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**Authors**
Villas-Boas, Sofia B
Toledo, Chantal

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# Safe or Not? Consumer Responses to Recalls with Traceability*

Chantal Toledo† Sofia Berto Villas-Boas‡

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**Abstract**

Product traceability is advocated as a way to target non-compliant products in recalls and protect the sales of compliant products. Using a large scanner-level dataset from a national grocery chain and a difference-in-differences approach, we test whether consumers in California reduced egg purchases after three consecutive egg recalls during the 2010 Salmonella outbreak. In a setting where contaminated eggs could be traced to the box level, leaving no contaminated eggs in stores, we find a 7 to 9 percent reduction in egg sales following the recalls. Moreover, sales dropped not only for non-contaminated eggs of the affected brand but also for eggs of unaffected brands. The effect lasted at least three months. We find no evidence of overall substitution toward "greener" types of eggs, such as organic eggs. Finally, although the national grocery chain had contaminated eggs only in Northern California, we find reductions in egg sales in Southern Californian stores as well. Our results show that, even with traceability, consumers' responses to recalls can negatively affect the sales of compliant products.

JEL Codes: D120, D180, Q1
Keywords: Consumer Behavior, Traceability, Spillovers

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†Mathematica Policy Research. Corresponding author: ctoledo@mathematica-mpr.com.
‡Professor, Agricultural and Resource Economics Department, University of California at Berkeley.

# 1 Introduction

When making purchasing decisions about products, consumers traditionally consider factors such as price, quality and availability of substitutes. It is less clear what happens when a very similar product is removed from the market for safety reasons, especially if consumers are able to precisely identify safe products. On the one hand, if a product with safety concerns is removed from the market and the remaining products experience additional safety checks, consumers may perceive the market as being at least as safe as before. On the other hand, if the removal of the unsafe product provides negative information about closely related products or an industry as a whole, consumers may respond by decreasing demand, even in the absence of safety concerns about the remaining products. The empirical question is whether a recall of an unsafe product can have a direct impact on consumer purchases and preferences, even if the remaining products are safe. From a policy perspective, the question is relevant if firm incentives to invest in risk reduction and regulatory compliance in existing regulation depend, to some degree, on consumer responses to recalls.

In early July 2010, the Center for Disease Control and Prevention (CDC) identified a nationwide, four-fold abnormal increase in the number of reported Salmonella infections. A month later, on August 2010, three nationwide voluntary recalls took place on August 13 (about 228 million eggs), August 18 (approximately 152 million eggs), and August 20 (about 170 million eggs). In total, from August 13 to August 20, 2010, more than 500 million eggs were recalled, in what would be the largest egg recall in U.S. history (around 0.7% of production). Contaminated eggs from two major egg producers were distributed in fourteen U.S states, among which was California. Eggs were recalled using specific plant numbers and codes that allowed tracing back to the box level, leaving no contaminated eggs in stores. Consumers and stores could return contaminated eggs for a full refund. The three egg recalls received extensive national and local media coverage. Media interest persisted over a 12 week period following the recalls, in particular covering farm inspections that found numerous violations and showed that the egg farms were infested with flies, maggots, rodents and overflowing manure pits, as well as the appearance of both farm owners before Congress. The fact that there were three consecutive egg recalls within one week could have led consumers to think that this was a major outbreak, and not a regular food recall. Furthermore, given the media coverage, some consumers may have obtained information or updated their beliefs on the egg industry as a whole. If consumers were perfectly informed, did not update their beliefs, and expected no further recalls, we could anticipate no effect of the recalls on consumer purchases. However, if consumers did not have perfect information on the outbreak or the recall codes, updated their beliefs about the egg industry, or "over-reacted" to the recalls, we could expect a drop in egg purchases following the outbreak, at least temporarily. We find that the latter was true.

Using a unique product-level scanner dataset of a national grocery chain that has stores in both high and low income zip codes, we examine how consumers reacted to the three consecutive egg recalls. First, we test whether consumers changed their egg purchases in California following the recalls; we hypothesize that egg purchases might have decreased in California after the three egg recalls. Second, we study whether consumers substitute away from conventional eggs toward other types of value-added specialty "greener" eggs that may be perceived as having a lower probability of Salmonella, such as organic or cage-free eggs. We hypothesize two possible results for purchases of unaffected eggs. On one hand, consumers might substitute away from conventional types of eggs to non-conventional value added specialty eggs (a substitution effect across egg classes). On the other hand, some consumers might choose to reduce all egg purchases, leading to a decline in purchases of all types of eggs. Third, we investigate whether different socio-economic groups reacted differently to the egg recalls. We look at whether education (in particular, college attainment), income and household size affect the response to the recalls. To do this, we use demographic data for the zip code where the store is located. Education may affect consumer responses if more educated households are able to obtain more information about the recalls and identify safe eggs through codes on egg boxes. Income may affect the response if wealthier consumers are able to substitute to greener alternatives, which can cost up to twice as much as traditional shell eggs. Household size may affect consumer purchases after the event if larger households have more children, and thus a higher risk that someone in the household might become infected. Fourth, we examine whether separate areas within California reacted differently to the egg recalls. Although other chains in Southern California had contaminated eggs, our national grocery chain, due to its distribution system, had contaminated eggs only in Northern California and not in Southern California. We use variation within California to test whether consumers in Southern California reduced egg purchases as well. Fifth, we test for brand spillover effects by studying whether brands that did not have contaminated eggs also experienced lower egg sales.

We perform a difference-in-differences analysis of the recalls and use a control state that did not receive contaminated eggs: Washington.[1] In this grocery chain, no eggs were diverted between California and Washington or within California due to the recalls and prices and marketing changes are all centrally administered at the division level (e.g., Northern California or Southern California). The recalls removed about one percent of the Northern California division eggs on the shelves and only the subclasses "large" and "extra-large" traditional shell eggs were affected. We are able to control for seasonality (i.e., seasonal changes that could be occurring at the time of the recalls in California) by using data from previous years around the recall date. We use the fact that contaminated eggs could be traced to the box level to establish a clear definition of the treatment and follow a panel of over 650 stores during a four-year period around the event date. Given the geographical distribution of contaminated eggs, we are able to measure potential spillovers to stores in Southern California. We are also able to show brand spillover effects from the affected brand to non-affected brands.

We find a 7 to 9 percent significant reduction in egg sales in California following the egg recalls and we show that the effect lasted at least three months after the event.[2] We find that this decrease in sales was driven by a drop in purchases of large traditional shell eggs and find no overall evidence of substitution toward greener type of eggs such as organic or cage-free eggs. We do, however, find that a $10,000 increase in the median income of the zip code in which stores are located increases purchases of specialty eggs by 2 to 4 percent.[3] We also find that, one and two months after the recalls, stores that were located in zip codes where residents had on average at least one year of college had 3 percent higher overall sales than those where residents had less than one year of college. In addition, we find differentiated effects among Northern and Southern Californian stores. Although the national grocery chain had contaminated eggs only in Northern California, we find that Southern Californian stores had lower egg sales as well. The sales reduction in Southern California lasted at least three months after the recalls and is consistent with both geographical spillovers (from Northern California

[1] In a robustness check, we also use Southern California as a control for Northern California (and exclude data from Washington) and find similar results one month after the first recall.

