properties of the relative price of the commodity of interest to a substitute good. Using the stable relationship between sorghum and corn spot prices, the StarLink contamination incident decreased corn prices by 6.8 percent for at least a year.

Looking at the effects of media coverage in agricultural commodity markets, Attavanich, McCarl and Beesler (2011) evaluated lean hogs, live cattle, corn and soybeans futures prices responses to the 2009 H1N1 flu, inappropriately labeled at the beginning of the outbreak as “swine flu,” using a subset vector autoregressive model. Media coverage was associated with a significant negative effect on lean hogs futures prices, but slight impact on the other futures prices. This impact, which persisted for about four months, occasioned market revenue loss of about $200 million. Hence, indicating that futures markets are also influenced by media coverage.

2.4 Food Safety Regulations and Recall Management

Food safety scares have the potential not only to alter consumers’ purchasing patterns, but also shake public trust in food safety regulatory agencies and decrease confidence in the safety of the food supply chain (Onyango et al., 2008). Periodic discovery of contaminated meat and poultry products led the Food and Drug Administration (FDA) and the FSIS to develop a quality control system that improves the scientific basis for meat and poultry inspection and mitigates the firm’s economic losses. In 1996, the FSIS published a final rule that mandates all federally inspected meat and poultry plants to adopt a food safety control system known as HACCP (Hazard Analysis Critical Control Points). HACCP is a food safety monitoring system designed to identify and prevent hazards (e.g. introduction of pathogens or foreign materials) along the production process. This program was established to improve the safety of meat and poultry products by placing more emphasis on preventing potential hazards, rather than detecting and treating contamination problems at the end of the production line (Unnevehr and Jensen, 1996). The movement towards the implementation of mandatory HACCP regulations led researchers to investigate the benefits and costs of such regulations. For example, Roberts et al. (1996) and McDonald and Crutchfield (1996) estimated that the cost of designing and implementing a HACCP plan is lower on a per unit basis for a larger food processing firm compared to smaller firms. Thus, the regulatory costs imposed on smaller firms negatively impacted their competitiveness. However, the econometric estimates were based on data taken before the rule was issued.

Jensen et al. (1998) discussed preliminary results from a cost-effectiveness analysis of several technological interventions for microbial control in beef and pork processing. Their results suggested that marginal improvements in food safety can be obtained at increasing costs. Antle (2000) developed a theoretical model and estimated a cost function to test the hypothesis that product safety does not affect variable cost of production in the meat industry. After rejecting this hypothesis, results from the cost function were used to estimate the impacts of food safety regulations on the variable cost of producing beef, pork, and poultry. He concluded the costs of food safety regulation could plausibly exceed the benefits estimated by previous studies. More recently, Ollinger and Moore (2009) evaluated the costs of HACCP. Economies of scale in the implementation of the system provide larger firms with substantial cost advantage over smaller firms. In addition, the implementation of federal mandated food safety regulations is five times more costly than using generic performance standards. Altogether, these findings indicate that complying with food safety regulations can be costly, especially for small firms.

Focusing on food recall management, Hooker, Teratanavat and Salin (2005) examined the overall effectiveness of food recall management efforts undertaken by meat and poultry plants, supervised by FSIS. To conduct this analysis, three measures of recall effectiveness were defined: recovery rate, completion time and recovery rate-completion time ratio. In addition, managerial and technical variables were compared to these measures of effectiveness. Recalls carried out by the smallest size plants, those that took place after the implementation of HACCP and recalls involving processed products are more effective. Furthermore, although Class I recalls involve severe health hazards to consumers, there is no evidence that these are more effectively managed.

Chapter 3 - Methods

This chapter is divided into two subsections: event study and effects of meat recall characteristics. The former, provides a discussion regarding the conceptual framework driving this analysis and also, a detailed explanation of empirical methods used to calculate the magnitude of impact of meat recalls on stock prices – this magnitude of impact is known as abnormal returns. In addition, this subsection illustrates the implementation of parametric and non-parametric tests used to assess the level of significance of estimated abnormal returns. The latter provides a description of methods used to evaluate the effects of meat recall characteristics on post event abnormal returns. Here, the application of cross-sectional and panel data models is discussed.

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3.1 Event Study

To assess the impact of meat recalls on the market value of firms, ideally one would like to compare the firm's actual stock returns to the returns the firm would have experienced in the absence of the recall (known as normal return). The event study approach provides a framework for estimating this normal return. This method was introduced by Ball and Brown (1968) and by Fama et al. (1969), and since then it has been widely used in the fields of economics, finance, accounting, and marketing. The usefulness of event studies comes from the assumption that the effects of an event will be reflected immediately in stock prices. Therefore, a measure of the event's economic impact can be constructed using stock prices observed over a relatively short period of time, instead of using direct profit or cost related measures (MacKinlay, 1997).

3.1.1 Conceptual Framework

The theory underlying the use of the event study method is the efficient market hypothesis (EMH). This hypothesis implies that stock prices will reflect the discounted value of future earnings and all available information that influences the market upon which a firm's stock is traded. Here, the discount rate is determined by the perceived riskiness of the firm. Therefore, changes in stock prices, and thus firm's value, reflect changes in expectations about future earnings and risk. In other words, this hypothesis assumes that new information is quickly incorporated into stock prices as investors continually re-evaluate the firm's value (Srinivasan and Hanssens, 2009).

In general terms, stock prices are defined as:

$$P_t = \sum_{t=1}^{\hat{\tau}} \frac{ES_t}{(1+r)^t}, \tag{1}$$

where, ES represents the stream of future earnings per share at time t and r is the company's risk adjusted discount rate. It is important to note that product recalls might affect P through either ES or r. That is, as investors recalculate the value of stock prices considering their risk perceptions, they are implicitly affecting the value of r. In a similar fashion, as consumers and customers include new information into their recalculation of product quality, they would affect the value of ES. The current empirical framework, however, does not allow estimating the impact of product recalls using this distinction. In other words, it only allows estimating overall impacts.

3.1.2 Abnormal Returns Modeling

The assessment of the event's impact on stock prices requires a measure of the abnormal return. The abnormal return is defined as the difference between the actual ex post return of the stock and the normal return, both calculated over the event window. The normal return is defined as the expected return without conditioning on the event taking place (MacKinlay, 1997). For firm i and event date t the abnormal return is defined as:

$$AR_{it} = R_{it} - E[R_{it} | I_t], \tag{2}$$

where R_{it} is the actual return of a stock at time t, $E[R_{it} | I_t]$ is the normal return conditional on some information I_t which allows one to predict the expected return had the event not occurred. A test of statistical significance for the abnormal return is constructed using the following hypothesis:

$$H_o\colon R_{it} - E[R_{it} | I_t] = 0, \tag{3}$$

The null hypothesis is that the value of the actual return, conditional on the event, is not different from the expected value of the normal (benchmark) return. The test in equation (3) can be generalized to deal with aggregation over time. Note that returns on stock investments are used instead of stock prices in order to account for dividend payments and capitalization (Fama et al., 1969).[2] Daily returns for firm's i stock are calculated as the percentage change in closing stock prices as:

$$(4) \qquad R_{it} = \frac{P_{it} + D_{it} - P_{i,t-1}}{P_{i,t-1}}, \quad for\ i = 1, \dots, n\ and\ t = 1, \dots, T$$

where P_{it} is the stock price of firm i observed at the end of day t. D_{it} are the dividends per share paid at time t, and $P_{i,t-1}$ is the stock price of firm i observed at the end of day $t-1$. T denotes the total number of observations of time series data (may vary across firms) and n is the total number of firms considered in the analysis.

In the application of event study to meat recalls, six steps are followed: (i) identify the event timeline which consists of dates before, on and after the recall announcement; (ii) model the normal behavior of the returns according to a benchmark model estimated using observations prior to the recall announcement; (iii) forecast the expected returns over the event window using the benchmark model; (iv) compute the difference between actual and expected returns to obtain a measure of abnormal returns; (v) aggregate abnormal returns over intervals of the event window to obtain the cumulative impact of a meat recall on the value of firm i –these aggregated measures are known as cumulative abnormal returns (CAR); (vi) aggregate CAR over events (recalls) to obtain a measure of the cumulative average abnormal returns ($CAAR$); (vii) test for the statistical significance of $CAAR$.

Figure 3.1 illustrates the timeline of the event study where observations are divided into two mutually exclusive sub-periods: the estimation window and the prediction window. The

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[2] In addition, from an econometrics standpoint, using returns instead of stocks allows accounting for the presence of unit roots in the time series sample.

estimation window contains observations prior to the recall announcement (i.e., $t \in [T_1 + 1, T_2]$). The prediction window, also referred to as the event window, contains the day of the recall announcement (i.e., $t = 0$) and observations surrounding the event day (i.e., $t \in [T_2 + 1, T_3]$). Here, several trading days before the event are included to account for the possibility that stock markets become aware of food safety outbreaks before the formal announcement date.[3] To model the normal behavior of stock returns, a benchmark model is estimated using observations from the estimation window. Then, this model is used to predict or forecast normal returns (those expected to occur in the absence of a meat recall) using observations from the event window.

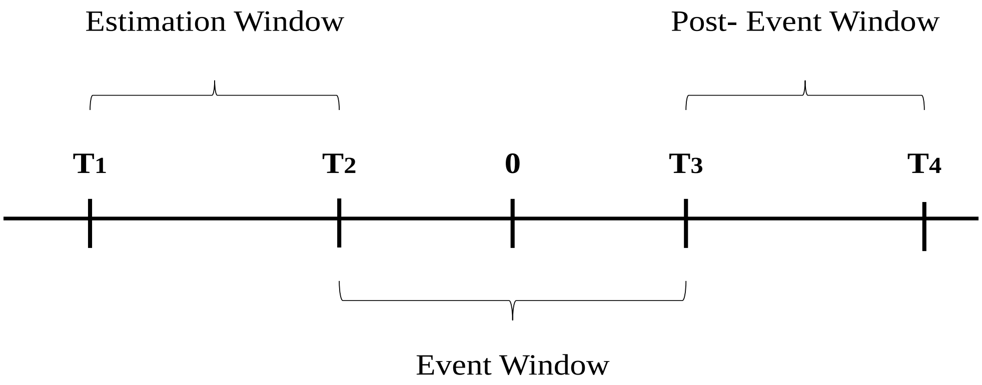

Figure 3.1 Event Study Timeline

Defining $L_1 = T_2 - T_1$ as the length of the estimation window and $L_2 = T_3 - T_2$ as the length of the event window, the estimation window considered in this study consists of $L_1 = 250$ trading days. Previous studies have considered event windows beginning at day $[T_2 + 1]$ = – 10 (Thomsen and McKenzie, 2001). However, to account for the sensitivity of results to the choice

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[3] In some cases, firms may determine to issue a recall as many as 24 hours before FSIS is formally notified, while in others, FSIS might require additional evidence (e.g., inconclusive laboratory results) before issuing a recall. Thus, any of this situations may allow the stock market to learn about the recalls before its official announcement.

of sampling periods, event windows starting at day $[T_2 + 1]$ = – 10 and $[T_2 + 1]$ = – 5 are used. That is, the estimation window $[T_1 + 1, T_2]$ is equal to [–260, –11] and [–255, –6] trading days, respectively. In addition, alternative lengths of event windows are examined to allow for comparison of cumulative effects after the recall. Hence, T_3 is specified as +5, +10, +15 and +20 trading days (Salin and Hooker, 2001).

There are two main statistical approaches used to estimate normal returns. These are the constant mean return model and the market model. The constant mean return model assumes that average returns are constant across time and any unexpected news will cause returns to deviate from this constant mean. Using this approach, normal returns are estimated as:

$$R_{it} = \mu_i - \nu_{it}, \ \ for\ all\ \ t \in [T_1 + 1, T_2], \tag{5}$$

where μ_i is the mean stock return for firm i and ν_{it} is the error term. On the other hand, the market model assumes that returns of stock prices are correlated with returns of a market portfolio. That is, returns are assumed to be a linear function of the overall market index (e.g., S&P 500, NASDAQ Composite, NYSE Composite, etc.) and deviate out of this relationship in the presence of an event. Here, normal returns are estimated as:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \ \ for\ all\ \ t \in [T_1 + 1, T_2], \tag{6}$$

where R_{mt} is the return of the market index at date t; α_i and β_i are parameters to be estimated and reflect the mean excess return (or unsystematic risk) and the systematic risk of firm's i stock, respectively (Mazzocchi, Ragona and Fritz., 2009); and ε_{it} is the error term assumed to be independent and normally distributed with zero mean.[4] Once estimates of α_i and β_i are obtained using observations from the estimation window, it is possible to predict (out of sample) normal returns from the event window as:

$$E[R_{it}|\, I_t\,] = \hat{\alpha}_i + \hat{\beta}_i R_{mt},\ \ for\ all\ t \in [T_2 + 1, T_3]. \tag{7}$$

Then, daily abnormal returns are calculated as:

$$AR_{it} = R_{it} - \hat{\alpha}_i - \hat{\beta}_i R_{mt},\ \ for\ all\ t \in [T_2 + 1, T_3]. \tag{8}$$

Mackinlay (1997) suggests that the market model represents a potential improvement over the constant mean return model because it allows reducing the variance of the abnormal return by removing the portion of the return that is related to the market's return variation. This in turn can increase the ability to detect event effects. Therefore, in this study, normal returns are estimated using the market model.

The market model in equation (6) relies upon the assumption that the residuals ε_t are serially uncorrelated. However, significant serial correlation is probable, particularly among food firms that perceive thin trading in some days (Henson and Mazzocchi, 2002; Mazzocchi, Ragona and Fritz, 2009). This issue is addressed by employing an autoregressive distributed lag (ARDL) specification of the market model:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \gamma_i R_{it-1} + \delta_i R_{mt-1} + \tilde{\varepsilon}_{it},\ \ for\ all\ \ t \in [T_1 + 1, T_2]. \tag{9}$$

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[4] According to Fama (1976), stock returns are not normally distributed. Thus, this issue needs to be accounted for when conducting hypothesis testing.

Abnormal return observations must be aggregated in order to draw overall inferences for the event of interest (MacKinlay, 1997). Thus, abnormal return measures are aggregated over time into a measure of cumulative abnormal returns, reflecting the change in stock prices caused by a particular meat recall over an interval of the event window. Cumulative abnormal returns for firm's i stock return, calculated over an interval $\tau = [\tau_1, \tau_2]$ consisting of one or more days, are obtained as:

$$CAR_i(\tau_1, \tau_2) = \sum_{t=\tau_1}^{\tau_2} AR_{it}, \tag{10}$$

where $T_2 < \tau_1 \leq \tau_2 \leq T_3$.

Then, the average proportional impact of a meat recall is obtained by taking the mean of $CAR_i(\tau_1, \tau_2)$ over the N recall events in the sample:[5]

$$CAAR(\tau_1, \tau_2) = \frac{1}{N} \sum_{i=1}^{N} CAR_i(\tau_1, \tau_2). \tag{11}$$

That is, the magnitude of $CAAR(\tau_1, \tau_2)$, known as cumulative average abnormal returns, reflects whether the observed stock price movements are the result of meat recall events. Thus, the primary interest of this analysis is to test the following hypothesis:

$$H_o\text{:}\ \ CAAR(\tau_1, \tau_2) \geq 0, \tag{12}$$

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[5] It is important to note that a particular firm could register more than one recall over the sample period. Thus, instead of aggregating over n, the total number of firms considered in this study, the aggregation is performed over the total number of recalls.

$$H_a: \ CAAR(\tau_1, \tau_2) < 0.$$

Under the null hypothesis, recall outbreaks do not have a significant impact on stock prices and consequently $CAAR(\tau_1, \tau_2)$ will be zero, whereas under the alternative hypothesis recalls have a significant impact on stock prices causing $CAAR(\tau_1, \tau_2)$ to be negative.

3.1.3 Statistical Tests of Abnormal Returns

There are two main problems related to statistical tests of abnormal returns that need to be considered in this study. The first one is clustering (or cross-sectional correlation), which occurs when event windows overlap in calendar time. Since traditional *t*-statistics assume independence of abnormal returns, results from hypothesis testing can be misleading (over-rejection of the null hypothesis). Meat and poultry recalls occur frequently, so they are prone to portray cross-sectional correlation of abnormal returns. Previous studies have addressed this issue by requiring a minimum number of trading days between events as a prerequisite for inclusion in the analysis (Moghadam, Schmidt and Grier, 2013; Thomsen and McKenzie, 2001). This solution implies, however, reducing the event study sample and loosing relevant information about meat recalls. As an alternative, the modified Boehmer, Musumeci and Poulsen (1991) *t*-statistic (hereafter ADJ-BMP) proposed by Kolari and Pynnonen (2010) is used in this study to test the null hypothesis from equation (12).[6] The advantage of using the ADJ-BMP *t*-statistic is that it takes into account cross-correlation. Therefore, it is not necessary to reduce the event study sample to conduct statistical inference.

The ADJ-BMP *t*-statistic for $CAAR$s is calculated as follows:

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[6] This *t*-statistic is chosen over the adjusted Pattell's (1976) *t*-statistic because it alleviates the issue of autocorrelation in cumulative abnormal returns by rescaling with cross-sectional standard deviation.

Step 1: Estimate the variance of $CAR_i(\tau_1, \tau_2)$, for which is necessary to first compute the conditional covariance matrix of abnormal returns (also known as forecast variance matrix) as follows:

$$\mathbf{V}_{\boldsymbol{i}} = \sigma^2_{\varepsilon_i} \left[\mathbf{I} + \mathbf{X}^*_i \, (\mathbf{X}'_i \mathbf{X}_i)^{-1} \, \mathbf{X}^{*\prime}_i\right], \tag{13}$$

where $\sigma^2_{\varepsilon_i}$ is substituted by the estimated variance of the residuals from equations (6).[7] $\mathbf{I}$ is an identity matrix of length $L_2 \times 1$. $\mathbf{X}^*_i$ is a $L_2 \times 2$ matrix of regressors used to forecast normal returns (it includes a vector of ones in the first column). And $\mathbf{X}_i$ is a $L_1 \times 2$ matrix of regressors used to estimate equation (6).[8] Then, the variance of $CAR_i(\tau_1, \tau_2)$ can be computed as:

$$s^2_i(\tau_1, \tau_2) = \mathbf{W}'\mathbf{V}_{\boldsymbol{i}}\mathbf{W}, \tag{14}$$

where $\mathbf{W}$ is of dimension $L_2 \times 1$ with elements taking a value of one if $\tau_1 \leq t \leq \tau_2$ and zero otherwise.

Step 2: Calculate the standardized cumulative abnormal return ($SCAR$) defined as:

$$SCAR_i(\tau_1, \tau_2) = \frac{CAR_i(\tau_1, \tau_2)}{\sqrt{s^2_i(\tau_1, \tau_2)}}. \tag{15}$$

Step 3: Calculate the cross-sectional standard deviation of $SCAR_i(\tau_1, \tau_2)$:

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[7] That is, $\sigma^2_{\varepsilon_i} \approx \hat{\sigma}^2_{\varepsilon_i} = \frac{1}{L_1 - 2} \hat{\varepsilon}'_i \hat{\varepsilon}_i$, where L_1= 250.

[8] In the case of the ARDL model, $\mathbf{X}^*_i$ is a $L_2 \times 4$ matrix, $\mathbf{X}_i$ is a $L_1 \times 4$, and residuals are obtained from equation (9).