[2] We formally test whether, in our national grocery chain, price responded to the recalls. We find that, due to its pricing system, the national grocery chain did not adjust overall prices. We estimate the effect with and without prices and, consistent with a rather inelastic demand, we find very similar results.

[3] We are unable to establish why most consumers did not switch to specialty eggs. It is possible that most consumers did not switch to specialty eggs because the price is higher than traditional eggs or because they did not perceive that specialty eggs had a lower probability of having Salmonella. Using out-of-stock data, we are able to show that the event did not increase the probability that specialty eggs were out-of-stock (not supplied).

to Southern California within our chain) and with between-chain spillovers (within Southern California). Finally, we are able to show that non-affected brands show drops in sales that are comparable to the affected brand, up to three months after the event.

This paper contributes to the existing literature in the following ways. First, this research contributes to the evidence on the effects of recalls and food-safety related information on consumer demand and preferences. Recent studies have found large and significant effects of safety warnings about E. coli on spinach (Arnade, Calvin and Kuchler 2009), mercury on fish consumption (Shimshack, Ward and Beatty 2007), and health warnings about mad cow disease (Schlenker and Villas-Boas 2009).[4] Arnade, Calvin and Kuchler (2009) study the impact of the Food and Drug Administration's (FDA) 2006 announcement warning consumers about E. coli O157:H7 contamination in spinach and find that retail expenditures decreased 20% for bagged spinach and 1% for bulk spinach over a period of sixty-eight weeks. Shimshack, Ward and Beatty (2007) examine responses to a U.S. national FDA advisory that urged at-risk individuals to limit store-bought fish consumption due to the dangers of methyl-mercury. The authors find that some targeted consumers significantly reduced canned fish purchases as a result of the advisory. The advisory also had unintended spillover effects, where some consumers not considered at-risk reduced consumption in response to the advisory. Schlenker and Villas-Boas (2009) examine how consumers and financial markets in the United States reacted to two health warnings about mad cow disease and find a large (around 20%) and significant reduction in beef sales following the first discovered infection. The effect dissipates slowly over the next three months. In this study, we use a unique scanner level dataset with over 43 million observations from one of the

[4] Earlier studies found significant effects of safety warnings about contamination of milk with heptachlor on milk sales and milk consumption (Smith, van Ravenswaay and Thompson 1988; Foster and Just 1989), effects of Bovine Spongiform Encephalopathy (BSE or mad cow disease) on beef sales, demand and prices (Burton and Young 1996; Lusk and Schroeder 2002; Crowley and Shimazaki 2005; Marsh, Brester and Smith 2008), and effects of concerns about Alar on willingness-to-pay for Alar-free apples (van Ravenswaay and Hoehn 1991). In addition, several other studies have found effects of meat product recall events on consumer demand (Marsh, Schroeder and Mintert 2006), of meat and poultry recalls on shareholder losses (Thomsen and McKenzie 2001), and of publicized food safety information on meat demand (Piggott and Marsh 2004). Viscusi, Magat and Huber (1986) found that consumer behavior is responsive to information about product hazards. In particular, the authors found that the extent to which consumers take precautions is consistent with the level of risk indicated, the amount of risk information, the specific risk and precaution indicated, and the economic benefits of safety precautions. Brown and Schrader (1990) found that information on the links between cholesterol and heart disease decreased per capita shell eggs consumption by 16% to 25%. Shimshack and Ward (2010) highlight trade-offs in the use of information by showing that an advisory about mercury in fish reduced mercury loadings, but it did so at the expense of substantial reductions in healthful omega-3s.

largest grocery chains, use store-by-product-by-year fixed effects to pick up location-specific shifts in consumption patterns and include data from previous years to control for seasonality. While many studies use aggregated data to estimate effects of recalls, we use detailed transaction data. We are able to show an overall decrease in sales, to study possible substitution effects, and to show that the effect was not driven by a lack of supply of eggs at our grocery chain. Further, we provide evidence on consumer responses in a context where traceability is high. We are able to show that recalls can have substantial effects, even when traceability is high and contaminated products can be traced down to very small units (in our case, an egg box). This has implications for the targeting of messages delivered after recalls. In a setting where demand is rather inelastic and the remaining products can be identified as safe, messages after outbreaks could benefit from supplying more detailed and targeted information.

Second, this study provides insights on spillover effects of recalls. Our findings are consistent with previous literature on spillover effects in different settings. Freedman, Kearny and Lederman (2012) examine consumer demand for toys following the discovery of high levels of lead content in certain toys and find evidence of sizable spillover effects of product recalls to non-recalled products and manufacturers that were not affected by the recall. Cawley and Rizzo (2008) find spillover effects in a case of withdrawal of a drug from the market, as do Reilly and Hoffer (1983) in a study on automobile recalls. In food-related settings, Brown (1969) cites concerns that producers of cranberries from unsprayed bogs also suffered during a pesticide scare. The author finds temporary declines in the number of households that purchased cranberries and in per capita purchases among purchasing households but does not find evidence that the recall affected the elasticity of demand for processed cranberries. More recent studies such as Thomsen, Shiptsova, and Hamm (2006) measure sales losses by frankfurter brands following a recall for a foodborne pathogen. The authors find that sales of recalled brands declined by around 22% after the recall, and that brand recovery began two to three months later. However, they find no evidence that non-recalled brands experienced sales losses. Bakhtavoryan, Capps and Salin (2014) study the effect of negative publicity linked to pathogen contamination of a recalled peanut butter brand. The study finds that the recall was associated with negative impacts for the implicated brand and positive effects on the leading competitor brand, showing that problems of one brand do not necessarily harm rival brands within the category. This paper exploits an unusual situation in our national grocery chain, where only stores in the Northern California division had contaminated eggs and stores in the Southern California division did not, and finds evidence of spillovers. This study also exploits detailed brand data to quantify the brand spillover effect and shows that non-affected brands experienced drops comparable to the affected brand. The findings from this study have policy implications for food safety. Given the evidence of spillovers, and, assuming all non-recalled eggs were safe, the results show that producers of safe eggs were meaningfully affected and that producers responsible for the outbreak did not bear all of the costs, even in a context of high traceability. This suggests that, when considering up-front investments in safety measures, it is possible that producers responsible for outbreaks do not completely internalize costs and thus under-invest in food safety. As discussed in Pouliot and Sumner (2013), an industry can benefit from improved traceability because traceability protects the collective reputation of a group of firms from negative demand shocks from safety incidents. Traceability does this by removing the anonymity of the firm source of contamination. This paper suggests that the effect of the recalls could have been even larger, had traceability not been possible.

Third, this paper contributes to the literature on heterogeneous effects of responses to recalls. Schlenker and Villas-Boas (2009) find that stores located in zip codes with higher mean income exhibit additional reductions in sales (an additional 1.3% drop in sales for each $10,000 in median income), as do stores located in zip codes with a higher fraction of minority groups. Shimshack, Ward and Beatty (2007) find that college educated consumers in the target group responded strongly to a mercury advisory. Consistent with previous literature, we find heterogeneous responses by demographic characteristics. In particular, we find college, income and household size effects. Because stores located in zip codes with higher educational attainment decrease purchases of eggs less than those in areas with lower educational attainment, messages delivered after recalls could focus on areas with lower educational attainment.

The remainder of this paper is organized as follows. The next section provides some brief background on current egg production methods, Salmonella, traceability and the 2010 Salmonella egg outbreak. The third section outlines our data and the fourth section describes the analytical framework. The fifth section presents our empirical results and the sixth section provides a series of robustness checks. The last section concludes.

# 2 Background

In this section, we provide background information on the context in which the 2010 Salmonella egg outbreak occurred. First, we provide information on egg production in the United States. Second, we briefly introduce Salmonella and how infections occur. Third, we present the concept of traceability. Fourth, we describe the 2010 Salmonella outbreak and how it was reported in the media.

## 2.1 "An Egg is No Longer an Egg"

According to the American Egg Board, in 2010, the per capita consumption of eggs in the United States was 248 eggs per year.[5] Eggs are one of the most inelastic products in the U.S., with a price elasticity of demand of around -0.1 (Krugman and Wells 2009). The five largest egg-producing states (IA, OH, PA, IN, CA) have 50% of all U.S. layers. Although eggs are produced under a variety of production methods, 95% of the egg production in 2010 came from conventional battery cages. Conventional battery cages are stacks of cages that can be up to two stories high and keep about six hens to a cage. Each hen gets on average 67 square inches of floor space (about $\frac{3}{4}$ of a sheet of notebook paper). Hens are unable to stretch their wings and have no access to natural light. According to the United States Department of Agriculture (USDA), as many as 100,000 birds may be grouped together under a single roof. The remaining 5% of egg production comes from production methods that are classified by how hens are kept (e.g, cage-free, free range, pasture-raised)[6] and/or by what they are fed (e.g., organic, vegetarian-fed, no hormones, no antibiotics).[7] A single egg box usually contains more

[5]Per capita consumption is a measure of total egg production divided by the total population. It does not represent demand.

[6]For example, for an egg to be labeled "cage free," hens must have been kept out of cages and had continuous access to food and water, but not necessarily access to the outdoors. The label "free range" means that, in addition to meeting the cage-free standards, the birds must have continuous access to the outdoors, unless there is a health risk present. However, there are no standards for what that outdoor area must be like. "Pasture-raised" implies that hens get at least part of their food from foraging on greens and bugs, which adherents say can improve flavor, but there is no federal definition for this label. There are also several animal care labels but they are not harmonized.

[7]For example, the USDA "organic" label requires that birds must be kept cage-free with outdoor access (although the time and the type of access are not defined), they cannot be given antibiotics (even if ill) and their food must be free from animal by-products and made from crops grown without chemical pesticides, fertilizers, irradiation, genetic engineering or sewage sludge. If an egg box labeled as organic does not have the program's label, it may be part of an independent or state-run program. The USDA grade shield "vegetarian-fed" certifies that the eggs came from hens raised on all-vegetarian feed (as opposed to animal by-products that can be included in conventional chicken feed).

than one label (for example, "Cage-Free, Kosher and Vegetarian-fed hens"). In our California and Washington sample, around 86% of eggs sold came from battery cages. There are also different egg grades (grades AA, A or B), which depend mainly on the firmness of the whites.

## 2.2 Salmonella

Salmonellosis is an infection caused by a bacteria called Salmonella. It is one of the most common causes of food poisoning in the United States. Salmonella is spread through food (e.g., contaminated eggs, poultry or meat) and animals. Most people infected with Salmonella develop diarrhea, fever, and abdominal cramps 12 to 72 hours after infection. The illness usually lasts 4 to 7 days, and most people recover without treatment, but some infected individuals need to be hospitalized. In some cases, the Salmonella infection can spread from the intestines to the blood stream and then to other body parts. This can cause severe illness or death if the person is not treated promptly with antibiotics. Children under 5 years old, the elderly and those with impaired immune systems are most at risk. According to the CDC, an estimated 1.2 million cases occur annually in the United States and 450 deaths occur due to non-typhoidal Salmonella annually. Salmonella is killed by cooking and pasteurization.

Studies in the United States have produced mixed evidence on the link between the type of egg (e.g., battery cage, cage-free, organic) and the probabilities of Salmonella infection, with confounding factors such as production size and age of the farm.[8] Evidence shows that Salmonella spreads through livestock animals (especially when kept in large numbers in confined spaces), runoff from livestock pastures, and leaky or over-topped waste lagoons at industrial farming sites.

## 2.3 Traceability

Given the setting of diverse production methods and the risk of Salmonella infection described above, the concept of traceability is key to understanding the effect of recalls on consumer behavior. Traceability systems are "recordkeeping systems designed to track the flow of products or product attributes through the production process or supply chain" (Golan et al. 2004). In particular, traceability refers to the recording of product movements and steps within the production process. As described in Golan et

[8] In January 2012, battery cages were banned in the European Union due to animal welfare concerns.

al.(2004), while complete traceability (the tracking of each and every input and process with precision for every private or public objective) is virtually impossible, "good" traceability systems are available. Traceability systems tend to vary across products and across characteristics such as breadth (the amount of information the traceability system records), depth (how far back or forward the system tracks) and precision (the degree of assurance with which the tracing system can pinpoint a particular food product's movement or characteristics). Traceability is particularly relevant when issues of contamination arise. If adequate traceability is available, it is possible to identify, often by precise date, time and exact location, which products must be recalled and which are safe. This process can protect public health by allowing health agencies to quickly and accurately identify the source of contaminated products, remove them from the market, and communicate this to the supply chains. From the supply side, if a firm can produce documentation that shows that a safety failure did not occur in its plant, it may be able to protect itself from liability or other negative consequences (Golan et al. 2004). In addition to facilitating traceback for food safety and quality, traceability is also used by firms to improve supply management and to differentiate and market foods with subtle or undetectable quality attributes.