(16) $$s_{SCAR,\tau} = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(SCAR_{i\tau} - \overline{SCAR_{\tau}}\,)^2},$$

where for convenience the subscript $\tau = (\tau_1, \tau_2)$, and

(17) $$\overline{SCAR}_{\tau} = \frac{1}{N}\sum_{i=1}^{N} SCAR_{i\tau}.$$

Step 4: Compute the ADJ-BMP *t*-statistic for $CAAR(\tau_1, \tau_2)$:

(18) $$Z_{BMP,\tau} = \frac{\overline{SCAR}_{\tau}\sqrt{N}}{s_{SCAR,\tau}\sqrt{1+(N-1)\bar{\rho}}},$$

where $\bar{\rho}$ is the average of the sample cross-correlations of the estimation period residuals.

The second problem regarding statistical inferences in event study analyses is that stock prices are not normally distributed (Fama, 1976), thus, the need to conduct nonparametric tests to address this issue (while also checking for the robustness of statistical inferences based on parametric tests). Evidence suggests that, although nonparametric tests dominate their parametric counterparts in event study analyses of abnormal returns on a single day, they fail to do so when the analysis is extended to multiple day tests of cumulative abnormal returns (Kolari and Pynnonen, 2011). To overcome previous pitfalls in nonparametric tests applied to CARs, Kolari and Pynnonen (2011) propose a generalized rank (GRANK) testing procedure that can be used on both single day and CARs. This *t*-statistic is based on the traditional rank testing approach previously proposed by Corrado (1989) and Corrado and Zivney (1992).

The GRANK t-statistics for $CAAR$s is computed as follows:

Step 1: Calculate the re-standardized $SCAR$ using the cross-sectional standard deviation:

$$SCAR_{i\tau}^{*} = \frac{SCAR_{i\tau}}{s_{SCAR,\tau}}. \tag{19}$$

Step 2: Calculate the generalized standardized abnormal returns ($GSAR$) vector:

$$GSAR_{it} = \begin{cases} SAR_{it} & for\ t \in [T_1 + 1, T_2] \\ SCAR_{i\tau}^{*} & for\ t = 0 \end{cases}, \tag{20}$$

where, SAR_{it} is the standardized abnormal return of firm's i stock on day t, computed by dividing the abnormal return by the standard deviation of the residuals obtained from equation (6):

$$SAR_{it} = \frac{AR_{it}}{s_{AR_i}}. \tag{21}$$

To derive the rank test, the time index is redefined such that $t \in T^{*} = \{T_1 + 1, \dots, T_2, 0\}$, where $CAR_i(\tau_1, \tau_2)$, represented by $SCAR_{i\tau}^{*}$, is introduced as a whole into one observation with time index $t = 0$. Thus, the length of $T^{*} = L_1 + 1$ observations. The idea behind $GSAR$ is that the event impact is captured on a single measure $SCAR_{i\tau}^{*}$, which under the null hypothesis behaves like any other standardized return, but it starts to deviate if affected by the event under the alternative hypothesis (Kolari and Pynonnen, 2011).

Step 3: Obtain the demeaned standardized abnormal return ranks of the $GSAR$ vector (there is one vector for each CAR_i over interval τ), as follows:

$$U_{it} = \frac{Rank(GSAR_{it})}{L_1 + 1} - \frac{1}{2}. \tag{22}$$

Step 4: Compute the mean and standard deviation of U_{it} for $t \in T^* = \{T_1 + 1, \dots, T_2, 0\}$ and $i = 1, \dots, N$.

$$\bar{U}_t = \frac{1}{N}\sum_{i=1}^{N} U_{it}, \tag{23}$$

$$S_{\bar{U}} = \sqrt{\frac{1}{L_1}\sum_{t \in T^*} \bar{U}_t^{\,2}}. \tag{24}$$

Step 5: Calculate the GRANK *t*-statistic defined as:

$$Z_{GRANK,\tau} = \bar{Z}_\tau \left(\frac{L_1 - 2}{L_1 - 1 - \bar{Z}_\tau^{\,2}}\right)^{\frac{1}{2}}, \tag{25}$$

where,

$$\bar{Z}_\tau = \frac{\bar{U}_0}{S_{\bar{U}}}, \tag{26}$$

and, $\bar{U}_0$ is the mean $\bar{U}_t$ at $t = 0$.

3.2 Effects of Meat and Poultry Recall Characteristics

The event study analysis is extended by examining what factors determine the magnitude of post event abnormal returns. The main focus of this assessment is to estimate the effects of characteristics specific to meat and poultry recalls and the firm issuing the recall, which are considered as explanatory variables. However, control variables are also introduced to avoid misspecification problems. In addition, this analysis utilizes both cross-sectional and panel data type models. In the cross-sectional model, the dependent variable is the cumulative abnormal return over a particular interval of the event window. On the other hand, the dependent variables in the panel model are either abnormal returns or cumulative abnormal returns. The difference between these two models is that the panel model includes all cross-sectional observations from a particular interval of the event window, whereas the cross-sectional model includes one observation per interval. Using both models, different intervals of the event window are analyzed to check whether the effects of explanatory variables change over time.

Following Savor (2012), the cross-sectional model is specified as:

$$CAR_{i\tau} = \phi_0 + \phi_1 X_{1i} + \cdots + \phi_J X_{Ji} + \eta_i, \tag{27}$$

where, $CAR_{i\tau}$ is the cumulative abnormal return for firm i over interval τ starting τ_1 and ending τ_2 trading days after the event day, X_j are J explanatory variables, ϕ_j are parameters to be estimated (for j =1, 2,…, J), and η_i is the error term with zero mean and assumed to be uncorrelated with the $X's$.[9] This model is estimated using ordinary least squares (OLS) and inference is based on robust standard errors when necessary.

The panel model is specified as:

$$CAR_{it} = \theta_0 + \theta_1 X_{1it} + \theta_2 X_{2i} \dots + \theta_J X_{Ji} + \xi_i \quad for\ all\ t \in \tau, \tag{28}$$

where, CAR_{it} is the cumulative abnormal return for firm i at time t over interval τ. Notice the inclusion of explanatory variables that have a time t index (such as X_{1it}) indicating that these vary across time. As in the previous model specification, θ_j are parameters to be estimated (for j =1, 2,…, J), and ξ_i is the error term with zero mean and assumed to be uncorrelated with the $X's$. The

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[9] Because some firms register more than one recall, subscript $i = 1, \dots, N$, where N is the total number of recalls.

use of an aggregated variable (or a rolling sum of the original series) as the dependent variable are found in the finance literature (Campbell and Shiller, 1988; Fama and French, 1988). Models that use this type of variables are known as long-horizon regressions. In this literature, it is argued that long-horizon regressions produce more accurate results by strengthening the signal coming from the data while eliminating the noise. Hence, these models have been extensively applied to stock returns predictability (Valkanov, 2003). In this analysis, however, long-horizon observations for firm i are pooled. Thus, the resulting model is estimated as a panel data model, considering the implications of using long-horizon regressions. The main inferential issue in long-horizon regressions has been the proper calculation of standard errors, since the regression residuals might exhibit strong serial correlation. Therefore, inference is conducted using clustering robust standard errors. Note that when the dependent variable is the abnormal return, the model is estimated using standard panel data approaches and inference is based on robust standard errors.

3.2.1 Explanatory Variables Definition and Justification

The set of explanatory variables is divided into two groups: variables directly related to the meat recall and control variables associated with the firm. That is, considering the post event behavior of stock returns would not be influenced solely by characteristics of the meat recall, control variables are included to enhance the predictability of the model and avoid misspecification problems. The following are variables based on meat recall characteristics:

a. *Severity of the threat (Class).* There are three classes of FSIS meat recalls. Class I recalls are the most serious and involve a "situation where there is a reasonable probability that the use of the product will cause serious, adverse health consequences or death." Class II recalls involve a "situation where there is a remote probability of adverse health consequences from the use of the product." And, Class III recalls involve a "situation where the use of the product will not cause adverse health consequences." Hence, this variable categorizes a meat recall according to its class, where Class I recalls are anticipated to have a larger impact on abnormal returns than the other two.

b. *Recall Size*. The number of pounds recalled by a particular firm during a meat recall. Larger volume recalls are expected to have a larger impact on abnormal returns.

c. *Foodborne Pathogen.* Class I recalls can be caused by several reasons including foodborne pathogens. Hence, this binary variable indicates whether market reactions to recalls that are triggered by a pathogen differ from those originated by other "less severe" reasons (e.g., foreign materials or undeclared allergens).

d. *Media Index*. This index is constructed using the number of articles or media reports directly related to a particular meat recall. The level of media coverage a recall receives (perceived as an indicator of the severity of the recall) would be expected to influence the firm's stock price reaction.

e. *HACCP*. This variable is intended to capture the effects of the mandatory implementation of the Pathogen Reduction/HACCP final rule enacted on July 25, 1996. The number of recalls have increased since this rule became mandatory (Teratanavat and Hooker, 2004) and as such this event could result in a structural change in market reactions to recall events.

f. *Diversification.* This variable captures in very broad terms the level of diversification of the firm involved in the recall. That is, this variable indicates whether meat and poultry products are one of the main segments of production for a particular firm. The expectation is that a firm that produces mostly meat and poultry products would be more affected by a recall than a more diversified firm.

g. *Experience*. This variable measures whether a firm has been previously involved in a meat recall incident within the last year. It is intended to capture the difference in stock market reactions between recurring firms and those issuing a recall for first time over the past year.

h. *Cluster*. This variable captures the effect of another recall (either from the same firm or from a different firm) that occurred within 10 days. This variable is used to account for the cross-sectional correlation between recent recalls.

Following Savor (2012), the following are control variables that are well known predictors of stock returns:

i. *Firm Size.* Market equity is used as a proxy for this variable. It is calculated by multiplying the firm's total number of shares outstanding by the closing market price ten days before the recall announcement. Besides being an important predictor of stock returns, firm size is a potential determinant of the reduction in food company valuation caused by a food recall (Salin and Hooker, 2001).

j. *Trading Volume.* Computed as the percentage of shares outstanding that is traded.

k. *Momentum.* Calculated as the return over the previous 12 months or annual return (before the recall announcement).

l. *Size of initial shock.* This variable is defined as the abnormal return registered at the event date (time $t = 0$). The size of the initial shock is expected to reflect the impact of the event day abnormal return.

3.2.2 Variables Not Included

In addition to the variables indicated above, there are several other variables that may potentially help explain abnormal return variation following a food safety recall. However, either because of the lack of data or difficulty in specification, the variables have not been included in this analysis. For example, “number of illnesses” or “recall scope” (number of states where tainted product has been distributed) are not included because this information is not available for all recalls. We would expect these variables to be related to the severity and size of the recall, so likely some of these impacts are captured in those variables that are included in the models. Moreover, variables related to product type or level of processing are difficult to define. That is, certain products can be easily classified according to their meat type (e.g., ground beef). However, this is not the case for products containing more than one type of meat, such as sausages. Also, classifying products as “branded” versus “non-branded” (or “generic”) is a difficult task because these latter products can come from different sources.

Chapter 4 - Data

The effects of meat recalls on stock prices are analyzed from January 1994 to December 2013. Three different data sets were collected to conduct this analysis: meat recall data, firm data and media data. These data and their different sources are described in subsections 4.1 – 4.3. Finally, summary statistics are presented in subsection 4.4.

4.1 Meat Recall Data

Meat recall data were collected from the USDA FSIS website. These data are publically available and can be found in the recall case archive. Here, meat and poultry recalls are recorded by year, and each entry contains a case number and a recall report. There are three types of recall reports: a recall release, a recall notification report (RNR) and a retail report (RTR). When FSIS issues the recall, a recall release report is generated. This report summarizes specific information such as issuance date, class, information related to the company recalling the product (e.g., company's name, location, etc.), type of product subject to the recall (e.g., product's name, type, labels images, "best by" date, product's presentation, lot code, etc.), quantity recalled and recovered, cause for issuing the recall, and states where the unsafe product was distributed. On the other hand, an RNR is issued in situations involving a Class III recall or, regardless of the class, when FSIS does not issue a recall release.[10] Unlike a recall release, an RNR is not distributed to media wire services or media outlets in areas that received recalled products. However, it is posted on the FSIS website. Similarly, an RTR is issued when a recall is conducted by a retail

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[10] "FSIS will typically not issue a recall release for Class III recalls unless there are overriding public welfare reasons, such as a case of egregious economic adulteration" (FSIS Directive, 2013).

establishment under a State's inspection program, and only if requested, FSIS will provide State agencies with assistance and information.[11]

A total of 1,271 recalls have been issued during the period of interest of this study. However, not every firm involved in these recalls is publicly traded. To identify public companies, online sources and financial software terminals were consulted. First, an online search of the reported establishment issuing the recall was conducted to determine whether it was privately held, publicly held, or a subsidiary of a public company. Then, the Bloomberg terminal was used to verify the ownership status of subsidiaries on the recall dates. Here, public companies were screened to include only those traded in a U.S. stock exchange. There were several cases where the involved establishment had not been yet acquired by the public company. For example, Farmland Foods, a current subsidiary of Smithfield Foods Inc., issued a voluntary recall on May 16, 2003. However, it was not until October 28, 2003 that Smithfield completed the acquisition process of this establishment. Thus, this recall and others in similar cases, were not included in the analysis. Finally, the Bloomberg terminal was employed to determine the initial public offering date of each public company. This search was conducted to verify whether the involved establishment was public at the time of the recall. For instance, Kraft Foods Inc. became public on June 12, 2001. However, the FSIS website reports recalls issued by Kraft that date back to 1994. As result, 163 recalls corresponding to 31 different publicly traded companies were identified.[12]

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[11] For consistency, recalls registered on RNR and RTR were excluded from this analysis.

[12] Six recalls from four companies that do not have enough trading data were excluded from this date set. These four companies are: Cagle's, Hanover Foods, Rymer Foods and Seneca Foods.

Table 4.1 summarizes the number and size of meat and poultry recalls by year. From 1994 to 2013, over 630 million pounds of product have been recalled. Interestingly, recalls from publicly traded firms, which represent 13 percent of the recalls, account for almost 45 percent of the total number of pounds recalled during the past two decades (over 270 million pounds).

Table 4.1. Summary of All Recalls and Recalls from Publicly Traded Firms by Year

Year	**All Recalls**		**Recalls From Publicly Traded Firms**	
	No.	**Pounds**	**No.**	**Pounds**
1994	50	4,794,156	8	1,305,288
1995	42	5,653,608	9	3,824,570
1996	24	994,567	6	295,829
1997	27	28,152,989	6	26,442,681
1998	44	45,938,658	16	38,671,105
1999	62	39,927,909	8	35,193,493
2000	85	6,012,827	10	789,736
2001	97	31,814,235	12	4,295,100
2002	125	58,442,603	15	48,161,405
2003	68	3,285,324	5	239,550
2004	49	2,879,455	12	567,605
2005	53	6,446,231	4	3,309,655
2006	34	5,947,933	4	121,555
2007	58	143,063,822	7	87,667,231
2008	54	154,726,663	5	1,356,370
2009	69	9,488,664	10	2,113,251
2010	70	34,121,902	6	22,315,400
2011	103	39,702,319	9	663,089
2012	82	3,475,115	5	116,763
2013	75	13,096,784	6	206,495
Total	**1,271**	**637,965,764**	**163**	**277,656,171**

The 163 meat and poultry recalls included in this analysis are very diverse. These include beef, pork, chicken, turkey and other miscellaneous meat products. In addition, recalls consist of a large selection of products ranging from mostly meat products (e.g., ground beef, sausage, etc.)

to products where meat is only one of the ingredients (e.g. pizza, soup, etc.). Moreover, products recalled come in different package presentations and are sold raw, cooked or ready-to-eat. Regarding the recall classification based on the level of severity, the final data set contains 115 Class I, 39 Class II and 9 Class III recalls (Table 4.2). Not surprisingly, Class I recalls account for 98 percent of the total product recalled, followed by Class II recalls with 1.4 percent and the remaining Class III recalls with less than 0.6 percent.

Table 4.2. Summary of Recalls from Publicly Traded Firms by Class

Year	**Class I**		**Class II**		**Class III**	
	No.	**Pounds**	**No.**	**Pounds**	**No.**	**Pounds**
1994	2	49,168	6	1,256,120	-	-
1995	7	3,364,625	2	459,945	-	-
1996	4	146,129	2	149,700	-	-
1997	4	26,316,034	2	126,647	-	-
1998	10	37,994,799	5	659,026	1	17,280
1999	6	35,054,493	2	139,000	-	-
2000	9	788,200	1	1,536	-	-
2001	7	3,596,600	2	102,000	3	596,500
2002	8	47,323,305	3	795,800	4	42,300
2003	4	236,550	-	-	1	3,000
2004	12	567,605	-	-	-	-
2005	4	3,309,655	-	-	-	-
2006	2	18,277	2	103,278	-	-
2007	5	87,659,806	2	7,425	-	-
2008	4	1,305,010	1	51,360	-	-
2009	6	2,069,932	4	43,319	-	-
2010	6	22,315,400		-	-	-
2011	8	652,829	1	10,260	-	-
2012	2	84,069	3	32,694	-	-
2013	5	168,495	1	38,000	-	-
Total	**115**	**273,020,981**	**39**	**3,976,110**	**9**	**659,080**

Focusing on recall size, Figure 4.1 depicts the natural logarithms of the size of each recall in chronological order.[13] Here, it is shown that out of 163 recalls only 15 lie above the 13.8 mark (equivalent to 1 million pounds). However, these recalls account for approximately 95 percent of the total product recalled. Among these large scale recalls is one issued by ConAgra in 2007 caused by *Salmonella* contamination in frozen pot pie products. This recall is the largest of this data set with about 84 million pounds recalled. The second and third largest recalls were issued by Bil Mar Foods (a subsidiary of Sara Lee) in 1998 and Thorn Apple Valley in 1999, and were caused by a *Listeria monocytogenes* outbreak in hot dogs and frankfurters, respectively. Each company issued a recall of 35 million pounds. Not surprisingly, these three largest recalls are Class I and were caused by a foodborne pathogen outbreak. On the other hand, 101 recalls lie below the 11.5 mark (equivalent to 100,000 pounds).

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[13] To facilitate the analysis of this figure, recall size is expressed as the natural logarithms of the number of pounds recalled.