## 2.4 The 2010 Salmonella Outbreak and Egg Recall

From May 1 to November 30, 2010, the CDC observed a nationwide, four-fold increase (1,939 illnesses) in the number of Salmonella incidents reported. Figure 1 shows an epidemic curve of the number of Salmonella Enteritidis cases matching PFGE (Pulsed-Field Gel Electrophoresis) patterns for the year 2010. PFGE patterns are used to identify bacteria. The curve shows an increase in reports beginning in May, peaking in July, and returning to baseline in November. From August 13 to August 20, 2010, more than 500 million eggs (around 0.7 % of production) were recalled after dangerous levels of Salmonella were detected, in what would be the largest egg recall in U.S. history. Contaminated eggs were distributed in fourteen U.S states (AR, CA, IA, IL, IN, KS, MN, MO, NE, ND, OH, SD, TX, and WI). On August 13, 2010, Wright County Egg of Galt, Iowa, conducted a nationwide voluntary recall of around 228 million eggs. Five days later, on August 18, 2010, Wright County Egg expanded its recall to around 152 million additional eggs. Two days later, on August 20, 2010, a second producer, Hillandale Farms of Iowa, conducted a nationwide voluntary recall of around 170 million eggs. Contaminated eggs in all 14 states were recalled using specific plant numbers and codes that allowed tracing back to the box level. For example, the first recall (08/13/2010) had Julian dates[9] ranging from 136 to 225 and plant numbers 1026, 1413 and 1946. They were packaged under different brands and carton sizes (6 - egg, dozen, 18 - egg). Figure 2 shows an example of how contaminated eggs could be identified using codes on the egg box. Consumers and stores could return eggs for a full refund.

The three egg recalls linked to the 2010 Salmonella outbreak received extensive national and local media coverage through television, newspapers, the internet and the radio. In August 2010, the media reported on an inspection conducted by the FDA showing that barns of the two egg producers (Wright County Egg and Hillandale Farms) were infested with flies, maggots and rodents and had overflowing manure pits.[10] In September 2010, the media undertook extensive coverage of the appearance of both farm owners before Congress. As a proxy for the general media coverage of the recalls, we conducted a Lexis-Nexis search which gave us the daily count of newspaper articles that appeared on the 2010 Salmonella egg outbreak, starting 15 days before the first recall up to 94 days after. Figure 3 shows the number of articles in major newspapers that include the words "Salmonella" and "Eggs" on a given day for California (orange line), Northern California only (red line), Southern California only (blue line), Washington (green line), and all of the United States (black line). Newspaper coverage in California and Washington was very small, suggesting that consumers may have become informed through the national newspaper coverage (national articles mention that California was one of the states with contaminated eggs) or through other media, for example television, internet or radio. The first egg recall (August 13, 2010) seemed to pass relatively unnoticed in our newspaper search, while the second and third egg recalls (August 18 and August 20, 2010) received considerably more attention. Attention remained relatively high and peaked around five days after the third egg recall. It decreased until the media coverage of the farm inspection conducted by the FDA, when it increased again. Newspaper coverage then decreased considerably, until Congress released the results of investigations and both farm owners appeared before Congress. One month later, the media reported that one of the farms linked to the recall, Hillandale Farms, was allowed to sell eggs again, expanding the time the event persisted in the media. Finally, almost three months after the first recall, the largest egg seller in the United States,

[9]Julian dates are the numeric date of the year in which the eggs were cartoned. For example, eggs that were cartoned on January 1 have "001" printed on them and eggs cartoned on December 31 have 365, the 365th day of the year.

[10]It is possible that consumers correctly judged the safety of remaining eggs but reacted instead to the unhygienic factors that were shown in the media coverage.

Cal-Maine Foods, recalled 288,000 eggs that had been distributed across the country after Salmonella was detected at a farm in Ohio, where Cal-Maine had purchased the eggs.[11] The eggs involved in this last recall were distributed to food wholesalers and retailers in AR, CA, IL, IA, KS, MO, OK and TX. Thus, in total, media coverage lasted until around ninety days after the recalls, peaking around specific events linked to the outbreak. The media coverage also identified the main brands involved in the recalls, among which was the signature brand of our national grocery chain.

In light of these factors - the media coverage, the clear tracing back of contaminated eggs to the box level and the fact that both consumers and stores could return contaminated eggs for a full refund - consumers could have responded to the outbreak in various ways. Because contaminated eggs could be traced to the box level, some consumers might have decided not to change their purchasing behavior. Other consumers might have temporarily decreased egg purchases or consumed eggs from other (unaffected) sources.[12] In the next section, we proceed by empirically testing whether the 2010 outbreak of Salmonella in eggs had an impact on consumer purchases.

# 3 Data

We use a large and unique scanner dataset with over 43 million observations from one of the largest U.S. grocery chains to estimate the impact of the egg recalls on consumer purchasing decisions. This chain has a presence in both high- and low-income zip codes throughout California and Washington, and is a full-service neighborhood grocery store. Our raw dataset includes all egg sales transactions during our time period in 708 stores in California and Washington. In order to construct a balanced panel of stores, we exclude 57 stores that did not have data available for all months. These 57 excluded stores represent 4% of our raw data and 8% of our stores. Among these 57 stores, 41 dropped out of the dataset in 2007, 13 dropped out in 2008 and 3 stores dropped out in 2009. Our final dataset includes a balanced panel of 651 stores. Of these 651 stores,

[11] The farm in Ohio was linked to the owner of Wright County Egg.

[12] As anecdotical evidence, a Cable News Network (CNN) poll on August 19, 2010 with 9,244 votes answered the question "In light of the recall, will you eat eggs within the next week?" The responses were "The bad eggs are off the shelf, right? I'll go right ahead" (28.67%, 2,650 votes); "I think I'll hold off for now, but I'm not panicked" (16.02%, 1,481 votes); "These things upset me. I'll stay away for a while" (6.75%, 624 votes); "I'll eat eggs, but only from sources I trust" (34.12%, 3,154 votes); "I don't care about recalls" (7.39%, 683 votes); "I don't eat eggs" (4.14%, 383 votes); and "Other" (2.91%, 269 votes). The poll can be found at http://eatocracy.cnn.com/2010/08/19/lunchtime-poll-incredible-currently-not-as-edible-eggs/ (accessed February 2, 2016).

488 stores are in California, one of the fourteen states that had contaminated eggs, and 163 stores are in Washington, one of the states that did not have contaminated eggs.[13] Within California and Washington, data are further divided into divisions: California is divided into the Northern California and Southern California divisions and Washington is divided into the Seattle and Portland divisions.[14]

Observations in this dataset are daily sales at the product and store level, e.g., Store 91 sold 1 box of Large Eggs AA of a particular brand for a total of $2.69 on August 12, 2008, where a product is represented by a unique Universal Product Code (UPC). Closely related products (e.g., Large Eggs and Extra Large Eggs of the same brand) can have various UPCs, and thus we use several measures to aggregate sales of comparable products for a given time period and store. The variable subclass groups together UPCs with closely comparable product characteristics, e.g., all "Eggs Large A", or "Eggs Large AA." The next aggregation level is an egg class which groups similar egg types together, e.g., all "Traditional Shell Eggs," or "Value Added Specialty Eggs." Egg products are furthermore grouped into categories; in our analysis, we use only shell eggs, which account for 97% of all egg sales.[15] For example, when we use the category aggregation measure, we add all purchases of shell eggs. We drop two subclasses from the original dataset; these are "medium" traditional shell eggs and "fertile" specialty eggs, because they were not sold in all months in California and Washington. The dropped subclasses represent 2% of our raw dataset. The final dataset contains 7 subclasses (large, extra large, jumbo, brown, organic, cage-free and nutrient enhanced), 2 classes (traditional and value added specialty) and 1 category (all shell eggs). Data are for the period July 15 through November 16 in the years 2007, 2008, 2009 and 2010, thus spanning the period 4 weeks prior to and 12 weeks past the day of the first recall, August 13. The scanner data report both sales revenues and quantity sold, and we are therefore able to construct the price by dividing sales revenue by quantity for each observation. Prices are fixed for seven days from Wednesday to the next Tuesday.