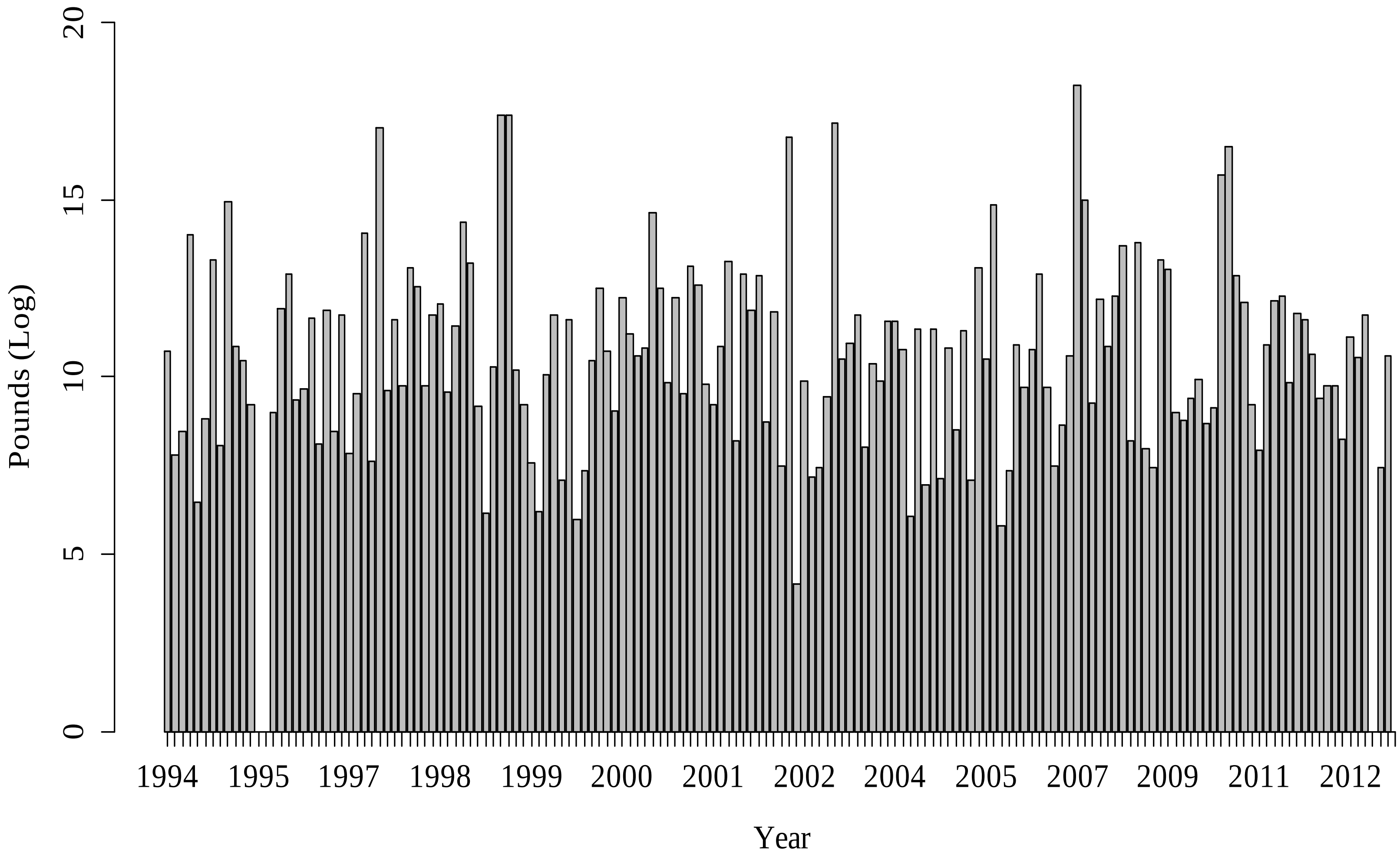

Figure 4.1 Recall Size per Recall

Table 4.3 summarizes the number of recalls by firm. These firms differ in size and level of diversification. In addition, their stocks are traded in either the New York Stock Exchange (NYSE) or NASDAQ Stock Market (with the exception of Nestle which trades on an OTC market).

Table 4.3. Summary of Recalls from Publicly Traded Firms by Firm

Ticker	Company	No.	Pounds
AHP	American Home Products Corp.	1	150,000
BOBE	Bob Evans Farms Inc.	1	8,500
CAG	ConAgra Inc.	24	114,669,426
COST	Costco Wholesale Corp.	4	222,123
CPB	Campbell Soup Co.	9	16,322,137
DEG	The Delhaize Group	1	Undetermined
DLM	Del Monte Foods Co.	1	31,650
GIS	General Mills Inc.	1	3,300,000
HAIN	The Hain Celestial Group Inc.	1	983,700
HFI	Hudson Foods Inc.	5	28,313,959
HNZ	Heinz H. J. Co.	3	94,886
HRL	Hormel Foods Corp.	6	234,946
IBP	IBP Inc.	5	1,160,355
K	Kellogg Co.	1	2,790
KFT	Kraft Foods Inc.	5	28,508
KR	Kroger Co.	3	490,131
NSRGY	Nestle SA	13	1,689,393
PPC	Pilgrim’s Pride Corp.	4	28,806,600
SAFM	Sanderson Farms Inc.	1	Undetermined
SFD	Smithfield Foods Inc.	13	1,007,821
SJM	Smucker J. M. Co.	1	3,000
SLE	Sara Lee Corp.	13	37,723,229
SVU	Supervalu Inc.	2	962
SYY	Sysco Corp.	1	16,800
TAVI	Thorn Apple Valley Inc.	2	35,009,936
THS	TreeHouse Foods Inc.	3	214,957
TSN	Tyson Foods Inc.	35	4,854,233
UVV	Universal Corp.	1	578,000
WFM	Whole Foods Market Inc.	1	1,275
WIN	Winn Dixie Stores Inc.	1	1,734,002
WMK	Weis Markets Inc.	1	2,852
Total		**163**	**277,656,171**

Three of these companies (CAG, SLE and TAVI) are responsible for almost 70 percent of the recalled product, whereas two (CAG and TSN) are responsible for 36 percent of the recalls. Also, the company with the largest number of recalls, Tyson Foods, is not the one recalling the largest amount of product. On a different aspect, some recalls are issued by a subsidiary of the "parent" companies (not distinguished in table 4.3). This is the case of 57 recalls (35 percent of the recalls).

4.2 Stock and Firm Data

Daily stock price data were obtained from the Bloomberg terminal. Regardless of the recall date, these data were collected for the entire period of this study (January, 1994 to December 2013). Then, the event timeline was established as in Figure 3.1.[14] Similarly, daily market index price data were collected for the following six indices: Standard and Poor's 500 Composite Index (S&P 500); S&P 500 Food, Beverage and Tobacco Industry Group Index (S&P 500 FBT); S&P 500 Packaged Foods Industry Index (S&P 500 PF); NASDAQ Global Select Market Composite (NQGS); New York Stock Exchange Composite Index (NYA); and Russell 2000 Index (RTY). That is, consistent with the literature, the S&P 500 indices are used to estimate the benchmark model. However, other indices are also included to account for stocks traded in NASDAQ and in the NYSE (i.e., NQGS and NYA, respectively), and for small capitalization stocks (i.e., RTY). Furthermore, the Bloomberg terminal was also used to collect daily trading volume for each firm.

Firm size is one of the variables included in this analysis and market equity is used as its proxy. Market equity is calculated as the product between the closing stock price (10 trading days

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[14] If the recall date fell on a weekend or holiday, the event date was defined as the nearest trading day following the announcement date.

before the recall announcement) and the total number of shares outstanding. The number of shares was collected from annual reports (or 10-K reports) which are publically available at the U.S. Securities and Exchange Commission website (SEC-EDGAR search tools). Particular attention was paid to ensure the recall date coincided with the report prepared on the corresponding fiscal year. Additionally, information regarding the diversification level of each firm was also gathered from annual reports. Ideally, this variable would have been constructed using the percentage of sales (or production) involving meat and poultry products. However, since not every firm reports the percentage of sales per product segment, a very broad variable was used instead reflecting whether meat and poultry products are one of the main lines of production in each firm. For example, meat is the main production/sales segment for Smithfield Foods, whereas for Kellogg, meat is a very small segment. In addition, for all firms in the sample, this broad level of diversification did not vary by year.

4.3 Media Data

Media information, more specifically the number of articles published per day, were collected using LexisNexis *Academic*. This search was conducted per recall, over the event window dates. That is, 15 calendar days prior and 30 calendar days after the recall announcement (corresponding to [–10, +20] trading days). Additionally, the selected source type included “all news” sources (e.g., newspapers, newswires and press releases, web-based publications, blogs, newsletters, news transcripts, magazines, etc.), covering the entire U.S. region. The keywords used in each search were recall specific, including: {“product recalled” AND recall}, {“cause” AND recall}, {“product” AND “cause” AND recall}, or {“product recalled” AND “cause”}. To ensure the articles were related to a specific recall, a within search was then performed using the “establishment’s name” as a keyword. For example, keywords for one of the entries would be: {ground beef AND E. coli AND recall} and then, the within search would include: ConAgra.

In some cases, individual searches resulted in duplicated articles. To deal with this issue several rules were defined:

i. Two articles, published on the same day by the same periodical on different feeds are considered one article.
ii. Two articles, published on the same day by the same periodical on different times are considered one article.
iii. The same article, published by two different periodicals on the same day is considered two articles.
iv. The same article, published by the same periodical on different dates is considered two articles.
v. One article, making reference to two different recalls is counted twice, once for each recall.

Figure 4.2 depicts the total number of articles per recall (in chronological order). In general, it is noticeable the increase in the number of articles through time. Removing the three outliers from the first half of the sample, the number of articles almost doubled in the last decade. Furthermore, zero articles were published regarding 30 out of 163 recalls. This is the case of recalls that occurred during the 1990’s with few exceptions. On the other hand, three recalls present a number of articles above 100. These recalls were issued by Hudson Foods in 1997 (412 articles), ConAgra in 2002 (190 articles) and Pilgrim’s Pride in 2002 (122 articles). The common denominator of the three recalls is that these are Class I, caused by contamination with a foodborne pathogen (*E. coli* O157:H7 in the first two and *Listeria monocytogenes* in the last), and exceeded

18 million pounds of product recalled. In particular, the case of Hudson Foods received widespread media attention because at that time, it was considered the largest beef recall in history, and also because the tainted product (hamburger patties) had been sold to Burger King.

In addition, Figure 4.3 presents a comparison between recall size (expressed in natural logarithms of the number of pounds recalled) and the number of articles issued per recall. The number of articles seems to be proportional to the size of the recall in most of the cases. In particular, recalls with the largest number of pounds recalled, also have the largest number of articles issued.

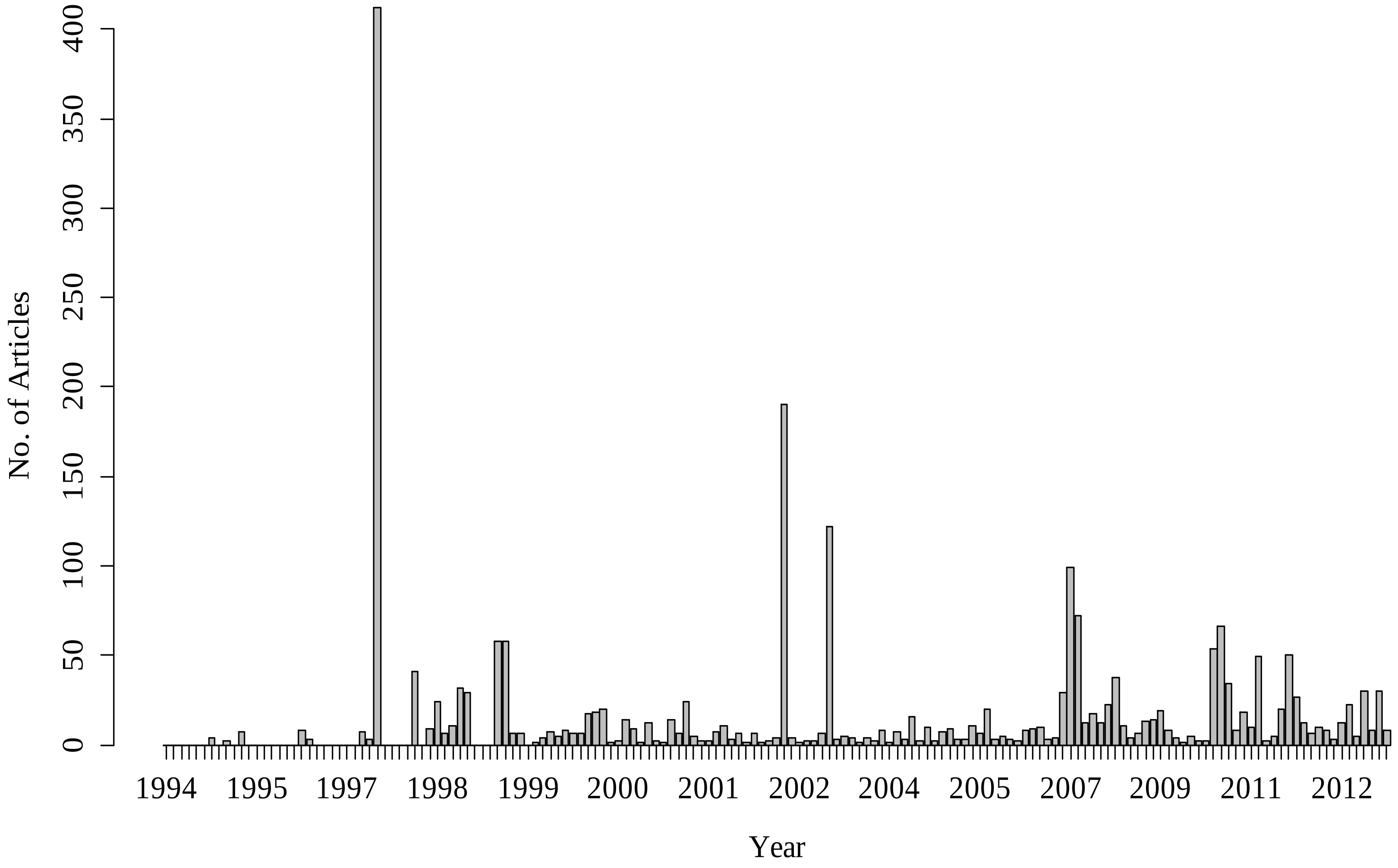

Figure 4.2 Number of Articles per Recall

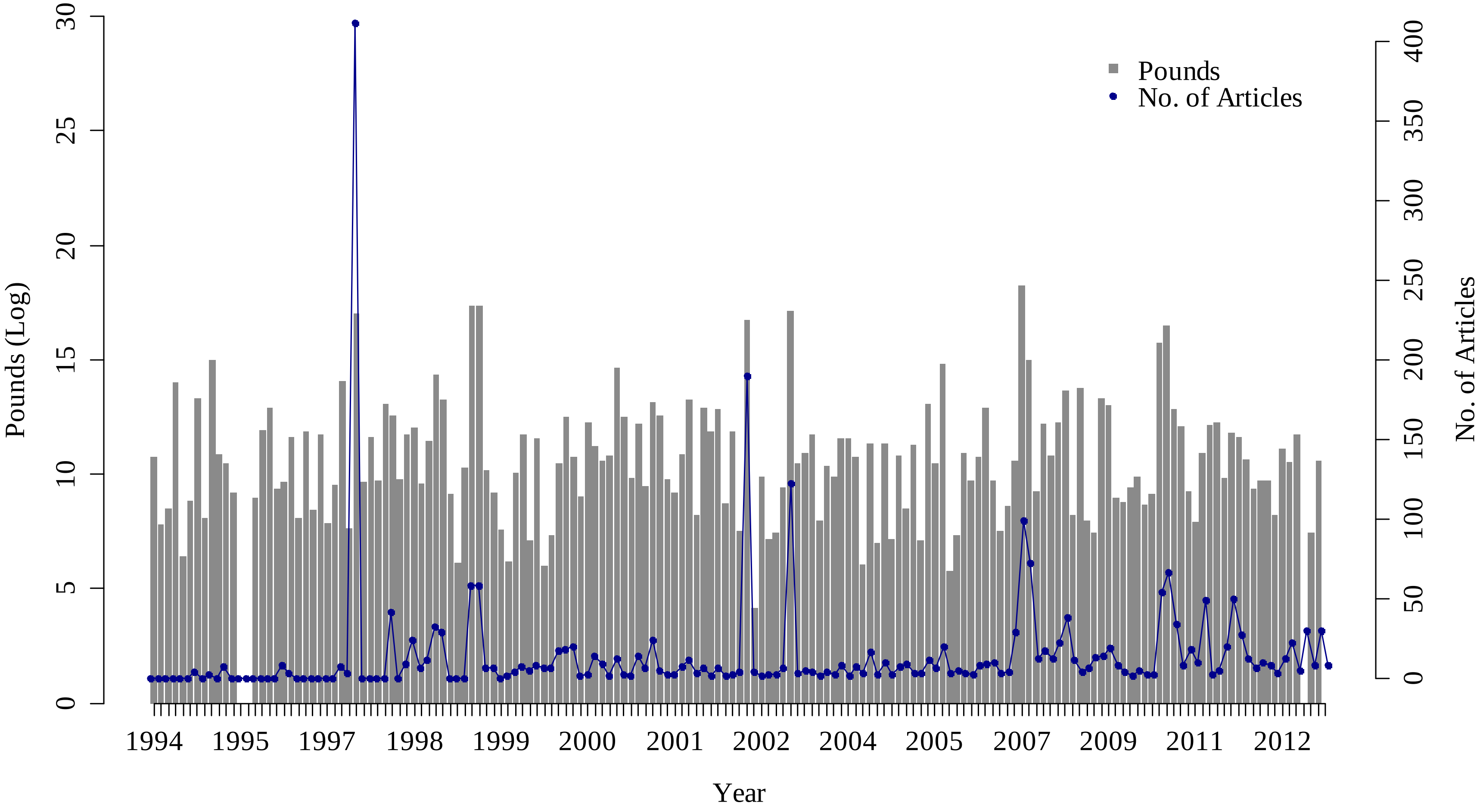

Figure 4.3 Comparison of Recall Size versus Number of Articles per Recall

4.4 Summary Statistics

Table 4.4 presents a description and summary statistics of the explanatory variables used to determine post event abnormal returns. Some of these statistics were already discussed in previous sections.

Table 4.4. Description and Summary Statistics of Explanatory Variables

Variable	Description	Statistics			
		Mean	**Std Dev**	**Min**	**Max**
Recall Size	No. of pounds recalled (natural log)	10.64	2.58	4.17	18.25
Firm Size	Market equity (natural log)	22.15	1.47	16.73	26.10
Momentum	Return over previous 12 months (%)	11.44	29.83	-85.21	116.60
Initial Shock	Return on the event day 0 (%)	0.00	1.97	-4.75	9.63
Trading Volume	Percentage of shares outstanding that is traded [a]	10.89	13.59	0.24	138.70
Media Index	No. of articles [a]	14.37	38.50	0.00	412.00
		No.	**% Freq**		
Class					
Class I	1 if Class I, 0 otherwise	115	70.55		
Class II	1 if Class II, 0 otherwise	39	23.93		
Class III	1 if Class III, 0 otherwise	9	5.52		
Pathogen	1 if recall was caused by a pathogen, 0 otherwise	54	33.13		
Experience	1 if the specific firm had another recall in the past year, 0 otherwise	75	46.01		
Diversification	1 if meat is the main segment, 0 otherwise	86	52.76		
HACCP	1 if recall occurred after HACCP implementation, 0 otherwise	144	88.34		
Subsidiary	1 if subsidiary, 0 otherwise	57	34.97		
Cluster	1 if any firm had other recall that occurred within the last 10 days, 0 otherwise	46	28.22		

[a] Overall statistics over the event window interval [0, +20] days.

Focusing on *Firm Size*, the firm with the largest market value of equity in this sample is Nestle (almost $216 billion), whereas the smallest is Thorn Apple Valley ($18.5 million). In addition, for the average firm the value of market equity is $4 billion. On the other hand, looking at *Momentum*, the firm with the largest annual return over the year previous to the recall is Sanderson Farms (116.6 % return in 2001), whereas the smallest is Pilgrim's Pride which in 2009 had a negative return of 85.2 %. In this latter case, the company had filed for bankruptcy at the end of 2008.