The summary statistics are given in Table 1. The final dataset includes 43, 575, 891 observations. In the main regressions, we aggregate observations to the store by

[13] Although a very small proportion of contaminated eggs might have reached the state, all the major sellers in WA said they did not have contaminated eggs, including our national grocery chain.

[14] The metropolitan areas in the Northern California division are the San Francisco Bay Area and Sacramento. The metropolitan areas in the Southern California division are Los Angeles and San Diego. The metropolitan area in the Seattle division is Seattle. The "Portland" division includes several cities in Washington; these cities are included in the Portland division because of division pricing. Prices are common in a division regardless of state lines.

[15] The remaining 3% of eggs are liquid eggs, which we exclude from our final dataset.

month by aggregation level, where the aggregation levels are either the category level (all shell eggs), the class level (traditional or specialty eggs) or the subclass level (large, extra large, jumbo, brown, organic, cage free or nutrient enhanced).[16] Panel A in Table 1 shows summary statistics for the quantity and price of eggs when observations from the scanner dataset are aggregated at the store by month by category level, at the store by month by class level (traditional and specialty), and at the store by month by subclass level (only the large traditional shell eggs subclass is shown). Panel A also includes summary statistics on the year, month and store identification. Panel B includes socio-economic data for the zip code in which stores are located. We obtain the exact location for each of the 651 stores and are able to match the location with education, income and household size statistics from the 2000 U.S. Census, based on the zip code in which a store is located. Panel C includes brand and out-of-stock data. In particular, Panel C includes summary statistics for whether egg products are from the signature chain brand and whether egg products were out-of-stock (not supplied) during our time period and in our stores.

Panel A shows that the average egg quantity sold per store and month for all shell eggs in our data was around 5,011 egg boxes and the price was \$3.72 on average. When looking at only the traditional eggs class, the average egg quantity sold per store and month was around 4,386 egg boxes and the price was \$3.66 on average. When looking at only the specialty eggs class, the average egg quantity sold per store and month was around 625 egg boxes and the price was \$4.13 on average. For the large traditional eggs subclass, the average egg quantity sold per store and month was around 3,884 egg boxes and the price was \$3.66 on average. Panel B in Table 1 shows that around 33% of our stores were located in zip codes that had an average educational attainment of at least one year of college, that the median income was \$55, 213, and that the average household size was 2.63 household members. Panel C shows that 85% of the UPCs in our stores were from the signature chain brand and that 12% of UPCs were out-of-stock.

In this grocery chain, no eggs were diverted between California and Washington or within California due to the recall. Prices and marketing changes are all centrally administered at the division level (e.g., Northern California or Southern California). The recall covered about one percent of the Northern California division eggs on the

[16] The dataset also includes a household identification variable which links egg sales to a (masked) customer loyalty card number. This variable would allow us to follow households over time. However, due to the large number of households that move in and out of our data, we do not use this variable in the analysis. Instead, we follow a panel of stores, which are a more stable unit over time.

shelves[17] and only the subclasses "large" and "extra-large" traditional shell eggs were affected.

## 4 Analytical Framework

In order to estimate the abnormal change in purchases after the recalls, we use a difference-in-differences approach.[18] We consider a "treatment" state, California, which had contaminated eggs distributed in its stores, and a "control" state, Washington, which did not have contaminated eggs distributed in its stores. We also use observations for the same months in previous years to control for seasonal changes that could be occurring at the time of the recall dates in California.

The baseline reduced form econometric model we use for estimating the effect of the recalls is:

$$y_{asnt} = \alpha_{ast} + \beta_{1,n} I_n + \beta_{2,n} I_n I_{CA} + \gamma P_{asnt} + \delta_{1,n} I_{event} + \delta_{2,n} I_{event} I_{CA} + \varepsilon_{asnt} \quad (1)$$

where $y_{asnt}$ is the log of quantity sold by aggregation level $a$ (e.g., category, class, subclass) in store $s$ in month $n$ of year $t$, $\alpha_{ast}$ is an aggregation level by store by year fixed effect, $I_n$ is an indicator variable equal to one if the purchase occurred in a post-event "month" (i.e., 4, 8 or 12 weeks after the day of the first recall, August 13), $I_{CA}$ is a dummy equal to one if the purchase occurred in California, $P_{asnt}$ is the log of the *average* price of all products in aggregation level $a$ in store $s$ in month $n$ of year $t$, $I_{event}$ is a dummy variable equal to one if the purchase occurred one, two or three "months" after August 13, 2010 and $\varepsilon_{asnt}$ is an error term. The fixed effects $\alpha_{ast}$ allow for shifts of the average purchases by stores $s$, aggregation levels $a$ and period $t$ due to, for example, trends in buying habits by products between stores and years. The coefficient $\beta_{1,n}$ picks up seasonal effects in month $n$ and the coefficient $\beta_{2,n}$ captures the *additional* effect in California. We include up to four months per year (N=3) and we are thus able to estimate the effect of the recalls up to three months after the event.[19]

[17] Personal conversation with the chain's retail category director.

[18] We do not estimate a full structural demand system. Instead, we focus on the event study and use a reduced form specification. Given that prices are set at the division level and not at the store level, prices are not endogenous to each store's unobserved determinants of demand.

[19] Bertrand et al. (2004) show that auto-correlation can give incorrect estimates of the error term and reject the null hypothesis too often if several pre-event and post-event months are included. To address potential concerns about temporal correlation across months (such as weather shocks, for example), we include two months per year (N=1) in Columns (5)- (8) in Table 14 in the appendix and find very similar results.

We also control for the log of the average price of all products in aggregation level $a$ in store $s$ in month $n$ of period $t$, $P_{asnt}$, and show in a separate regression that overall prices did not respond to the recalls.[20] The coefficient $\delta_{2,n}$ estimates the treatment effect. The treatment effect comes from abnormal changes in egg purchases in month $n$ in the event period in California, in addition to the seasonal effects, captured by $\beta_{1,n}$ and $\beta_{2,n}$, and in addition to the trend in Washington, captured by $\delta_{1,n}$. Finally, to address potential issues of contemporaneous correlation of purchases in a given month and region, we cluster the error terms $\varepsilon_{asnt}$ at the month-by-division (Northern CA, Southern CA, Seattle and Portland) level.