Furthermore, daily data were collected for: *Trading Volume* and *Media Index* over the event window. Therefore, these are the only two explanatory variables that vary over time (the statistics presented in Table 4.4 are based on the aggregation of these variables over the interval [0, +20] of the event window). To provide a more detailed description of these variables through time, Figure 4.4 and Figure 4.5 show the average percentage of shares outstanding traded and the average number of articles per recall over the event window, respectively. Note that figure 4.4 represents the average volume (specified as a percentage of shares outstanding) traded across all recalls. Although some firms trade more than 5 percent of their shares outstanding every day, most of them only trade less than 1 percent. Therefore, the average trading volume does not exceed 1 percent.

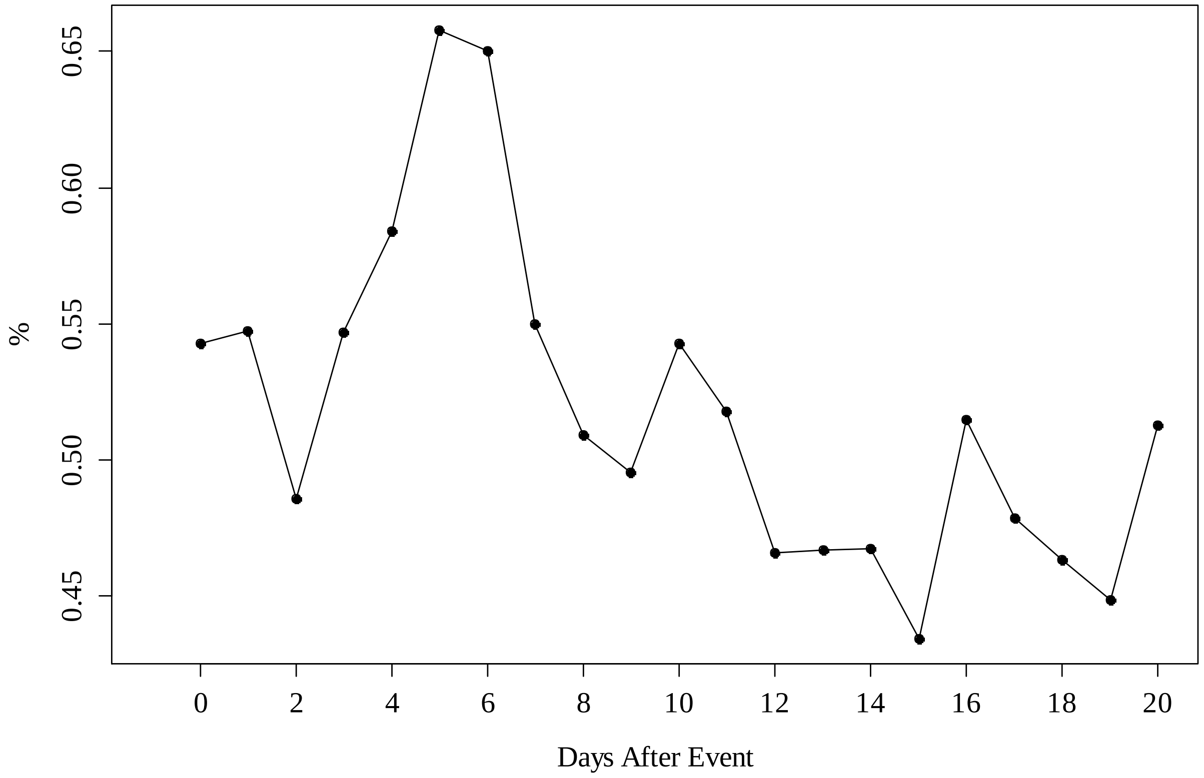

Figure 4.4 Average Percentage of Shares Outstanding Traded per Recall

In Figure 4.4, it is observed that on average trading volume decreases right after the recall, followed by a steep increase two days after which last until day 5. Then it decreases until day 8 to follow an oscillatory pattern in the remaining days. On the other hand, Figure 4.5 shows that, on average, the day with the highest number of articles related to a recall is the day following the recall announcement by FSIS. Then, as expected, the average number of articles per recall decreases continuously over time.

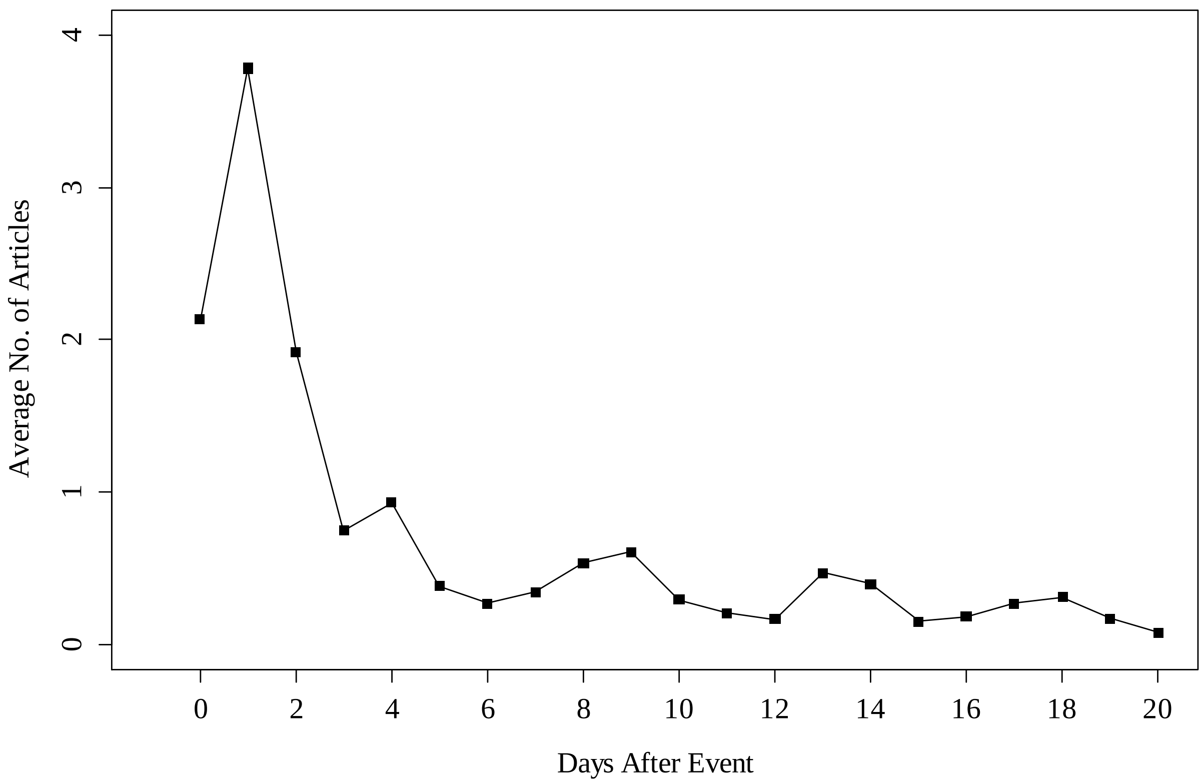

Figure 4.5 Average Number of Articles per Recall

Chapter 5 - Results and Discussion

This chapter is divided in three subsections. The first subsection presents results from the estimation of AR. Here, two estimation windows $[T_1 + 1, T_2]$ are considered to account for the sensitivity of results to the choice of sampling periods: one equal to [–260, –11] and the other equal to [–255, –6] trading days. For simplicity, results obtained from benchmark models estimated with observations from the first estimation window are referred to as $w1$, whereas those from the second window are referred to as $w2$.[15] This notation is extended all the way to the estimation of abnormal returns and its aggregations. In the second subsection, results from the prediction of ARs and CARs, using recall specific and control variables, are discussed. Lastly, simulation examples based on obtained findings are presented in the third subsection.

5.1 Abnormal Returns Estimation

Before estimating the market model in equation (6) or the ARDL model in equation (9), preliminary analysis of the time series properties of stock returns was conducted. Here, returns are expected to follow a stationary process. Therefore, unit root tests were applied to stock returns on the estimation window. Results from the Augmented Dickey-Fuller (ADF) test indicate that all stock return series are stationary at the 0.05 significance level.[16]

In the estimation of the market model, AIC was used to select the best market index among the six indices available. Then, the Ljung-Box test was applied to test for serial correlation among

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[15] The comparison of these results is important because it is assumed that the predictive power of models estimated using $w2$ observations is higher (shorter forecasting horizon).

[16] The ADF tests were applied using both a trend and a drift as deterministic components, with a maximum of 21 lags allowed. In addition, the Akaike information criterion (AIC) was used for lag selection.

residuals. If serial correlation was present in a particular market model, the ARDL(1) model was estimated instead. Thus, a total of 163 × 2 different benchmark models (one for each meat recall multiplied by two estimation windows) were estimated. Among these, 87 and 89 correspond to the market model and 76 and 74 to the ARDL model, for $w1$ and $w2$, respectively. A summary of the regression results from the benchmark models is reported in Table 5.1. As expected, the estimates of α are not statistically different from zero (0.05 significance level), with few exceptions (7 cases out of 326). In addition, all estimates of β are positive, indicating a positive relationship between individual stock returns and the selected market index. All β coefficients are statistically significant (0.05 significance level), except in three cases. Also, consistent with previous event study literature using daily stock price returns, adjusted R^2 values are low (0.25 on average across all benchmark models). This simply reflects the fact that individual company stock returns vary relative to benchmarks.

Table 5.1. Summary Statistics of Coefficients from Benchmark Models

Coefficients	**$w1$ Models**				**$w2$ Models**			
	Mean	Median	Min	Max	Mean	Median	Min	Max
Market Model								
α	0.033	0.031	-0.599	0.300	0.040	0.038	-0.091	0.301
β	0.831	0.804	0.162	1.466	0.830	0.802	0.172	1.439
ARDL Model								
α	0.019	0.009	-0.342	0.465	0.009	0.011	-0.741	0.543
β	0.806	0.811	0.236	1.868	0.804	0.822	0.197	1.877
γ	0.077	0.100	-0.561	0.843	0.085	0.121	-0.557	0.830
δ	-0.086	-0.118	-0.303	0.238	-0.092	-0.117	-0.325	0.241

Once abnormal returns are calculated by taking the difference between expected normal returns (predicted using the benchmark models) and actual returns, they are aggregated over time intervals of the event window and across events to obtain overall measures of the impact of a meat recall. Table 5.2 reports cumulative average abnormal returns ($CAAR$) for all recalls, corresponding to $w1$, along with t-statistics from parametric (equation 18) and nonparametric (equation 25) tests. Regardless of the interval, $CAAR$ are non-negative at time $t = 0$. Thus, suggesting that on average the stock market does not react immediately to every recall. It takes from 1 to 3 days after the recall announcement for the stock market to react. This in itself is not surprising because the recall may not be announced until after the market closes. However, these responses do not become statistically significant until day 4, with one exception. Also, note that both t-statics are consistent (provide the same results) in the last three intervals. By day 5, all $CAAR$ are negative and statistically significant in all intervals. Here, results suggest that on average stock returns decreased up to 0.6% within five days after the recall announcement. This is not the case, however for intervals ending at days 10 or 15 ($CAAR$ are not significant). Surprisingly, $CAAR$ become more negative and significant at day 20, indicating that on average stock returns decreased up to 1% within twenty days after the recall. Figure 5.1 helps to illustrate these findings by showing $CAAR$ plotted over different intervals of the event window.[17] The magnitude of $CAAR$ is influenced by the starting point of aggregation. In addition, most adverse stock price movements occur within five trading days after the event day and then, after recovering for a short time, these decrease again on days 18 to 20 and bounce back up afterward. Table 5.3 shows $CAAR$ for all recalls, corresponding to $w2$, along with t-statistics. As expected, some of the $CAAR$ measures that were not statistically significant in $w1$, become significant in $w2$. Also, $CAAR$ are slightly larger (in absolute value) in $w2$. Figure 5.2 demonstrates this. For example, the line

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[17] Event window intervals are extended with the purpose of analyzing $CAAR$ responses beyond 20 days after the recall announcement. Also, results from the interval [1, 30] are not shown because these are very similar to those in interval [0, 30].

showing the behavior of $CAAR$ on interval [-5, 30] is slightly below the one in Figure 5.1. Thus, in general, evidence indicates there are slight differences between results from $w1$ and $w2$. That is, results show some variation depending on the selection of estimation window. However, at this point it is not possible to assess which results are better.

Table 5.2. Cumulative Average Abnormal Returns [*w*1], All Recalls

	$\tau_1 = -10$			$\tau_1 = -5$			$\tau_1 = -2$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-10	-0.059	-0.483	0.515						
-5	0.084	-0.366	0.083	0.192	0.713	0.329			
-1	0.242	-0.536	-0.534	0.350	-0.029	0.575	0.053	-0.735	-0.280
0	0.243	-0.588	-0.633	0.350	-0.102	0.156	0.053	-0.676	-0.989
1	0.152	-0.735	-0.766	0.259	-0.337	0.081	-0.038	-0.898	-1.057
2	0.145	-0.623	-0.546	0.252	-0.197	0.503	-0.044	-0.669	-0.925
3	-0.045	-0.882	-0.156	0.062	-0.546	0.401	-0.234	-1.010	-1.063
4	-0.263	-1.397*	-0.606	-0.156	-1.168	-0.374	-0.453	-1.685**	-1.684**
5	-0.369	-1.606*	-0.940	-0.262	-1.402*	-0.702	-0.558	-1.920**	-2.020**
10	-0.052	-1.102	-0.777	0.055	-0.844	-0.553	-0.241	-1.194	-1.370*
15	-0.084	-1.059	-1.106	0.023	-0.861	-0.699	-0.274	-1.108	-1.173
20	-0.764	-1.524*	-1.542*	-0.656	-1.380*	-1.248	-0.953	-1.561*	-1.618*

	$\tau_1 = 0$			$\tau_1 = 1$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-10						
-5						
-1						
0	0.000	-0.181	-0.233			
1	-0.091	-0.594	-0.841	-0.091	-0.565	-0.671
2	-0.097	-0.295	-0.275	-0.098	-0.198	0.088
3	-0.287	-0.800	-0.522	-0.288	-0.754	-0.268
4	-0.506	-1.697**	-1.656**	-0.506	-1.726**	-1.410*
5	-0.611	-1.931**	-2.017**	-0.612	-1.933**	-1.782**
10	-0.294	-0.975	-1.069	-0.295	-0.978	-0.981
15	-0.327	-0.941	-0.996	-0.327	-0.936	-0.969
20	-1.006	-1.446*	-1.572*	-1.007	-1.472*	-1.485*

Note: ** and * denote statistical significance at the 0.05 and 0.10 level for a one tailed test (equation 12).

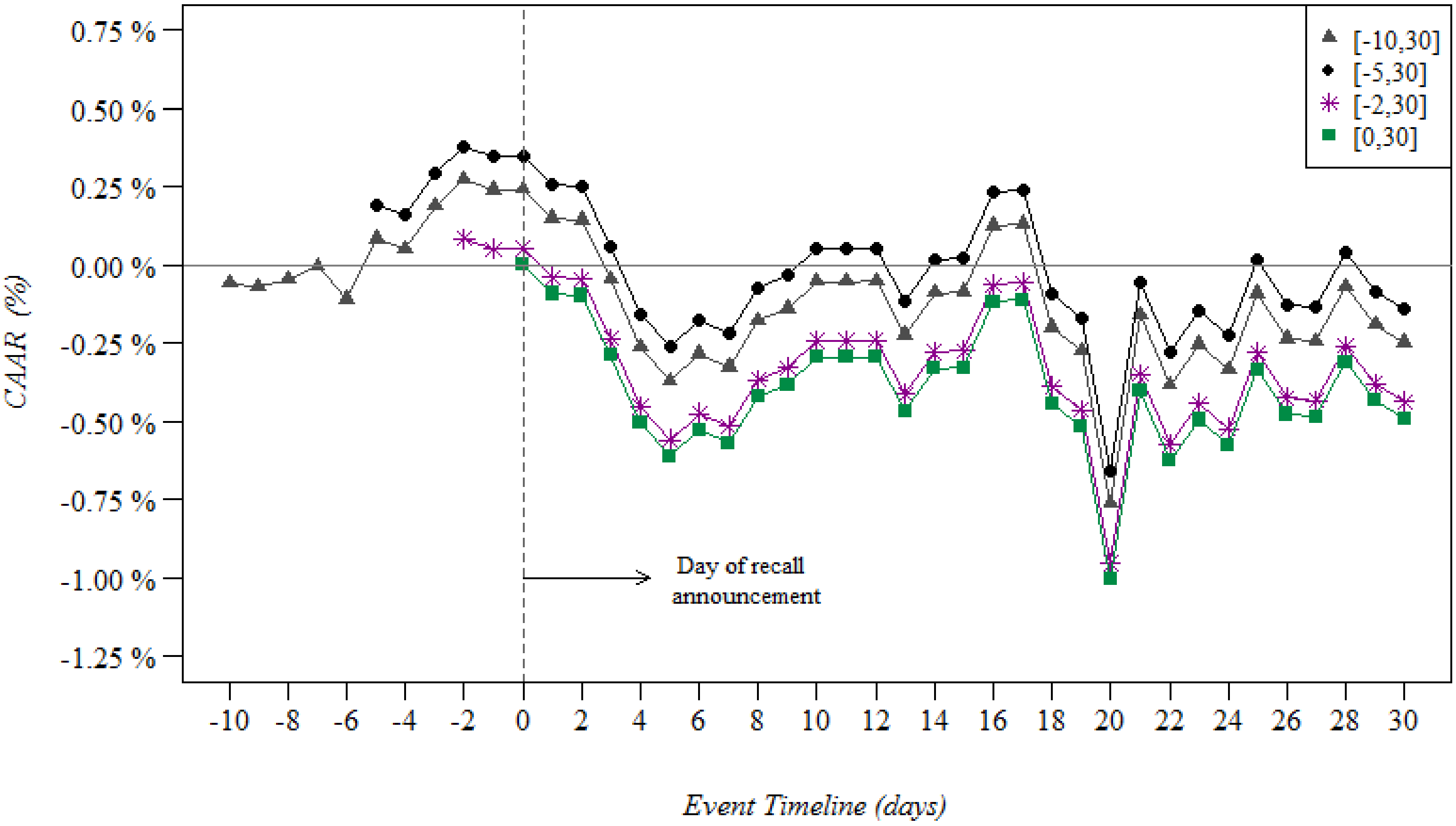

Figure 5.1 Cumulative Average Abnormal Returns [*w*1] for All Recalls

Table 5.3. Cumulative Average Abnormal Returns [*w*2], All Recalls

	$\tau_1 = -5$			$\tau_1 = -2$			$\tau_1 = 0$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-5	0.167	0.577	0.288						
-1	0.326	-0.061	0.502	0.048	-0.668	-0.242			
0	0.315	-0.238	-0.039	0.036	-0.756	-1.001	-0.011	-0.409	-0.424
1	0.223	-0.479	-0.039	-0.056	-0.986	-1.112	-0.103	-0.797	-1.072
2	0.230	-0.306	0.380	-0.049	-0.721	-0.958	-0.097	-0.429	-0.460
3	0.034	-0.629	0.338	-0.244	-1.047	-1.038	-0.292	-0.888	-0.584
4	-0.191	-1.302*	-0.571	-0.469	-1.787**	-1.804**	-0.517	-1.870**	-1.828**
5	-0.305	-1.539*	-0.889	-0.583	-2.030**	-2.171**	-0.631	-2.091**	-2.248**
10	-0.012	-1.020	-0.729	-0.290	-1.342*	-1.545*	-0.338	-1.162	-1.309*
15	-0.046	-1.005	-0.789	-0.324	-1.230	-1.273	-0.372	-1.087	-1.147
20	-0.725	-1.490*	-1.333*	-1.003	-1.648**	-1.690**	-1.051	-1.550*	-1.669**

	$\tau_1 = 1$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}
-5			
-1			
0			
1	-0.092	-0.608	-0.757
2	-0.085	-0.181	0.076
3	-0.281	-0.733	-0.217
4	-0.506	-1.799**	-1.499*
5	-0.620	-2.013**	-1.968**
10	-0.327	-1.095	-1.162
15	-0.361	-1.028	-1.113
20	-1.040	-1.527*	-1.472*

Note: ** and * denote statistical significance at the 0.05 and 0.10 level for a one tailed test (equation 12).

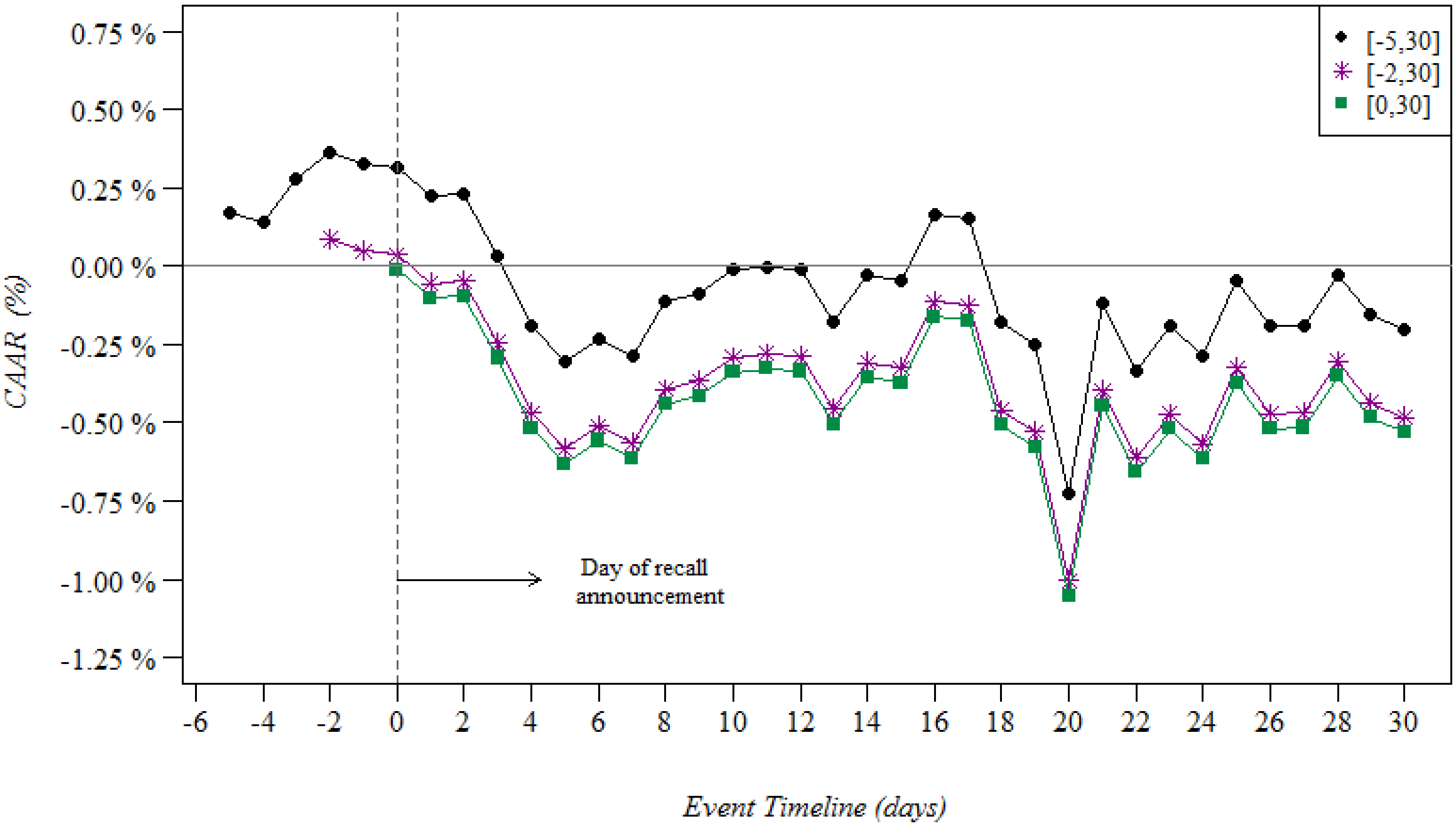

Figure 5.2 Cumulative Average Abnormal Returns [*w*2] for All Recalls

Thomsen and McKenzie (2001), found significantly negative $CAAR$ at day 20 as well.[18] To verify if this finding is caused by outliers, individual CAR are analyzed by looking at their behavior over time. This evaluation is also conducted as a robustness check. Figure 5.3 shows plots of individual CAR on different horizons over interval [0, 30] trading days of the event window. Each circle represents an individual recall which always maintains the same order. Looking at the plots, it is evident that there are few outliers (or influential observations) on both sides of CAR. In particular, recall 124 is the most noticeable because its return consistently decreases reaching -157%. To know precisely which recalls are outliers, sorting tools were applied on each horizon. The three recalls that appeared more frequently on the last ten positions of negative returns are: Thorn Apple Valley (1999), Pilgrim's Pride (2002) and Pilgrim's Pride (2009). In these three cases, the range of CAR variation across all horizons is -157 to -12%. In addition, these recalls are Class I and resulted in 64 million pounds of product recalled overall. Thorn Apple Valley filed for bankruptcy right after this recall, whereas Pilgrim's Pride had already done so prior to its 2009 recall. On the other hand, the recalls that appear more frequently on the first ten positions of positive returns are: Tyson Foods (2002), Smithfield Foods (2000) and Sanderson Farms (2001). Here, the range of CAR variation across all intervals is 7 to 27%. The first two are Class I recalls and the last is Class III, with 12,000 pound of product recalled overall.

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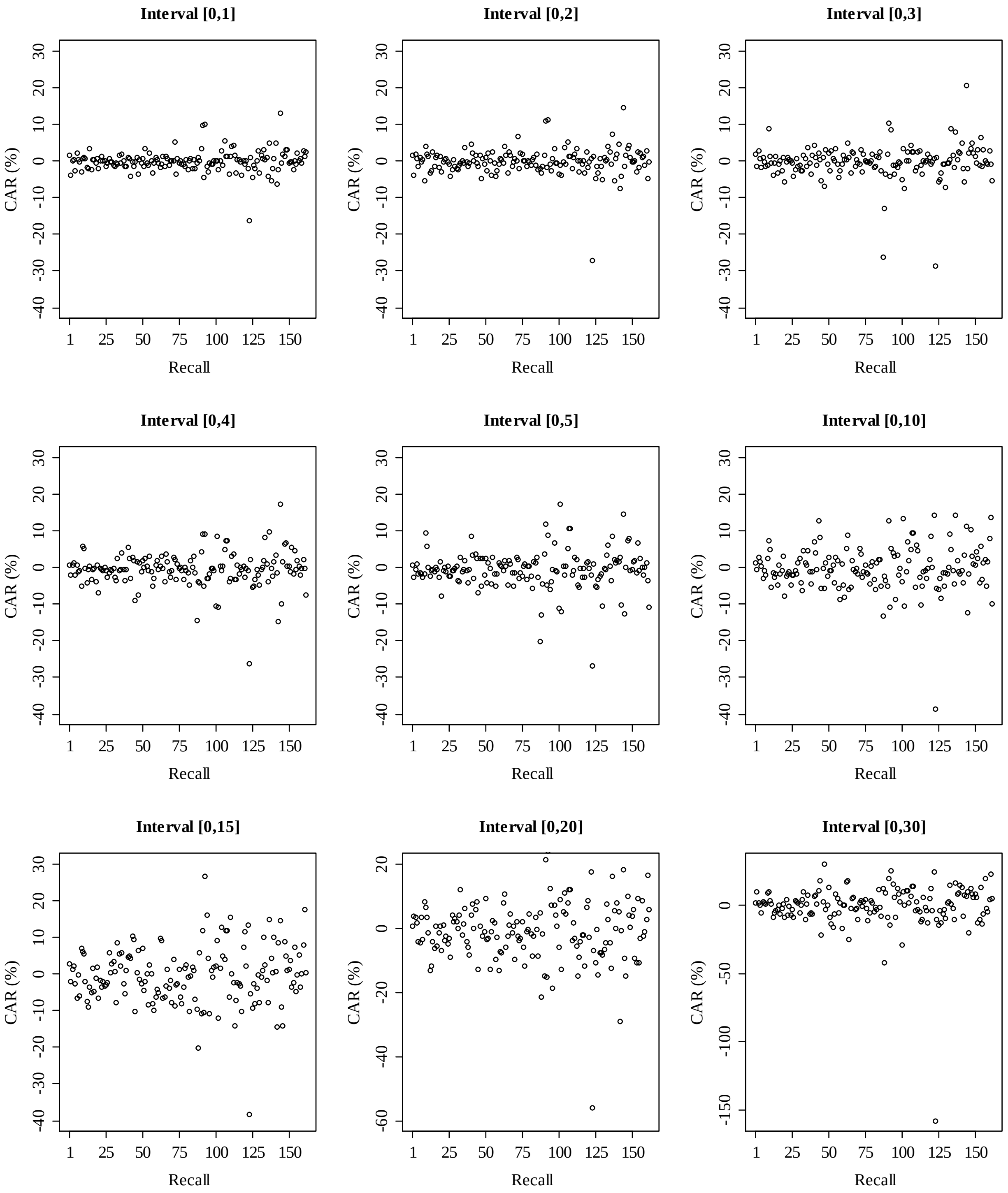
[18] The authors, however, did not provide an explanation for this unexpected behavior.


Interval [0,1]

Interval [0,2]

Interval [0,3]

Interval [0,4]

Interval [0,5]

Interval [0,10]

Interval [0,15]

Interval [0,20]

Interval [0,30]

Figure 5.3 Cumulative Abnormal Returns for All Recalls over Interval [0, 30] Days

To further analyze the influence of outliers on $CAAR$ for all recalls, they were calculated without including their corresponding CAR observations. Figure 5.4 illustrate the results of this comparison over interval [0, 30] trading days. Here, the first plot summarizes the original results of the $CAAR$ estimation, the second and third removes three negative and three positive CAR, respectively and the fourth, shows $CAAR$ results when both negative and positive outliers are removed (six total).

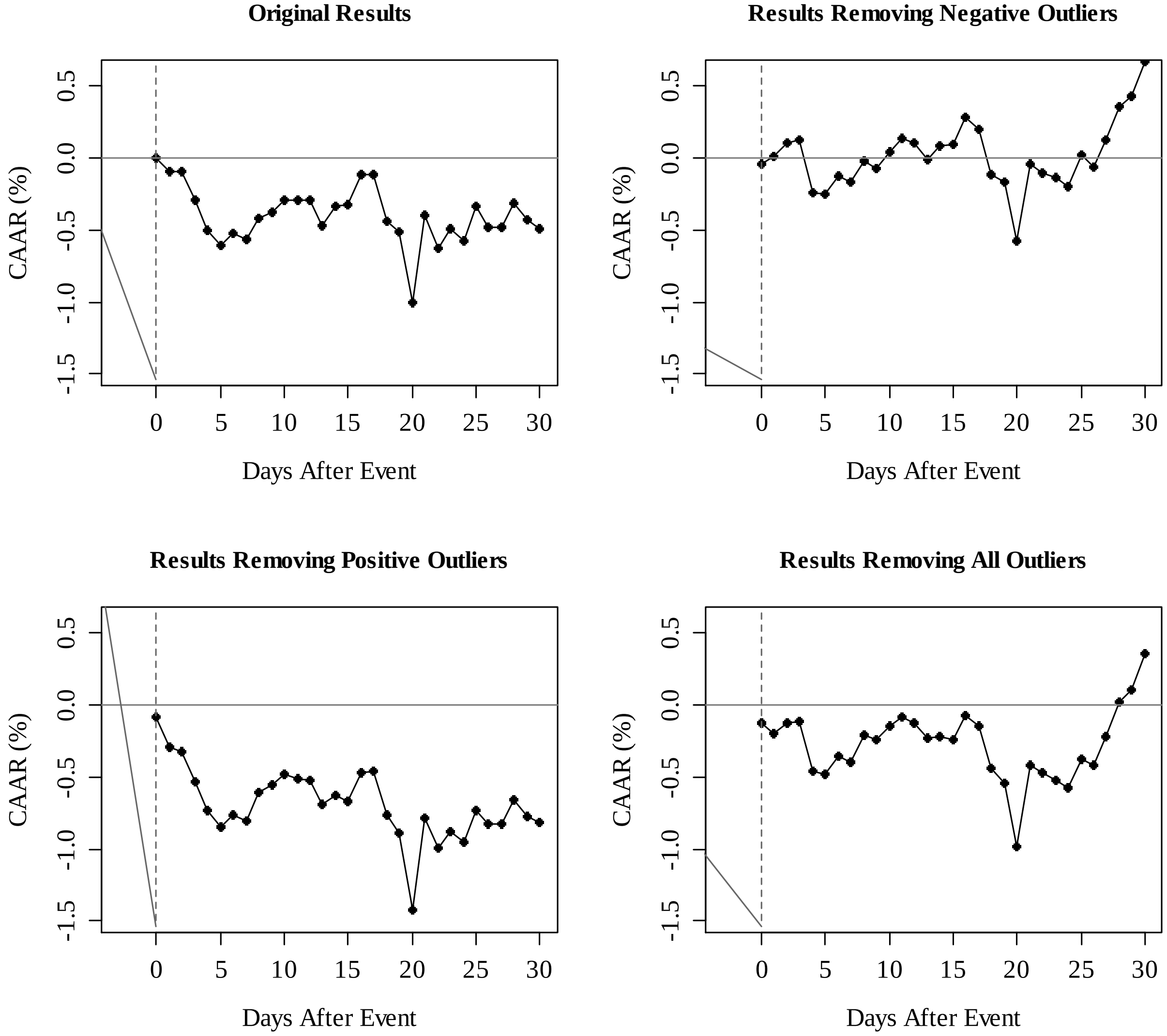


Figure 5.4 Influence of Outliers on *CAAR* over Interval [0, 30] Days

Looking at this figure, the influence of both negative and positive outliers becomes evident. That is, by removing negative outliers, the $CAAR$ plot shifts upwards. In particular, the return over day 20 increases from -1 to -0.6%. The opposite occurs when positive outliers are removed. It is interesting to observe that the original and last plot (without the six outliers) are fairly similar up to day 20. From there, returns start increasing consistently in the last plot, when negative outliers are removed. Thus, indicating that returns start going back to pre-event levels after day 20. Unlike Thomsen and McKenzie (2001), results from this study suggest that shareholder losses are not persistent. Furthermore, since there are no marked differences between the original and the last plot, it can be concluded that factors other than outlier observations (not know at this point) influence the behavior of CAR.

5.1.1 Analysis of CAAR by Recall Class

$CAAR$ are analyzed separately according to their recall classification. Here, it is assumed that Class I recalls have a more adverse impact in stock prices compared to the other two classes. Table 5.4 shows $CAAR$ computed for Class I recalls, based on $w1$. In contrast to the previous tables, $CAAR$ become negative at day $t =$ -2. However, they are not significant until day zero (interval [-2, +20] days). As expected, the reaction of stock prices is larger (in absolute value) for this type of recalls. For example, at day 5, stock returns decreased on average from 0.89 to 1.02% after a Class I recall. Also, the level of statistical significance of $CAAR$ increases in every interval. For instance, all $CAAR$ from day 0 to 20 are significant in interval [-2, +20] days. Figure 5.5 shows the plots of Class I $CAAR$ over different intervals, based on $w1$. Interestingly, these plots follow a similar pattern of those in Thomsen and McKenzie (2001). However, differences exist regarding the magnitude of $CAAR$. For example, in their study the magnitude of $CAAR$ following day six is within the range of 1.5 to 3% decrease. In this analysis, however, the maximum percentage decrease following day six is 1.25%. Moreover, results provide little evidence that stock markets become aware of a recall prior to the official announcement date. This was not the case in Thomsen and McKenzie (2001), where stock markets started reacting a few days before FSIS issued a recall release. These differences in findings are most likely related to the time periods considered for analysis.

Results for Class II recalls are reported in Table 5.5. Unlike results associated with Class I recalls, $CAAR$ are mostly positive. Here, we fail to reject the null hypothesis that $CAAR$ are greater or equal to zero in all cases. To check if $CAAR$ are strictly positive, a two tailed test was used instead. Results indicate that in few cases, stock returns experience increases after a Class II recall. These findings are consistent with Thomsen and McKenzie (2001). The authors argue that a possible explanation for these results is that stock markets only react adversely to Class I recalls because of the health risk involved. Considering that direct costs associated with both types of recalls are similar, the main difference is that Class I recalls affect the profitability of the firm by reducing the firm's revenues. Since revenues are affected by consumers' and customers' responses, this suggests that stock markets react to negative impacts on the demand side.

Table 5.6 report results from Class III recalls. Similarly to those for Class II recalls, $CAAR$ are positive, with some exceptions. However, t-statistics indicate that all except one (day 2 on interval [+1, +20] days), are equal to zero. Results from the analysis of $CAAR$ by recall class, are very similar to those based on $w2$ (Appendix A). The only difference is that the magnitude of $CAAR$ based on $w2$ are relatively smaller (in absolute value) for Class II and III recalls.

Table 5.4. Cumulative Average Abnormal Returns [$w1$], Class I Recalls

	$\tau_1 = -10$			$\tau_1 = -5$			$\tau_1 = -2$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-10	-0.132	-0.376	0.258						
-5	0.197	-0.291	-0.165	0.231	0.552	0.020			
-1	0.263	-0.435	-0.970	0.296	-0.023	0.136	-0.101	-0.611	-0.561
0	0.191	-0.462	-1.176	0.224	-0.080	-0.267	-0.173	-0.580	-1.323*
1	0.001	-0.578	-1.342*	0.034	-0.263	-0.489	-0.363	-0.735	-1.557*
2	-0.116	-0.496	-1.303*	-0.083	-0.155	-0.388	-0.480	-0.543	-1.769**
3	-0.423	-0.693	-1.019	-0.390	-0.427	-0.425	-0.787	-0.811	-1.977**
4	-0.801	-1.115	-1.729**	-0.768	-0.939	-1.426*	-1.165	-1.385*	-2.770**
5	-0.892	-1.310*	-1.845**	-0.859	-1.164	-1.489*	-1.256	-1.622*	-2.816**
10	-0.832	-0.875	-2.102**	-0.798	-0.686	-1.943**	-1.195	-0.986	-2.856**
15	-0.649	-0.845	-1.642**	-0.616	-0.701	-1.362*	-1.013	-0.904	-1.833**
20	-1.379	-1.220	-1.918**	-1.346	-1.138	-1.658**	-1.743	-1.292*	-2.077**

	$\tau_1 = 0$			$\tau_1 = 1$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-10						
-5						
-1						
0	-0.072	-0.164	-0.640			
1	-0.262	-0.505	-1.091	-0.190	-0.461	-1.065
2	-0.379	-0.241	-1.074	-0.307	-0.155	-0.865
3	-0.686	-0.630	-1.489*	-0.613	-0.579	-1.165
4	-1.064	-1.394*	-2.703**	-0.992	-1.398*	-2.484**
5	-1.155	-1.673**	-2.635**	-1.083	-1.635*	-2.296**
10	-1.094	-0.797	-2.299**	-1.022	-0.786	-2.233**
15	-0.912	-0.761	-1.457*	-0.839	-0.753	-1.332*
20	-1.642	-1.194	-1.927**	-1.570	-1.201	-1.777**

Note: ** and * denote statistical significance at the 0.05 and 0.10 level for a one tailed test (equation 12).