The identification in this analytical framework comes from comparing changes within aggregation levels and stores in the recall year, controlling for seasonality effects. In particular, we will estimate the seasonal difference in purchasing behaviors in a year (i.e., by how much are sales in the post-recall month higher than in the previous month) and compare the difference to the result obtained in other years. We include years before the recall year in order to obtain an estimate of the seasonality components $\beta_{1,n}$ and $\beta_{2,n}$. In a robustness check, we also estimate abnormal changes in egg purchases without the seasonal components.

Controlling for seasonality effects, we hypothesize that egg purchases will be lower in California after the recalls ($\delta_{2,n} < 0$). We also consider the possibility of substitution effects. It is possible that some consumers do not decrease overall egg purchases but rather substitute from certain egg classes (traditional) to other classes (value added specialty eggs) if they think these type of eggs have a lower probability of having Salmonella. We formally test this hypothesis and estimate Equation 1 for each separate subclass.

We also test whether responses to the recalls differ by socio-economic groups. We include interaction terms for education, income and household size with the abnormal change. The estimated regression used to test this possible effect is:

$$\begin{aligned} y_{asnt} &= \alpha_{ast} + \beta_{1,n} I_n + \beta_{2,n} I_n I_{CA} + \gamma P_{asnt} + \delta_{1,n} I_{event} + \delta_{2,n} I_{event} I_{CA} \\ &+ \lambda_{1,n} I_n C_s + \lambda_{2,n} I_n I_{CA} C_s + \theta_{1,n} I_{event} C_s + \theta_{2,n} I_{event} I_{CA} C_s + \varepsilon_{asnt} \end{aligned} \tag{2}$$

The first line is the same as in the main specification (Equation 1) and the second line includes the interactions of interest. In particular, $C_s$ is the demeaned socio-economic characteristic of the zip code in which store $s$ is located; $\lambda_{1,n}$ and $\lambda_{2,n}$ allow

[20] This assumes that no "trade" occurred between Washington and Northern California. We have confirmed with the chain's retail category director that there was no trade between these two areas or within California.

the seasonality components $\beta_{1,n}$ and $\beta_{2,n}$ to be different by socio-economic subgroups; and our coefficient of interest, $\theta_{2,n}$, captures whether the abnormal change in California differs by socio-economic characteristics. In this specification, we test whether the effect of the recalls differs by college attainment, income and household size.

Finally, we exploit an unusual situation in our national grocery chain, where only stores in the Northern California division had contaminated eggs and stores in the Southern California division did not. Thus, we now consider two treatment areas, Northern California, which had contaminated eggs, and Southern California, which did not have contaminated eggs, but may also have experienced decreased egg sales as well due to, for example, consumers' uncertainty about the distribution of contaminated eggs. In this specification, Washington is still our control state. The estimated regression used to test this possible effect by Californian geographical divisions is:

$$\begin{aligned} y_{asnt} = \alpha_{ast} + \beta_{1,n} I_n + \beta_{2,n} I_n I_{NorthernCA} + \beta_{3,n} I_n I_{SouthernCA} + \gamma P_{asnt} \\ + \delta_{1,n} I_{event} + \delta_{2,n} I_{event} I_{NorthernCA} + \delta_{3,n} I_{event} I_{SouthernCA} + \varepsilon_{asnt} \end{aligned} \tag{3}$$

where the additional effect for California from Equation 1 is allowed to vary by whether stores are in Northern or Southern California.

# 5 Empirical Results

In this section, we examine how consumers reacted to the three consecutive egg recalls. First, we test whether consumers changed their egg purchases in California following the recalls. Second, we study whether consumers substituted away from conventional eggs toward other types of value added specialty "greener" eggs that may be perceived as having a lower probability of Salmonella, such as organic or cage-free eggs. Third, we investigate whether different socio-economic groups reacted differently to the egg recalls. Fourth, we examine whether separate areas within California reacted differently to the egg recalls. Finally, we test whether brands that did not have contaminated eggs (non-chain brands) also experienced lower sales as a consequence of the recalls.

## 5.1 Changes in Egg Sales

We begin by exploring whether there are any differences in monthly egg sales over the four years of data by comparing the treatment stores (stores in California) and the control stores (stores in Washington).[21] Figure 4 plots the evolution of store monthly average egg sales (in egg boxes sold) by month and geographic area (Northern California, Southern California and Washington) for all shell eggs during the 2007-2010 period, using the raw data and no controls. For each year (2007, 2008, 2009 and 2010), there is one month before the event (labeled "pre month" for pre-08/13) and up to three months after the event (labeled "post month 1", "post month 2", and "post month 3" for each month after August 13, the day of the first recall). Changes are percent changes with respect to the pre-event month, which is normalized to 100 percent. The top left panel shows data for 2007, the top right panel for 2008, the bottom left panel for 2009, and the bottom right panel for 2010. Figure 4 shows that in 2007, 2008 and 2009, changes in egg boxes sold varied by around 5% above or below the pre-event month. However, in 2010, the quantity of eggs sold in Northern California after the event is around 7 to 12 percent lower than the pre-event month, and the quantity sold in Southern California after the event is around 4 to 8 percent lower than the pre-event month. The quantity sold in Washington after the event is around 0 to 2 percent lower than the pre-event month.

A potential concern is that reduced egg sales in the months after the event in 2010 were merely the consequence of broader adjustments in consumer purchasing behavior during this time period. For example, consumers may have purchased fewer eggs during that time of the year due to macroeconomic conditions or changes in trends in buying habits of individual products between years in each store. To investigate this issue, Figure 5 shows the evolution of daily sales around the day of the first recall (August 13, 2010) in Northern California (red line), Southern California (blue line) and Washington (green line). Figure 5 switches the time scale to the daily level and plots changes in log egg purchases (in quantities of egg boxes sold) for all shell eggs for stores in Northern California, Southern California and Washington. It plots data starting 30 days before the day of the first recall (August 13, 2010) up to 86 days after August 13, 2010. In particular, Figure 5 shows the results of a two-step process. In a first step, we estimate the following regression:

$$y_{asd} = \alpha_{as} + \beta_d + \gamma P_{asd} + \eta_w + \varepsilon_{asd} \tag{4}$$

[21] To further investigate whether Washington is an appropriate control for California, we present a robustness check in Table 9 in the appendix with results that exclude observations from Washington and use Southern California as the control "state" and Northern California as a treatment "state." We find similar results for the first month after the event. In Table 13 in the appendix, we also show a series of single differences estimates of abnormal changes in egg purchases and find similar results.

where $y_{asd}$ is the log of quantity sold by aggregation level $a$ (in this case, we use only the category aggregation level, all shell eggs) in store $s$ and day $d$, $\alpha_{as}$ is a store-by-aggregation fixed effect, $\beta_d$ includes day of the month fixed effects, and $P_{asd}$ is the log of the average price of all shell eggs in store $s$ on day $d$. Because we analyze daily data, $\eta_w$ includes weekday fixed effects (e.g., purchases are always higher on weekends). In a second step, we use the regression coefficients from Equation 4 to derive residuals $\varepsilon_{asd}$ for all observations. The first step removed the portion of the residuals that are due to changing prices or seasonality effects. The remaining residuals are then smoothed using a locally weighted regression. We use Epanechnikov Kernel weights with a window of 10 days, or around a week and a half, since prices are fixed for seven consecutive days, and the window is not allowed to cross the event date. Observations prior to the event date are demeaned.