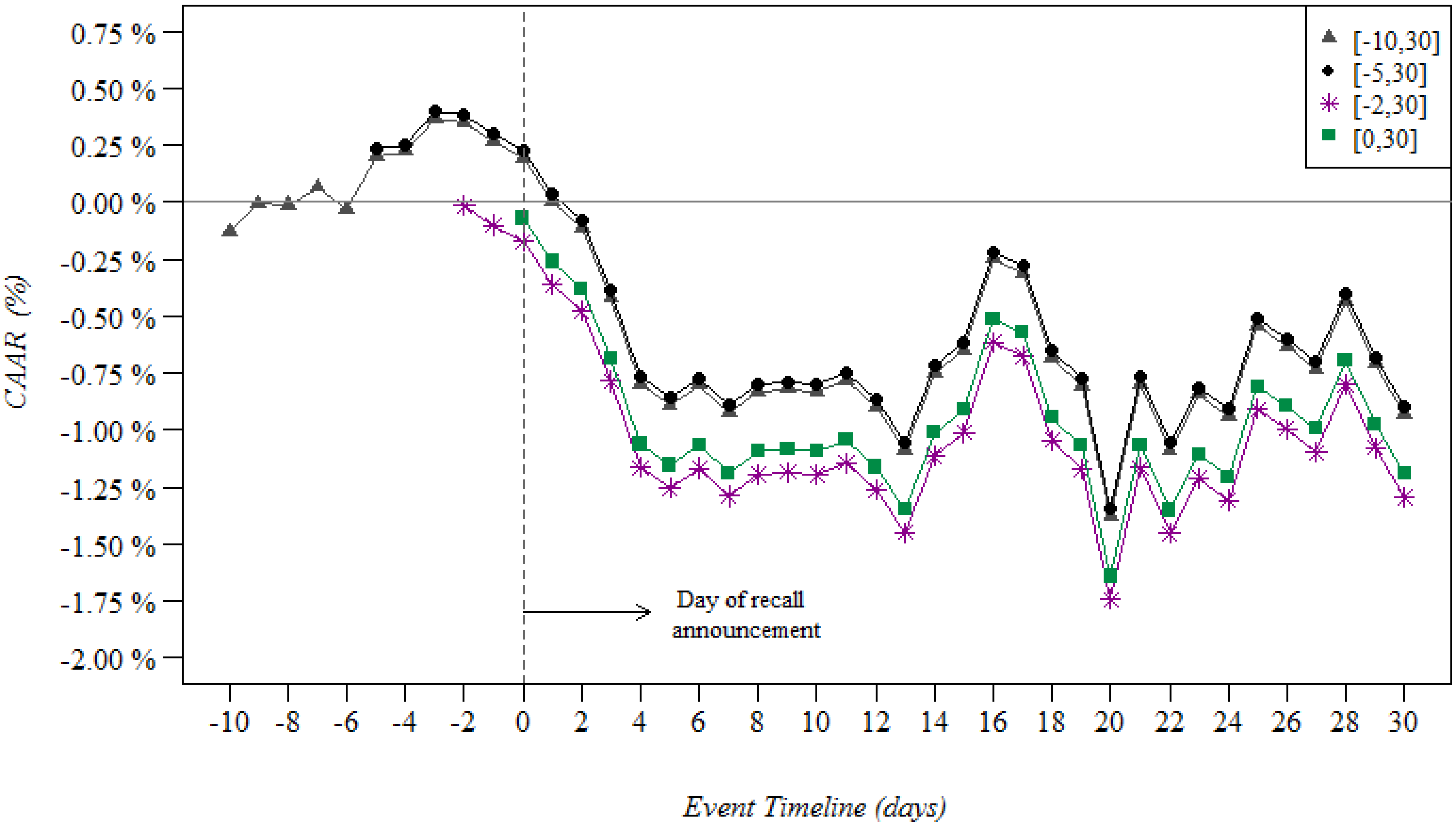


Figure 5.5 Cumulative Average Abnormal Returns [*w*1] for Class I Recalls

Table 5.5. Cumulative Average Abnormal Returns [*w*1], Class II Recalls

	$\tau_1 = -10$			$\tau_1 = -5$			$\tau_1 = -2$		
τ_2	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}
-10	0.069	-0.283	0.321						
-5	-0.048	-0.211	0.054	0.161	0.400	0.584			
-1	0.476	-0.266	0.403	0.684	-0.014	0.921	0.597	-0.319	0.469
0	0.636	-0.346	0.698	0.845	-0.055	0.826	0.758	-0.282	0.556
1	0.576	-0.438	0.601	0.784	-0.191	0.740	0.697	-0.448	0.426
2	0.830	-0.336	0.869	1.039	-0.104	1.210	0.951	-0.325	1.084
3	1.101	-0.477	1.250	1.310	-0.285	1.312	1.222	-0.491	1.246
4	1.248	-0.706	1.444	1.456	-0.544	1.362	1.369	-0.744	1.214
5	0.919	-0.755	0.946	1.128	-0.607	0.779	1.041	-0.799	0.623
10	1.892	-0.574	1.570	2.101	-0.393	1.663*	2.013	-0.535	1.766*
15	1.520	-0.529	0.569	1.728	-0.397	0.850	1.641	-0.509	0.852
20	0.485	-0.741	-0.110	0.693	-0.613	0.095	0.606	-0.687	0.215

	$\tau_1 = 0$			$\tau_1 = 1$		
τ_2	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}
-10						
-5						
-1						
0	0.161	-0.069	0.591			
1	0.100	-0.276	-0.138	-0.061	-0.301	-0.189
2	0.354	-0.149	0.837	0.194	-0.111	0.734
3	0.625	-0.421	1.293	0.465	-0.439	1.086
4	0.772	-0.762	0.977	0.611	-0.796	0.994
5	0.444	-0.777	0.153	0.283	-0.802	-0.080
10	1.416	-0.455	1.231	1.255	-0.486	1.147
15	1.044	-0.447	0.437	0.883	-0.455	0.244
20	0.009	-0.647	-0.076	-0.152	-0.681	-0.240

Note: * denotes statistical significance at the 0.10 level for two tailed test ($H_0: CAAR = 0$ and $H_a: CAAR \neq 0$).

Table 5.6. Cumulative Average Abnormal Returns [*w*1], Class III Recalls

	$\tau_1 = -10$			$\tau_1 = -5$			$\tau_1 = -2$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-10	0.327	-0.147	0.502						
-5	-0.793	-0.088	0.830	-0.173	0.290	-0.007			
-1	-1.030	-0.146	0.387	-0.410	-0.015	-0.151	-0.337	-0.274	-0.185
0	-0.795	-0.154	0.050	-0.175	-0.037	-0.228	-0.102	-0.191	-0.589
1	0.242	-0.186	0.310	0.862	-0.104	0.459	0.935	-0.220	0.262
2	0.517	-0.173	0.493	1.137	-0.071	0.810	1.210	-0.204	0.099
3	-0.185	-0.301	0.252	0.435	-0.280	0.291	0.508	-0.372	-0.094
4	0.060	-0.471	0.493	0.680	-0.606	0.555	0.754	-0.729	0.195
5	0.731	-0.521	0.618	1.351	-0.561	0.714	1.424	-0.716	0.295
10	1.486	-0.355	0.829	2.106	-0.309	0.992	2.179	-0.409	0.574
15	0.178	-0.379	0.041	0.798	-0.325	0.108	0.872	-0.407	-0.190
20	1.689	-0.594	0.743	2.309	-0.518	0.574	2.382	-0.577	0.262

	$\tau_1 = 0$			$\tau_1 = 1$		
τ_2	*CAAR*	Z_{BMP}	Z_{GRANK}	*CAAR*	Z_{BMP}	Z_{GRANK}
-10						
-5						
-1						
0	0.235	-0.045	0.026			
1	1.272	-0.126	0.753	1.037	-0.123	1.485
2	1.547	-0.073	0.873	1.312	-0.065	1.869*
3	0.845	-0.293	0.315	0.610	-0.334	0.675
4	1.090	-0.644	0.608	0.855	-0.779	0.819
5	1.761	-0.593	0.733	1.526	-0.717	1.031
10	2.516	-0.316	1.060	2.281	-0.316	1.378
15	1.209	-0.342	0.132	0.974	-0.333	0.224
20	2.719	-0.498	0.574	2.484	-0.515	0.767

Note: * denotes statistical significance at the 0.10 level for two tailed test ($H_0: CAAR = 0$ and $H_a: CAAR \neq 0$).

5.1.2 Analysis of Shareholders' Wealth after a Meat Recall

This analysis is conducted by calculating the percentage of CAR that are negative (or less than a negative threshold value) over intervals of the event window. That is, this percentage represents the proportion of recalls that caused shareholder wealth losses.[19] Table 5.7 reports results from this analysis based on all recalls and by recall class.[20] Here, reported percentages are divided into two panels. The first panel represents the percentage of CAR that are negative, whereas the second represents the percentage of CAR that are below -2 percent. This distinction is useful because it allows distinguishing recalls according to their magnitude of impact. For example, looking at results from all recalls in the first panel (interval [0, +20] days), it can be inferred that 54 percent of the recalls caused shareholder's wealth losses on the event day. However, only 12 percent of the recalls caused losses greater than 2% (second panel). On the other hand, comparing results across recall classes, on average, a higher percentage of Class I recalls result in negative returns (regardless of the threshold value). This confirms that Class I recalls produce more severe effects on stock price returns than Class II.

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[19] This percentage is based on 163 recalls, without making the distinction that some firms had more than one recall during the period considered for analysis.

[20] Results from Class III recalls are not reported because this is a small sample (9 recalls).

Table 5.7. Percentage of Recalls Causing Shareholders' Wealth Losses

	All Recalls					Class I					Class II				
τ_2 / τ_1	-10	-5	-2	0	1	-10	-5	-2	0	1	-10	-5	-2	0	1
< 0 % Returns															
-10	49.7					50.4					48.7				
-5	54.0	54.0				53.0	54.8				59.0	48.7			
-1	55.2	47.9	50.9			57.4	49.6	52.2			48.7	41.0	48.7		
0	54.0	50.9	56.4	54.0		59.1	52.2	59.1	57.4		43.6	46.2	46.2	46.2	
1	56.4	50.9	55.8	52.1	51.5	59.1	53.0	60.9	53.0	53.9	51.3	43.6	43.6	51.3	48.7
2	57.1	48.5	59.5	50.9	47.2	61.7	53.0	65.2	52.2	50.4	46.2	35.9	43.6	48.7	43.6
3	54.6	47.2	55.2	53.4	48.5	60.0	51.3	61.7	57.4	55.7	38.5	35.9	35.9	41.0	28.2
4	52.8	50.9	56.4	58.3	52.8	59.1	57.4	63.5	64.3	58.3	35.9	35.9	38.5	43.6	38.5
5	53.4	53.4	58.3	56.4	57.1	59.1	57.4	64.3	61.7	62.6	38.5	46.2	43.6	46.2	46.2
10	52.8	54.0	57.7	56.4	55.2	58.3	60.0	64.3	60.9	60.0	41.0	41.0	38.5	48.7	48.7
15	57.1	53.4	52.8	51.5	52.8	60.9	57.4	57.4	55.7	53.9	46.2	43.6	38.5	38.5	51.3
20	53.4	53.4	54.6	55.2	54.0	55.7	53.9	58.3	57.4	58.3	51.3	51.3	46.2	51.3	46.2
< - 2% Returns															
-10	9.2					11.3					2.6				
-5	25.8	6.7				27.8	6.1				23.1	7.7			
-1	30.7	23.9	15.3			32.2	26.1	16.5			28.2	20.5	10.3		
0	30.1	22.7	21.5	12.3		33.9	25.2	21.7	13.0		17.9	15.4	15.4	10.3	
1	29.4	25.8	25.8	17.2	11.7	33.9	27.8	28.7	19.1	13.9	17.9	23.1	15.4	12.8	7.7
2	31.9	26.4	28.8	20.2	14.1	34.8	29.6	31.3	22.6	16.5	23.1	20.5	23.1	15.4	10.3
3	28.8	28.2	30.1	21.5	17.8	33.9	31.3	33.9	23.5	19.1	15.4	23.1	20.5	17.9	12.8
4	33.7	33.7	35.0	28.2	25.2	38.3	37.4	38.3	30.4	28.7	20.5	25.6	28.2	25.6	20.5
5	37.4	35.6	36.8	30.1	27.6	40.9	37.4	38.3	30.4	28.7	28.2	33.3	35.9	30.8	25.6
10	41.7	38.7	38.7	32.5	33.1	48.7	46.1	45.2	40.0	40.0	23.1	23.1	25.6	15.4	15.4
15	42.9	41.1	42.3	43.6	41.7	44.3	45.2	42.6	47.0	43.5	38.5	30.8	38.5	33.3	38.5
20	45.4	44.8	46.0	45.4	42.3	49.6	47.0	49.6	48.7	45.2	38.5	41.0	38.5	38.5	38.5

5.2 Estimation of the Effects of Meat and Poultry Recall Characteristics

To examine the effects of meat recall characteristics on the magnitude of abnormal returns, either as individual (AR) or aggregated (CAR) measures, both cross-sectional and panel data type models are estimated. Since CAR have been aggregated over several different intervals of the event study window, these models are estimated using observations from the interval [+1, +20] days. This selection was based on two criteria: i) results from the analysis of $CAAR$ do not support the premise that stock markets react prior to the day of recall announcement; ii) information regarding the timing when the recall release was issued is not available. This is important to determine when stock markets start to react. That is, if a recall release was issued during early hours, stock markets would be able to react on the event day. However, if it was issued during late hours of the day, stock markets would not be able to react until the following day. Thus, for consistency, the event day observation is not included. Furthermore, to evaluate the sensitivity of predicted effects over time, models are estimated using observations from the following horizons: [+1, +5], [+1, +10], [+1, +15], and [+1, +20] trading days. Again, analyses are conducted contrasting $w1$ with $w2$.[21]

5.2.1 Results from Cross-Sectional Models

The dependent variable in these models is CAR over horizons ranging from 5 to 20 days. In addition, explanatory variables remain fixed over time except for *Trading Volume* and *Media Index* which are aggregated over the corresponding horizon. For instance, in the model estimated

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[21] Recall $w1$= [-260, -11] and $w2$ = [-255, -6] trading days, are the estimation windows used to predict normal returns, which in turn are used to calculate abnormal returns. Hence, this comparison is conducted to analyze the sensitivity of results to the choice of estimation window periods.

using observations from a 5-trading day horizon, *Media Index* is specified as the total number of articles issued from 1 to 5 days after the recall announcement. Regardless of the horizon, all cross-sectional models are estimated using the same number of observations.

Table 5.8 presents results from the model estimated using observations from horizon $\tau' = [+1, +5]$. According to this table, *Experience* and *Initial Shock* are the only two variables that help explain the variability of CARs in this horizon. However, regression diagnostics (analysis of variance inflation factors) detect the presence of multicollinearity on *Class I* and *Class II* variables.

Table 5.8. Results from Cross-Sectional Model for a 5-Trading Day Horizon [$w1$]

Variable	Coefficient	*t*-Value
Intercept	-11.907	-1.251
Class I	-2.372	-1.502
Class II	-1.256	-0.750
Recall Size	-0.250	-1.407
Firm Size	0.677	1.592
Pathogen	0.562	0.652
Experience	2.327 ***	3.138
HACCP	-0.676	-0.568
Cluster	0.209	0.265
Media Index	-0.044	-1.416
Momentum	0.024	1.442
Diversification	0.529	0.643
Initial Shock	-0.425 *	-1.913
Trading Volume	0.012	0.091
Subsidiary	-0.073	-0.085
Adjusted R^2	0.149	
No. Observations [b]	159	

Notes: [b] four observations were deleted because recall size entries were undetermined.
t-Values calculated using robust standard errors.
***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.

To solve this issue, Class III observations are deleted from the sample (9 observations). From an economic perspective, eliminating these observations is justified because Class III recalls do not cause adverse health consequences. Thus, it cannot be expected, for example, that these would have the same media impact as Class I or Class II recalls. In addition, Class III recalls represent a small portion of the sample (5.5 percent).

Table 5.9 reports results from cross-sectional models (for *w*1) estimated using observations from different post-event horizons, where Class III observations are excluded. Comparing results from the 5-trading day horizon models, it can be observed that the adjusted R^2 is greater in the model estimated without Class III observations. This is also reflected on the significance of the coefficients, since more coefficients become significant in the latter model. Also, the *intercept* becomes substantially more negative and the *Class I* coefficient increases, reflecting now the impact with respect to Class II recalls. Other coefficients also change when Class III observations are excluded. This is the case of *Firm Size*, *HACCP*, *Cluster* and *Subsidiary* (which switched its sign). Based on this, it can be inferred that the presence of Class III observations affect coefficient stability, justifying the approach used for dealing with this issue.

Looking at Table 5.9, in all models the intercept is negative as expected, and statistically significant only on the first horizon. The coefficient of *Class I* is also negative in all models, indicating that on average Class I recalls have a larger (negative) impact on stock returns compared to Class II recalls. Depending on the horizon this impact ranges from -0.838 to -1.682 percent. However, it is not statistically significant. *Recall Size* is also negative in all horizons and statistically significant in the last three. Also, the impact of this variable increases (in absolute value) as the horizon increases. This finding indicates that on average a one unit increase in the size of a recall (equivalent to 170 percent increase in the number of pounds recalled for the average recall in this sample), causes abnormal returns to become more negative (ranging from -0.251 to -

0.783 percent). On the other hand, *Firm Size* is positive in all horizons and statistically significant only on the first. This result indicates that on average larger firms experience lesser impacts after a recall. More specifically, a one unit increase in the size of the firm (equivalent to 170 percent increase in the market value of equity for the average firm in this sample), causes abnormal returns to become less negative by approximately 1 percent within 5 days after the recall. Furthermore, the coefficient of *Pathogen* is negative in all horizons except for the first. Here, this coefficient indicates that recalls triggered by a foodborne pathogen have, on average, a larger (negative) impact on stock returns than those caused by other reasons (except in the first model which indicates the opposite). However, regardless of the horizon this coefficient is not statistically significant.

An interesting result is observed on the coefficient of *Experience*. Besides being statistically significant in the first three horizons (almost in the fourth), this coefficient is positive and relatively large compared to those from other variables. Contrary to a priori expectations that firms incurring in more than one recall within the past year would reflect more negative abnormal returns, this coefficient indicates the opposite. That is, recurrent firms have on average a lessened impact after a recall. These results are consistent with Salin and Hooker (2001). A possible explanation for this finding is that investors take into consideration the past performance of a company when dealing with product recalls at the moment of making their valuations. Thus, when a firm efficiently follows the protocols for managing a recall event and establishes clear communication channels with stakeholders, it actually sends a good signal to the stock market, indicating investors not to consider a new recall as a threat.