Figure 5 shows that there is a clear discontinuity at the event day, when egg quantity sales drop sharply compared to pre-event levels and compared to egg quantity sales in Washington. Although egg quantity sales drop in Washington as well, the drop in Washington is the lowest. Northern California experiences the largest drop, followed by Southern California. The figure shows that the drop persisted during our time period, up to three months after the first recall.

## 5.2 Analysis of Monthly Egg Purchases

We proceed by testing whether there are any abnormal changes in egg purchases following the recalls. The observations are aggregated at the store by month by aggregation level.[22] Table 2 shows the results. The dependent variable is the log of egg purchases (in egg boxes). All regressions include aggregation level-by-store-by year fixed effects and month fixed effects to account for seasonal purchasing patterns. Column (1) shows the results when egg sales are aggregated at the category level (all shell eggs), Column (2) when they are aggregated at one class level (Traditional Shell Eggs) and Column (3) when they are aggregated at another class level (Value Added Specialty Eggs). Because local events and habits may lead to correlated error terms for a given month, we cluster error terms at the division by month level.[23] We include one month before the event

[22]This aggregation implicitly gives each store the same weight. In Columns (1) - (4) of Table 14 in the appendix, we use the raw dataset (which gives each store a weight proportional to its number of transactions) and we find very similar results.

[23]Given the use of fixed effects, we test whether the clustered standard errors have large downward biases (Stock and Watson 2008). In Table 15 in the appendix, we present results from the main

and up to three months after the event.[24] The four-week period following August 13 is labeled "Event N1", the next four-week period is labeled "Event N2", and the final four-week period is labeled "Event N3." The rows "Event * CA N1", "Event * CA N2" and "Event * CA N3" show our coefficients of interest, i.e., the additional abnormal change in California one month, two months and three months after the first recall. The price elasticity is given by "Log Price," where price is the average price of the corresponding aggregation level. Robust standard errors are reported in parentheses. Column (1) shows that egg purchases decreased by around 7.5 percent in the first month following the recalls in California, by around 9.5 percent after two months and by around 7.1 percent after three months (significant at the 5% or 1% level). The price elasticity for shell eggs is around -0.24, which shows that demand is rather inelastic in this setting. Column (2) shows that, when purchases are aggregated at the "Traditional Shell Eggs" class level, sales are around 8.1 percent lower in California than in Washington after one month. After two months, sales are around 9.6 percent lower in California than in Washington; after three months, sales are around 5.4 percent lower. The effects are significant at the 10%, 5% or 1% level. The price elasticity is around -0.12 (though not significant), which suggests that the demand for traditional shell eggs is also rather inelastic and lower than for all shell eggs. Column (3) aggregates purchases at the "Value Added Specialty Eggs" class level and suggests a sales decrease of around 3 to 8 percent, but the results are not significant. The number of observations for this class is lower than for the traditional eggs class and the overall shell eggs category because not all stores sell value added specialty eggs.

## 5.3 Heterogeneous Effects

### 5.3.1 Heterogeneous effects by subclass

Although egg sales decreased on average, consumers may have substituted away from traditional shell eggs toward other types of greener eggs. Even though greener eggs, such as organic or cage-free eggs, have a higher price than traditional shell eggs, consumers may have made this substitution toward these types of eggs if, for example, they thought that they had a lower probability of having Salmonella. We proceed by formally testing

regressions (all the regressions from Table 2 and the regression for the large traditional eggs subclass from Table 3) with and without clustering. Standard errors increase when clustering is applied.

[24] In a robustness check that addresses potential concerns about temporal correlations across months, we include only one month after the recalls and find very similar results; see Table 14 in the appendix (Columns (5) - (8)).

whether there are any substitution effects toward these types of eggs. Table 3 shows the results of regressions that test the effect of the recalls in California for each egg subclass. Columns (1) - (3) test the effect on "Traditional" eggs (large, extra large and jumbo) and Columns (4) - (7) test the effect on "Value Added Specialty Eggs" (brown, organic, cage-free and nutrient-enhanced). Column (1) shows that purchases of large traditional shell eggs decreased by around 9 to 12 percent in California in each of the three months following the first recall (significant at the 5% and 1% level). This is the only significant decrease at the subclass level for all months after the recalls. This result shows that the effect was largely driven by the decrease in purchases of large traditional shell eggs. Large traditional eggs represented 75% of sales in our sample in 2009. Table 3 shows lower sales for brown, cage-free and nutrient-enhanced eggs for some months but the results are not significant at the 5% level. Sales for extra large traditional shell eggs, jumbo eggs and organic eggs seem higher for some months but the results are not significant at the 5% level. Organic and nutrient-enhanced eggs show the most elastic demands. All subclasses do not show the same number of observations because not all subclasses are sold in all stores. The cage-free and nutrient-enhanced subclasses have large sales variations during our time period.

Given this decrease in egg purchases, prices could have responded in either of two ways. Price can decrease if sellers hope to increase demand by lowering egg prices. On the other hand, price can increase if the egg recalls caused a shortage of eggs.[25] To test whether the recalls had an effect on prices at our national grocery chain, Columns (1) - (4) in Table 4 formally test the effect of the recalls on price. Given the results from Tables 2 and 3, we focus the analysis on the overall category level, on both classes and on the subclass "Large Traditional Shell Eggs." Columns (1) - (4) in Table 4 do not a show a significant effect of the recalls on price during the first two months after the recalls. Three months after the recalls, Columns (1), (2) and (4) show a 10 to 12 percent decrease in price for the overall shell eggs category, the traditional shell eggs class and the subclass "Large Traditional Shell Eggs." Column (3) shows a price decrease of around 3 percent for the specialty eggs class. Results are significant at the 10% level. In Columns (5) - (8), we repeat the analysis on quantities from Tables 2 and 3 but do not control for price. Consistent with a rather inelastic demand, the estimated coefficients for all regressions are very similar and statistically indistinguishable from

[25]In a robustness check presented in Table 10 in the appendix, we show that the recalls did not increase the probability that egg products were out-of-stock in our chain during the first two months after the recalls.

the results when we include price in Tables 2 and 3.

### 5.3.2 Heterogeneous effects by demographics

Previous studies such as Schlenker and Villas-Boas (2009) and Shimshack, Ward and Beatty (2007) have found heterogeneous responses by socio-economic groups. In this section, we test whether egg purchases following the egg recalls decreased in a differentiated way based on education, income and household size. To do this, we match each grocery store with the socio-economic characteristics of the zip code in which it is located. We capture education in this setting through tertiary educational attainment, and we include an indicator for whether the average attainment level of the zip code in which the store is located is equal to at least one year of college. Income is captured by the demeaned median income in the zip code in which the store is located (in $10,000 increments) and household size is included by using the demeaned average household size in the zip code in which the store is located. Socio-economic data come from the 2000 U.S. Census.