The coefficient of *HACCP* is negative in all horizons and statistically significant only in the second. This result indicates that firms incurring a recall after the implementation of mandatory HACCP regulations in 1996, experience on average about 3 percent decrease on shareholder’s valuation within 10 days after the recall. The number of recalls has increased since the HACCP implementation, so perhaps this coefficient reflects this new trend. That is, the low incidence of recalls prior July 1996 causes on average a lesser impact on stock markets compared to the period after. In addition, the coefficient of *Cluster* has different signs depending on the horizon and is not statistically significant. This is also the case for *Momentum*.

The coefficient of *Diversification* has the expected sign (negative) in the last three horizons, indicating that firms with large meat and poultry production/sales segments are more affected after a recall. However, this coefficient is not significant in any of the horizons. Moreover, the coefficient of *Subsidiary* has the expected sign (positive) indicating that recalls initiated by a subsidiary have lesser impact on the parent firm, compared to recalls initiated by the parent firm itself. However, these are not statistically significant. On the other hand, the coefficient of *Initial Shock* is negative and statistically significant only in the first horizon. The magnitude of this coefficient implies that stocks suffering a negative price shock after a recall, experience reversals. That is, about 0.56 percent of the event day move is reversed over a 5-day trading day horizon.

Focusing on the variables that are accumulated over each horizon, unexpected results are observed. That is, the coefficient of *Media Index* is negative in the first and second horizon but not statistically significant. Then, it becomes positive and significant in the fourth horizon. This is not congruent with the expectations that an increase in the number of articles covering a recall, would send to the stock market a negative signal and, in turn, impact stock returns. Similarly, the coefficient of *Trading Volume* is positive and significant in the second and third horizons. Although several hypotheses have been proposed regarding the relationship between trading volume and stock returns, it seems more plausible that a meat recall would trigger an increase in the number of shares traded while prices drop, at least during the first days after the recall. Thus, the sign of this coefficient in the first horizon is unexpected. A possible explanation for these findings relies on the construction of these variables. That is, by accumulating them over different horizons, the true underlying relationship between these variables and CARs cannot be estimated. Hence, the need of estimating models using a panel data framework.

Results from the estimation of cross-sectional models (for $w2$) using observations from different horizons are presented in Table 5.10. Comparing these results to those from $w1$, there are few differences. Although, models from both $w1$ and $w2$ have the same fit, the predictive power of all $w2$ models is higher (based on AIC). This is very important because one of the objectives of this analysis is to predict abnormal returns. In addition, coefficients have the same sign and the same variables are statistically significant in both models. However, the magnitude of the intercept in $w1$ is larger than $w2$. Based on these findings, it can be concluded that the estimation of cross-sectional models is sensitive to the selection of estimation windows.

Table 5.9. Estimation Results from Cross-Sectional Models [*w*1]

	Model 1 $\tau' = [+1, +5]$	**Model 2** $\tau' = [+1, +10]$	**Model 3** $\tau' = [+1, +15]$	**Model 4** $\tau' = [+1, +20]$
Intercept	-20.388 **	-10.700	-1.662	-5.316
	[-2.035]	[-0.796]	[-0.101]	[-0.254]
Class I	-1.162	-1.682	-1.206	-0.838
	[-1.196]	[-1.621]	[-0.886]	[-0.504]
Recall Size	-0.251	-0.468 **	-0.634 *	-0.783 *
	[-1.394]	[-2.113]	[-1.833]	[-1.740]
Firm Size	1.018 **	0.803	0.456	0.674
	[2.277]	[1.299]	[0.595]	[0.674]
Pathogen	0.443	-0.475	-0.263	-2.437
	[0.514]	[-0.478]	[-0.164]	[-1.294]
Experience	2.379 ***	2.087 **	2.131 *	2.128
	[3.188]	[2.468]	[1.887]	[1.616]
HACCP	-1.196	-2.970 *	-2.786	-3.185
	[-1.011]	[-1.661]	[-1.442]	[-1.263]
Cluster	0.003	-0.274	-0.366	0.441
	[0.004]	[-0.276]	[-0.276]	[0.274]
Media Index	-0.042	-0.008	0.018	0.078 ***
	[-1.386]	[-0.846]	[1.194]	[3.552]
Momentum	0.013	-0.016	-0.036	-0.035
	[0.854]	[-0.836]	[-1.276]	[-0.967]
Diversification	0.727	-0.390	-0.796	-1.857
	[0.844]	[-0.375]	[-0.595]	[-1.254]
Initial Shock	-0.562 **	-0.301	-0.140	0.220
	[-2.369]	[-1.121]	[-0.271]	[0.401]
Trading Volume	0.054	0.100 ***	0.089 **	0.048
	[0.412]	[2.613]	[2.303]	[1.268]
Subsidiary	0.259	1.380	1.076	1.618
	[0.295]	[1.351]	[0.803]	[1.055]
Adjusted R^2	0.176	0.113	0.018	0.056
No. Observations	150	150	150	150
AIC	489.4	532.7	622.6	677.6

Notes: Numbers in brackets are *t*-values calculated using robust standard errors.

***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.

*w*1= [-260, -11] trading days, is the estimation window used to predict normal returns, which in turn are used to calculate abnormal returns.

Table 5.10. Estimation Results from Cross-Sectional Models [*w*2]

	Model 1	**Model 2**	**Model 3**	**Model 4**
	$\tau' = [+1, +5]$	$\tau' = [+1, +10]$	$\tau' = [+1, +15]$	$\tau' = [+1, +20]$
Intercept	-18.770 **	-10.553	-1.771	-5.982
	[-2.034]	[-0.809]	[-0.110]	[-0.283]
Class I	-1.051	-1.496	-0.975	-0.604
	[-1.074]	[-1.449]	[-0.725]	[-0.365]
Recall Size	-0.239	-0.464 **	-0.634 *	-0.800 *
	[-1.360]	[-2.144]	[-1.852]	[-1.773]
Firm Size	0.939 **	0.793	0.456	0.708
	[2.313]	[1.322]	[0.604]	[0.697]
Pathogen	0.493	-0.437	-0.265	-2.411
	[0.580]	[-0.444]	[-0.166]	[-1.281]
Experience	2.316 ***	1.949 **	1.910 *	1.896
	[3.137]	[2.336]	[1.721]	[1.468]
HACCP	-1.204	-3.115 *	-2.948	-3.389
	[-1.027]	[-1.739]	[-1.530]	[-1.323]
Cluster	0.053	-0.214	-0.262	0.577
	[0.068]	[-0.215]	[-0.198]	[0.360]
Media Index	-0.041	-0.008	0.018	0.078 ***
	[-1.337]	[-0.825]	[1.207]	[3.532]
Momentum	0.011	-0.016	-0.034	-0.030
	[0.752]	[-0.906]	[-1.237]	[-0.835]
Diversification	0.687	-0.346	-0.672	-1.741
	[0.800]	[-0.331]	[-0.506]	[-1.181]
Initial Shock	-0.591 **	-0.380	-0.236	0.073
	[-2.556]	[-1.506]	[-0.467]	[0.139]
Trading Volume	0.043	0.100 ***	0.088 **	0.046
	[0.332]	[2.622]	[2.292]	[1.222]
Subsidiary	0.210	1.405	1.160	1.712
	[0.243]	[1.389]	[0.872]	[1.120]
Adjusted R^2	0.176	0.113	0.018	0.056
No. Observations	150	150	150	150
AIC	485.2	529.8	619.6	676.7

Notes: Numbers in brackets are *t*-values calculated using robust standard errors.

***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.

*w*2 = [-255, -6] trading days, is the estimation window used to predict normal returns, which in turn are used to calculate abnormal returns.

5.2.2 Results from Panel Data Models

To estimate the panel data models, observations from each recall are pooled over horizons ranging from 5 to 20 trading days. The dependent variable is either CAR or AR and the independent variables are the same explanatory variables as used in the cross-sectional models, except for *Trading Volume* and *Media Index* which both vary over time in the panel models. For instance, in the model estimated using observations from a 5-trading day horizon, *Media Index* is specified as the number of articles issued per day on days 1 to 5 after the recall announcement. Focusing on panel models that use CAR as the dependent variable, these are a special case of long-horizon regressions. In these types of regressions, the independent variables do not necessarily need to be aggregated (Campbell and Shiller, 1988; Fama and French, 1988). In addition, time dummies are added to control for time effects in each model. For example, in 5-trading day horizon models, four dummies are included, where for day 1 the time dummy is specified as 1 if day equals 1 and 0 otherwise. The same specification applies for days 2-4.

The selection of the appropriate estimation method for panel data models was based on the following criteria: i) the estimation of the effects of time-invariant explanatory variables cannot be performed using (within) fixed effects models.[22] ii) The focus of this analysis is to draw inferences about the population and not only about the group of recalls in this sample. Thus, random effects or pooled OLS models are preferred over fixed effects models. iii) Testing for individual random effects when there is serial correlation might bias the results (Wooldridge, 2002). Results from this type of test suggest that in models estimated using CAR as the dependent variable, there are significant unobserved effects. This is not true, however, for models estimated using AR as the

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[22] An alternative would be to estimate the fixed effects model including a dummy variable for each recall. However, a disadvantage of using this approach is the loss of degrees of freedom.

dependent variable.[23] iv) Random effects estimators require stronger assumptions about the unobservable individual effects compared to pooled OLS estimators. Additionally, the pooled OLS estimator is still unbiased but inefficient. Based on these criteria and on the nonstandard structure of the panels, models are estimated using pooled OLS and inferences are conducted using clustered-robust standard errors, where each firm is considered a separate cluster.[24] This method is used to account for firm-specific, unobservable, time-invariant effects in the model (e.g., firm's management strategy, production practices outside of HAACP, percentage of shares owned by management).

Table 5.11 presents the results from pooled OLS models (for $w1$) estimated using CAR as the dependent variable, over different post-event horizons (note that the number of observations vary depending on the horizon). Similarly to cross-sectional models estimation, Class III observations are excluded because of statistical (multicollinearity) and economic issues. Comparing these results to those from cross-sectional models, the adjusted R^2 indicates that pooled OLS models have a better fit of the data. This is related to the increase in statistical significance in some of the variables (e.g., *Recall Size*, *Firm Size*, *Experience* and *Initial Shock*). In addition, some coefficients differ in magnitude and in few instances in sign. The most noteworthy difference is in the coefficients of *Media Index*. These are negative in all horizons and statistically significant in the first three. For instance, the coefficient in the first horizon indicates that an additional recall-related article, published within 5 days after the recall announcement, decreases CAR by 0.102 percent, on average. Additionally, the magnitude of these coefficients decrease as the horizon

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[23] The test used is the likelihood-based Lagrange multiplier test of Breusch and Godfrey (with refinements by Honda).

[24] The reference of nonstandard structure of the panels is used to indicate that panels are constructed using recalls that occurred over time and are not cross-sectionally related (except in some cases).

increases, indicating that the effects of media dissipates over time. These findings indicate that the use of a panel data framework reveal the impacts over time of this time-variant explanatory variable. This is not the case, however, for *Trading Volume*. Although it was expected that *Trading Volume* would have a negative sign on the first horizon, it is positive and insignificant (it follows that this slope remains positive and significant in the last three horizons).

Table 5.12 reports the results from the pooled OLS models (for $w1$) estimated using AR as the dependent variable, over different post-event horizons. As expected, the goodness of fit of these models is much smaller than those estimated using CAR. The magnitude of the coefficients, particularly the intercept, is also smaller on these models. For example, the coefficient of *Firm Size* is approximately 4 times smaller in models using AR. This finding reflects the difference between using an aggregated variable versus a disaggregated one. Furthermore, the coefficients of some variables became insignificant at a particular horizon. This is the case for *Recall Size*, *Firm Size* and *Initial Shock*. On the contrary, *Media Index* became also statistically significant on the fourth horizon, making it one of the most important explanatory variables in these models. Other variables that remain significant are *Experience* (all horizons) and *Trading Volume* (last three horizons). Both panels using CAR and panels using AR are explained by the same statistically significant variables in the 5-trading day horizon. Altogether, these findings corroborate those from previous studies indicating that the use of long-horizon variables allows finding significant results (Valkanov, 2003; Hjakmarsoon, 2011).

Table 5.11. Estimation Results from Pooled OLS Models Using *CAR* [*w*1]

	Panel 1	**Panel 2**	**Panel 3**	**Panel 4**
	$\tau' = [+1, +5]$	$\tau' = [+1, +10]$	$\tau' = [+1, +15]$	$\tau' = [+1, +20]$
Intercept	-13.387 *	-12.825	-9.271	-6.174
	[-1.798]	[-1.493]	[-0.890]	[-0.525]
Class I	-0.511	-0.965	-1.276	-1.144
	[-0.803]	[-1.229]	[-1.497]	[-1.180]
Recall Size	-0.268 *	-0.341 **	-0.426 **	-0.419 *
	[-1.923]	[-2.134]	[-2.265]	[-1.864]
Firm Size	0.732 **	0.785 *	0.691	0.545
	[2.063]	[1.919]	[1.384]	[0.963]
Pathogen	-0.231	-0.136	0.016	-0.015
	[-0.385]	[-0.191]	[0.019]	[-0.015]
Experience	1.382 ***	1.772 ***	1.863 ***	1.983 ***
	[2.834]	[2.982]	[2.780]	[2.555]
HACCP	-0.533	-1.529	-1.833	-1.885
	[-0.784]	[-1.576]	[-1.547]	[-1.348]
Cluster	0.419	0.301	0.135	0.253
	[0.727]	[0.441]	[0.173]	[0.271]
Media Index	-0.102 *	-0.100 ***	-0.078 **	-0.058
	[-1.791]	[-2.631]	[-1.992]	[-1.217]
Momentum	0.011	0.006	-0.004	-0.011
	[1.006]	[0.467]	[-0.258]	[-0.541]
Diversification	0.696	0.289	-0.176	-0.423
	[1.171]	[0.409]	[-0.220]	[-0.470]
Initial Shock	-0.375 **	-0.428 **	-0.357	-0.258
	[-2.150]	[-2.158]	[-1.379]	[-0.821]
Trading Volume	0.092	0.384 *	0.501 **	0.604 **
	[0.302]	[1.872]	[2.334]	[2.179]
Subsidiary	-0.202	0.273	0.607	0.570
	[-0.340]	[0.389]	[0.759]	[0.622]
Adjusted R^2	0.194	0.178	0.133	0.087
No. Observations	750	1500	2250	3000
AIC	2029.8	4631.8	7662.9	11076.1
Time Dummies	(0.162)	(0.185)	(0.688)	(0.928)

Notes: Numbers in brackets are *t*-values calculated using clustered standard errors.
***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.
Numbers in parenthesis are Wald test statistics of the joint significance of time dummy variables.

Table 5.12. Estimation Results from Pooled OLS Models Using *AR* [*w*1]

	Panel 1 $\tau' = [+1, +5]$	**Panel 2** $\tau' = [+1, +10]$	**Panel 3** $\tau' = [+1, +15]$	**Panel 4** $\tau' = [+1, +20]$
Intercept	-3.510 *	-1.440	-0.520	-1.018
	[-1.824]	[-1.040]	[-0.450]	[-0.883]
Class I	-0.241	-0.160	-0.072	-0.027
	[-1.217]	[-1.517]	[-0.774]	[-0.310]
Recall Size	-0.055 *	-0.033	-0.021	-0.003
	[-1.680]	[-1.593]	[-1.003]	[-0.123]
Firm Size	0.185 **	0.089	0.036	0.046
	[2.180]	[1.457]	[0.699]	[0.911]
Pathogen	0.108	-0.043	0.005	-0.091
	[0.606]	[-0.423]	[0.049]	[-0.940]
Experience	0.460 ***	0.226 ***	0.169 **	0.162 **
	[3.024]	[2.596]	[2.162]	[2.110]
HACCP	-0.201	-0.304 *	-0.184	-0.166
	[-0.885]	[-1.684]	[-1.446]	[-1.283]
Cluster	0.012	-0.020	-0.008	0.042
	[0.074]	[-0.190]	[-0.082]	[0.466]
Media Index	-0.036 *	-0.035 ***	-0.033 ***	-0.026 ***
	[-1.702]	[-2.887]	[-2.869]	[-2.692]
Momentum	0.003	-0.002	-0.003	-0.002
	[0.965]	[-0.936]	[-1.344]	[-1.146]
Diversification	0.128	-0.019	-0.036	-0.063
	[0.731]	[-0.174]	[-0.387]	[-0.740]
Initial Shock	-0.113 **	-0.028	-0.008	0.013
	[-2.386]	[-1.022]	[-0.229]	[0.455]
Trading Volume	-0.042	0.169 **	0.175 ***	0.234 **
	[-0.298]	[2.540]	[3.041]	[1.959]
Subsidiary	0.034	0.141	0.066	0.079
	[0.192]	[1.358]	[0.719]	[0.988]
Adjusted R^2	0.038	0.012	0.005	0.009
No. Observations	750	1500	2250	3000
AIC	1219.4	2360.2	3424.5	4579.5
Time Dummies	(0.828)	(0.754)	(0.850)	(0.339)

Notes: Numbers in brackets are *t*-values calculated using clustered standard errors.
***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.
Numbers in parenthesis are Wald test statistics of the joint significance of time dummy variables.

Results from the estimation of pooled OLS models for $w2$, using CAR and AR as dependent variables, are presented in Table 5.13 and Table 5.14, respectively. There are important differences between these results to those from $w1$. That is, models from $w2$ estimated using CAR have a slightly better fit than models from $w1$ and same fit on models estimated using AR. Similarly to results from cross-sectional models, the predictive power of all $w2$ models is higher than in $w1$ models. Moreover, coefficients have the same sign and the same variables are statistically significant in both models, except for *Recall Size* which is only significant in panel 1 ($w1$) estimated using AR. Slight differences also exist on the magnitudes of the coefficients. These are more evident, however, on the intercepts. Therefore, results from the estimation of panel models are also sensitive to the selection of estimation windows. Based on this finding, simulation examples in the following section are based on results from $w2$ models.

Table 5.13. Estimation Results from Pooled OLS Models Using *CAR* [*w*2]

	Panel 1	**Panel 2**	**Panel 3**	**Panel 4**
	$\tau' = [+1, +5]$	$\tau' = [+1, +10]$	$\tau' = [+1, +15]$	$\tau' = [+1, +20]$
Intercept	-12.295 *	-11.955	-8.569	-5.871
	[-1.836]	[-1.513]	[-0.879]	[-0.519]
Class I	-0.450	-0.860	-1.127	-0.972
	[-0.700]	[-1.089]	[-1.324]	[-1.007]
Recall Size	-0.255 *	-0.326 **	-0.415 *	-0.414 *
	[-1.917]	[-2.149]	[-2.303]	[-1.891]
Firm Size	0.677 **	0.739 **	0.653	0.528
	[2.139]	[1.982]	[1.403]	[0.970]
Pathogen	-0.182	-0.084	0.055	0.015
	[-0.311]	[-0.121]	[0.066]	[0.016]
Experience	1.348 ***	1.693 ***	1.740 ***	1.832 **
	[2.809]	[2.897]	[2.658]	[2.414]
HACCP	-0.534	-1.582	-1.913	-2.004
	[-0.800]	[-1.643]	[-1.625]	[-1.431]
Cluster	0.435	0.331	0.182	0.316
	[0.760]	[0.487]	[0.235]	[0.341]
Media Index	-0.101 *	-0.101 ***	-0.079 **	-0.058
	[-1.742]	[-2.643]	[-2.038]	[-1.213]
Momentum	0.010	0.005	-0.005	-0.010
	[0.961]	[0.382]	[-0.326]	[-0.544]
Diversification	0.654	0.282	-0.150	-0.366
	[1.108]	[0.400]	[-0.189]	[-0.410]
Initial Shock	-0.406 **	-0.473 **	-0.420 *	-0.335
	[-2.502]	[-2.535]	[-1.723]	[-1.122]
Trading Volume	0.062	0.379 *	0.496 **	0.600 **
	[0.208]	[1.859]	[2.336]	[2.194]
Subsidiary	-0.238	0.248	0.610	0.593
	[-0.408]	[0.359]	[0.777]	[0.655]
Adjusted R^2	0.193	0.178	0.135	0.090
No. Observations	750	1500	2250	3000
AIC	2001.23	4583.8	7587.9	11001.9
Time Dummies	(0.153)	(0.136)	(0.599)	(0.889)

Notes: Numbers in brackets are *t*-values calculated using clustered standard errors.
***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.
Numbers in parenthesis are Wald test statistics of the joint significance of time dummy variables.

Table 5.14. Estimation Results from Pooled OLS Models Using *AR* [*w*2]

	Panel 1	**Panel 2**	**Panel 3**	**Panel 4**
	$\tau' = [+1, +5]$	$\tau' = [+1, +10]$	$\tau' = [+1, +15]$	$\tau' = [+1, +20]$
Intercept	-3.215 *	-1.426	-0.530	-1.062
	[-1.823]	[-1.062]	[-0.467]	[-0.914]
Class I	-0.218	-0.141	-0.057	-0.016
	[-1.095]	[-1.347]	[-0.615]	[-0.177]
Recall Size	-0.052	-0.033	-0.022	-0.004
	[-1.634]	[-1.604]	[-1.021]	[-0.168]
Firm Size	0.170 **	0.088	0.036	0.048
	[2.216]	[1.484]	[0.714]	[0.938]
Pathogen	0.118	-0.040	0.004	-0.091
	[0.667]	[-0.394]	[0.035]	[-0.943]
Experience	0.449 ***	0.212 **	0.154 **	0.150 **
	[2.973]	[2.466]	[2.003]	[1.986]
HACCP	-0.204	-0.319 *	-0.196	-0.177
	[-0.903]	[-1.764]	[-1.540]	[-1.351]
Cluster	0.022	-0.014	-0.001	0.048
	[0.135]	[-0.134]	[-0.015]	[0.536]
Media Index	-0.036 *	-0.034 ***	-0.032 ***	-0.025 ***
	[-1.696]	[-2.937]	[-2.932]	[-2.726]
Momentum	0.003	-0.002	-0.003	-0.002
	[0.869]	[-1.006]	[-1.312]	[-1.033]
Diversification	0.121	-0.015	-0.028	-0.057
	[0.692]	[-0.134]	[-0.299]	[-0.668]
Initial Shock	-0.118 ***	-0.036	-0.015	0.005
	[-2.580]	[-1.402]	[-0.428]	[0.194]
Trading Volume	-0.048	0.169 **	0.175 ***	0.234 **
	[-0.344]	[2.539]	[3.040]	[1.971]
Subsidiary	0.025	0.144	0.072	0.084
	[0.142]	[1.395]	[0.793]	[1.060]
Adjusted R^2	0.038	0.012	0.005	0.009
No. Observations	750	1500	2250	3000
AIC	1210.7	2337.4	3384.8	4535.3
Time Dummies	(0.786)	(0.690)	(0.812)	(0.333)

Notes: Numbers in brackets are *t*-values calculated using clustered standard errors.
***, ** and * indicate statistical significance at the 0.01, 0.05 and 0.10 level, respectively.
Numbers in parenthesis are Wald test statistics of the joint significance of time dummy variables.

5.3 Application Examples

This assessment is intended to demonstrate how estimated results can be interpreted on real life applications. Here, the focus is on meat and poultry recall characteristics that are statistically significant. First, consider the average recall in this sample. This is a 42,000 pounds recall (equivalently to 10.64 in natural logs) issued by a firm with a value of market equity of $4 billion (equivalently to 22.15 in natural logs). In addition, 7 articles were published about this recall within 1 to 5 days after its announcement. Table 5.15 reports the individual effects of *Recall Size*, *Firm Size* and *Media Index* on CAR over a 5-trading day horizon. The effects of these characteristics are analyzed over different scenarios and are relative to the average recall. This table is constructed using results from Table 5.13 (panel 1). Column "*Ave. R*" represents the average recall and columns *R1* to *R6* represent a recall scenario for a particular characteristic. Note that *Experience* is not included in this table since there are only two scenarios based on this characteristic: firms that had a recall in the past year and firms that did not. In this sample, the average recall was issued by a firm that did not have a recall in the past year.

Table 5.15. Effects of Meat Recall Characteristics on *CAR* over a 5-Day Horizon

	R1	***R2***	***Ave. R***	***R3***	***R4***	***R5***	***R6***
Recall Size							
Pounds	6,000	15,500	42,000	115,000	310,000	850,000	2,300,000
% CAR	+0.510	+0.255	-	-0.255	-0.510	-0.765	-1.02
Firm Size							
ME	0.5 billion	1.5 billion	4 billion	11 billion	30 billion	83 billion	227 billion
% CAR	-1.354	-0.677	-	+0.677	+1.354	+2.031	+2.708
Media Index							
Articles	-5	-1	7	+1	+5	+10	+15
% CAR	+0.505	+0.101	-	-0.101	-0.505	-1.010	-1.515

The following is an example that illustrates the use of this table. Consider a 310,000 pound ground beef recall issued by a firm with a value of market equity of $1.5 billion and with media coverage of 12 articles within the first 5 days after the recall announcement. In addition, this is the first time this firm issues a meat recall. Looking at table 5.15, the marginal effect of *Recall Size* on CAR is -0.510, of *Firm Size* is -0.667 and of *Media Index* is -0.505. Also, the marginal effect of *Experience* in this example is zero. Adding up all these effects results in a 1.682 percent decrease on CAR, relative to the average recall. Now, in this sample the average CAR, regardless of the recall class, is -0.620 (table 5.3). Therefore, the total impact of this recall on the firm's CAR is (-1.682) + (-0.620) = -2.302 percent. That is, after 5 days of the recall announcement, stock returns are expected to decrease by 2.302 percent.

Chapter 6 - Conclusions

Food recalls can potentially cause significant economic losses for food firms. However, the assessment of the overall impact that may result from a food recall requires a thorough understanding of the costs incurred by firms. A direct measurement of a firm's total costs and losses of revenue associated with a recall requires firm-level data that is not available. Thus, quantifying these costs is daunting if not impossible. The method utilized in this study overcomes this severe limitation. Using an event study, the impact of meat and poultry recalls is quantified by analyzing price reactions in financial markets, where it is expected that stock prices would reflect the overall economic impact of a recall through the impact on the future profitability of the firm involved. Then, recall and firm specific characteristics are introduced in a second analysis to evaluate whether these are economic drivers of the magnitude of impact of meat and poultry recalls on stock prices. These group of characteristics are: severity of the threat, recall size, firm size, level of diversification, media information surrounding the recall, firm's experience and important meat industry events. In particular, this second analysis is a unique contribution of this study.

6.1 Summary of Main Findings

The main findings of this study are summarized as follows. First, consistent with Thomsen and McKenzie (2001), Class I recalls have a negative impact on the stock market value of firms, whereas Class II and Class III recalls have little discernable impact. On average, shareholder wealth is reduced by 1.15 percent within 5 days after a Class I recall announcement. This is most likely because of the human health risk involved in this type of recalls. Considering that direct costs associated with both Class I and Class II recalls are similar, the main difference is that Class I recalls affect the profitability of the firm by reducing the firm's revenues. Since revenues are affected by consumers (and customers) responses, this suggests that stock markets react to negative impacts on the demand side. On the other hand, contradicting results from Thomsen and McKenzie (2001), shareholders' losses are not persistent. Returns start going back to pre-event levels after day 20. Furthermore, stock markets do not appear to become aware of a recall before FSIS releases the official recall announcement.

Moreover, from a more technical perspective, results are sensitive to the selection of estimation and event windows. That is, since the event study approach relies on forecasting methods, the predictive power of benchmark models is influenced by the length of the forecasting horizon. Thus, it is important to caution researchers about this issue.

Findings related to the analysis of the impact of meat recall characteristics on stock market returns, suggest there are several important recall and firm specific factors driving the magnitude of this economic impact. These factors are: recall size, firm size, firm's experience and media information. Results related to recall size indicate that firms recalling a larger amount of product perceive greater reductions in company valuations. Furthermore, recalls issued by large firms are less likely to present negative effects on stock prices, compared to smaller firms.

Focusing on firm's experience, results confirm those from Salin and Hooker (2001) and Wang et al. (2002). That is, firms with a recent history of implication in a meat and poultry recall (more precisely over the past year), are less harmed by a new recall, compared to those firms issuing a recall for first time (or not issuing a recall in a while). This finding suggests that investors take into consideration the past performance of a company when dealing with food recalls at the moment of making their valuations. Additionally, findings regarding media information indicate that recall-related articles published within 20 trading days after the recall announcement, have a negative impact on shareholder's wealth. This result corroborates that stock markets react to situations affecting the demand side, since it is assumed that consumers and customers are directly exposed to media information.

6.2 Implications

Several implications for food companies, particularly regarding recall management, can be derived from this study. One of these implications is related to recall size. Firms should try to rapidly identify the contaminated product, perhaps by testing products in smaller lots, so that recalls of massive amounts of product are less likely. These massive recalls are immensely costly to the firm and result in sizeable stock price impacts which can potentially turn into firm bankruptcies. Additionally, this study provides implications for firm size. In particular, small firms should invest more of their total firms' value in food safety technologies and protocols as they have greater risk of bankruptcy.

Another implication of this study is related to the firm's experience, which is more precisely measuring the experience that recurrent firms have on managing food recalls. This is based on the premise that recurrent firms appear to be sending positive signals to the stock market, indicating investors not to consider a food recall a threat. Therefore, other firms without experience handling a food recall, need to learn from recurrent firms that have successfully managed food recalls.

The implication of media information is that once news reach the public, these will have a negative impact on the firm's valuation. Therefore, having a plan in place to deal with this situation is important. Recommendations concerning appropriate strategies for managing the influence of media fall outside of the scope of this study. Nevertheless, companies need to be ready to implement those plans to try to reduce the adverse impacts of media while dealing with a food recall.

Finally, the implication for investors is that although the effects of food recalls on stock prices appear to be short-lived, there are certain factors such as firm size, recall size and media information that can potentially cause substantial shareholders' loses. Therefore, while interested in an industry with a high level of food safety risk, investors may want to know more about the firm's food safety strategy before investing.

6.3 Future Research

This study focuses on analyzing the effects of meat and poultry recalls on own stock price valuations. However, it can also be extended to evaluate the spillover effects of a recall on other firms. That is, an interesting question unanswered in this study is whether the industry as a whole loses after a meat and poultry recall to any firm or, whether rival firms benefit from this food safety incident. One of the advantages of conducting this analysis is that it is not necessary to evaluate the effects of recalls affecting publicly traded firms. That is, one could evaluate spillover effects of a recall affecting a private firm on stock prices of publicly traded rivals.

Moreover, food safety incidents have the potential to affect both stock prices and volatility of stock returns. Therefore, another extension of this study would be to analyze the effects of meat and poultry recalls on the volatility of stock returns. However, one of the limitations in conducting such analysis relies on the availability of data. According to Andersen et al. (2001) previous work has relied on daily return observations for the construction of monthly realized stock volatilities. Yet, monthly measures of abnormal volatilities may not be able to capture all the relevant information found in daily price movements. This is because it is expected that the effects of some meat recalls on returns' volatility would last only few days after the recall. Data corresponding to daily standard deviations based on 15-minute equity returns will be needed to estimate daily stock volatilities. Unfortunately, this information is not easily accessible. Another possibility would be to use daily implied volatilities calculated using options or other derivatives prices. However, the estimation of such volatilities alone would be difficult since not every publicly traded food firm may trade options.

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Appendix A - Results from the Calculation of *CAAR* by Class for *w*2

Table A.1. Cumulative Average Abnormal Returns [*w*2], Class I Recalls

τ_2	$\tau_1 = -5$			$\tau_1 = -2$			$\tau_1 = 0$			$\tau_1 = 1$		
	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}
-5	0.209	0.448	-0.005									
-1	0.290	-0.049	0.068	-0.088	-0.557	-0.466						
0	0.210	-0.188	-0.419	-0.168	-0.650	-1.288*	-0.080	-0.370	-0.788			
1	0.021	-0.376	-0.624	-0.358	-0.812	-1.570*	-0.269	-0.682	-1.360*	-0.190	-0.497	-1.159
2	-0.074	-0.243	-0.491	-0.452	-0.588	-1.768**	-0.364	-0.353	-1.306*	-0.284	-0.142	-0.869
3	-0.380	-0.494	-0.446	-0.758	-0.845	-1.921**	-0.670	-0.704	-1.545*	-0.590	-0.565	-1.095
4	-0.759	-1.052	-1.550*	-1.138	-1.472*	-2.799**	-1.049	-1.541**	-2.801**	-0.970	-1.461*	-2.500**
5	-0.859	-1.285*	-1.598*	-1.238	-1.722**	-2.887**	-1.149	-1.818**	-2.796**	-1.070	-1.712**	-2.389**
10	-0.804	-0.831	-2.011**	-1.182	-1.107	-2.886**	-1.094	-0.950	-2.394**	-1.014	-0.880	-2.256**
15	-0.623	-0.817	-1.403*	-1.002	-1.000	-1.882**	-0.913	-0.876	-1.570*	-0.834	-0.825	-1.388*
20	-1.348	-1.228	-1.721**	-1.726	-1.359*	-2.096**	-1.638	-1.276	-1.998**	-1.558	-1.241	-1.741**

Note: ** and * denote statistical significance at the 0.05 and 0.10 level for a one tailed test (equation 12).

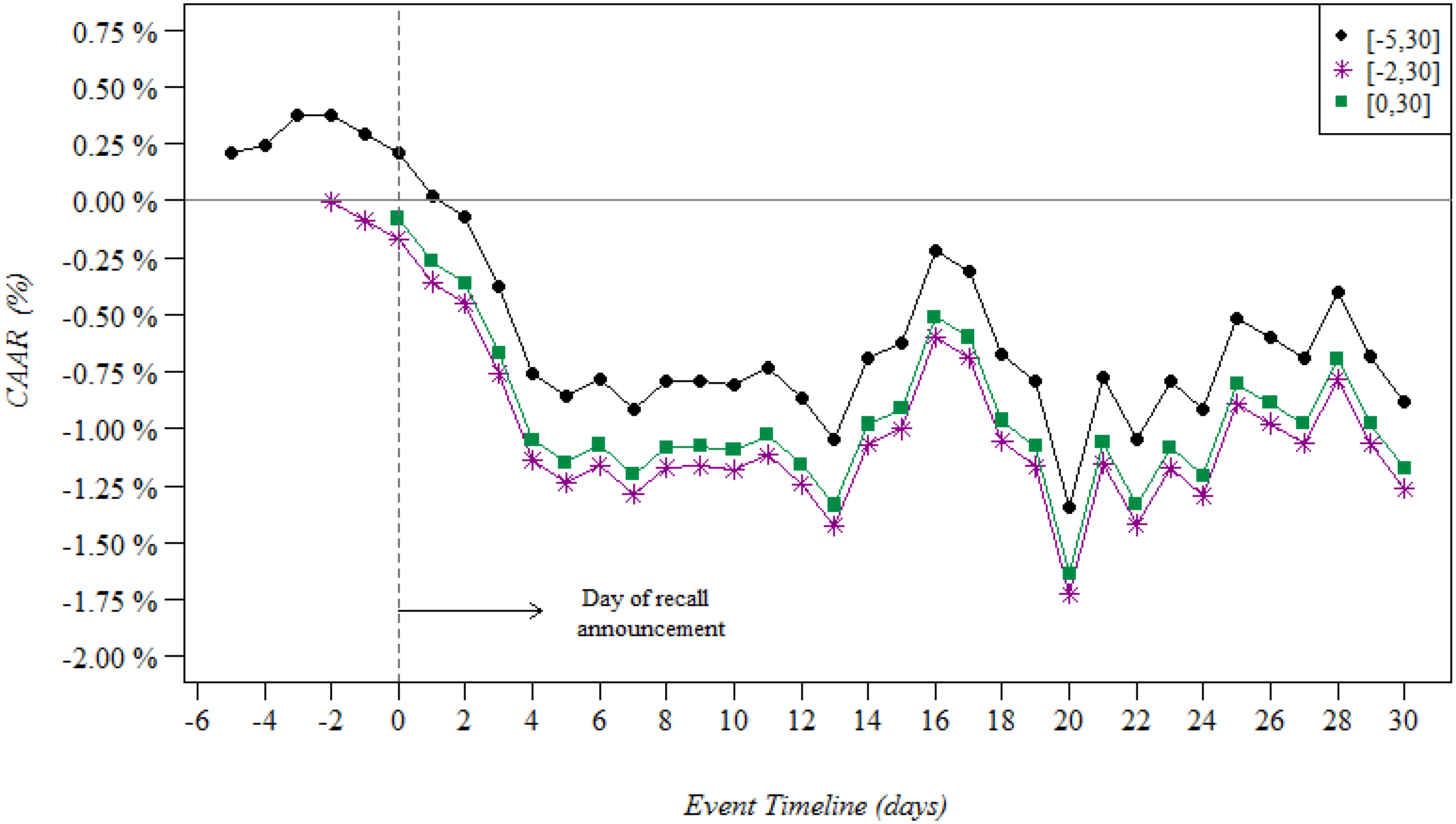

Figure A.1 Cumulative Average Abnormal Returns [*w*2] for Class I Recalls

Table A.2. Cumulative Average Abnormal Returns [$w2$], Class II Recalls

	$\tau_1 = -5$			$\tau_1 = -2$			$\tau_1 = 0$		
τ_2	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}	$CAAR$	Z_{BMP}	Z_{GRANK}
-5	0.156	0.325	0.586						
-1	0.644	-0.029	0.963	0.550	-0.288	0.387			
0	0.780	-0.125	0.793	0.685	-0.314	0.470	0.136	-0.156	0.477
1	0.710	-0.265	0.795	0.616	-0.481	0.351	0.066	-0.362	-0.140
2	0.948	-0.156	1.198	0.853	-0.342	1.042	0.303	-0.209	0.860
3	1.185	-0.318	1.261	1.091	-0.497	1.190	0.541	-0.455	1.240
4	1.306	-0.595	1.225	1.212	-0.782	1.032	0.662	-0.830	0.779
5	0.964	-0.654	0.633	0.870	-0.836	0.447	0.320	-0.836	-0.016
10	1.855	-0.472	1.471*	1.761	-0.604	1.493*	1.211	-0.544	0.916
15	1.463	-0.465	0.768	1.368	-0.574	0.736	0.818	-0.526	0.308
20	0.408	-0.664	0.050	0.313	-0.736	0.114	-0.236	-0.705	-0.150

	$\tau_1 = 1$		
τ_2	$CAAR$	Z_{BMP}	Z_{GRANK}
-5			
-1			
0			
1	-0.070	-0.320	-0.202
2	0.168	-0.100	0.716
3	0.405	-0.417	1.029
4	0.526	-0.821	0.772
5	0.184	-0.827	-0.283
10	1.075	-0.547	0.806
15	0.683	-0.508	0.048
20	-0.372	-0.722	-0.295

Note: * denotes statistical significance at the 0.10 level for two tailed test ($H_0\colon CAAR = 0$ and $H_a\colon CAAR \neq 0$).