Table 5 shows the results for the overall shell eggs category, the traditional shell eggs class, the value added specialty class and the large traditional shell eggs subclass. Columns (1), (2) and (4) show that stores in California that are located in zip codes with an average attainment of at least one year of college have egg sales that are 3 to 5 percent higher than stores in California that are located in zip codes with a lower average attainment. The effect is present in the first and second month after the recalls and is significant at the 5% and 1% level. A possible interpretation for these results is that consumers in zip codes with an average attainment of at least one year of college were more informed about the fact that contaminated eggs could be traced to the box level and that they were removed from stores. Three months after the recalls, the effect seems to be no longer present. Column (3) shows that one month after the recalls, stores in California that are located in zip codes with an average attainment of at least one year of college have specialty egg sales that are around 5 percent lower than stores in California that are located in zip codes with a lower average attainment. This effect is present only in the first month after the first recall and is significant at the 10% level.

Columns (2) and (4) show that, one month after the event, an increase in $10,000 of the median income in the zip code in which stores are located decreases traditional egg sales by around 1 percent (significant at the 10% and 5% level). The effect does not seem to be present two and three months after the recalls. Column (3) shows that an increase in \$10,000 of the median income increases specialty eggs sales by around 2 percent one month after the recalls, around 4 percent two months after the recalls, and around 3 percent three months after the recalls (significant at the 10%, 5% and 1% levels). This suggest that consumers in these zip codes may have partially substituted specialty eggs for traditional eggs.

In the first and second month after the event, stores in California that are located in zip codes with a higher average household size do not seem to have different sales of traditional shell eggs than stores in zip codes with a lower average household size. Three months after the event, stores in California that are located in zip codes with a higher average household size have lower sales (around 3 percent for an additional household member) of overall shell eggs than stores in zip codes with a lower average household size. The result is significant at the 10% level. A possible interpretation for this result is that stores located in zip codes with larger households have children and may be more sensitive to food safety risks. Column (3) shows that, two and three months after the recalls, stores in California that are located in zip codes with a higher average household size had specialty egg sales that were on average around 12 percent lower than stores in zip codes with a lower average household size. The results are significant at the 5% and 1% level.

#### 5.3.3 Heterogeneous effects by geographical divisions

In our previous sections, we considered California as our "treatment" state and Washington as our "control" state. In this section, we exploit the fact that, while other chains in Southern California had contaminated eggs, only stores in the Northern California division of our national grocery chain had contaminated eggs, while stores in the Southern California division of our chain did not. We now consider two "treatment" areas, Northern California and Southern California. We hypothesize that it is possible that stores in Southern California had drops in egg purchases although they did not have contaminated eggs themselves. We formally test this hypothesis in Table 6. Column (1) shows that when egg purchases are aggregated at the category level, they significantly decreased in both divisions one month after the recalls, by around 14 percent in the Northern California division and around 6 percent in Southern California. In other words, one month after the recalls, sales in Southern California were also lower, with a decrease around half as large as the decrease in Northern California. During the second and third months after the recalls, when egg sales remained lower than normal in Northern California (9 to 10 percent lower), sales in Southern California also continued to show effects, with sales 7 to 8 percent lower. When egg purchases are aggregated at the traditional shell eggs class level, egg purchases decreased by around 12 percent in Northern California one month after the recalls, as Column (2) shows. Results for Southern California suggest that sales one month after the recalls decreased by around 4 percent but the results are not significant. Two months after the recalls, sales in Southern California significantly dropped by around 8 percent. The effect in Southern California is no longer significant three months after the recalls. However, they are still significant in Northern California three months after the recalls. When egg purchases are aggregated at the specialty class level, as Column (3) shows, egg purchases were around 6 percent lower than normal in the Northern California division two months after the event (significant at the 1% level). Results in other months and in the Southern California division suggest that there were decreases in purchases of specialty eggs in all months and in both divisions but the results are not significant. Finally, Column (4) shows that, when egg sales are aggregated at the large traditional shell eggs subclass level, egg purchases decreased by around 10 to 14 percent during the three months after the recalls in Northern California. Sales in Southern California stores decreased by 5 to 11 percent. Results are significant at the 1% level for Northern California and significant at the 1% or 10% level for Southern California.

Table 6 shows that sales reductions of shell eggs in Southern California were around half as large as those in Northern California one month after the event and that this difference decreased in the following months, showing similar drops in both Northern and Southern California. Table 12 in the appendix tests the effect in Southern California by dropping observations from Northern California and by using Washington as the control state, and finds similar results. We interpret our spillover effects as being consistent with geographical spillovers (from Northern California to Southern California within our chain) and with between-chain spillovers (within Southern California). Updating of beliefs or unclear consumer understanding about the distribution of contaminated eggs could have led to the drop in Southern California stores.

### 5.3.4 Heterogeneous effects by brands

Given the spillover effects shown in Table 6, we proceed by testing whether there were spillover effects by brands. At our national grocery chain, only the signature chain brand had contaminated eggs. We divide egg brands into two categories: "chain brand"

and “non-chain/other” brands. The signature chain brand represents around 85% of egg sales in our data. To test whether non-chain brands (“other brands”) were also affected by the egg recalls, we estimate Equation 1 separately for the signature chain brand and for the other/non-chain brands. Standard errors are clustered at the division by month level. Table 7 shows the results. Columns (1), (3), (5) and (7) show results for the signature chain brand (which had contaminated eggs) and Columns (2), (4), (6) and (8) show results for the non-chain brands (which did not have contaminated eggs). All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Columns (1) - (4) show that when results are aggregated at the category level and at the traditional shell eggs class level, drops in egg sales of the chain brand are very similar to decreases for other brands, showing spillover effects from affected to non-affected brands. Sales of eggs from the chain brand were 6 to 10 percent lower during the three months following the recalls, and sales from other brands were 4 to 10 percent lower during the three months following the recalls. All results are significant at the 10%, 5% or 1% level. While specialty egg sales of the chain brand were affected, they were not significantly affected for other brands, as Columns (5) and (6) suggest. Columns (7) and (8) show that, while sales of large traditional shell eggs from the chain brand significantly decreased by 9 to 12 percent following the recalls, sales of large traditional shell eggs from other brands did not seem to be negatively affected. The results suggest a small drop in sales of large traditional shell eggs from other brands one month after the recalls and then a small increase two and three months after the recalls but the results are not significant. However, in our four-year sample, 94% of the sales of large traditional shell eggs came from the chain brand. Overall, Table 7 shows evidence of spillover effects across brands, where brands that did not have contaminated eggs were affected by recalls linked to the contaminated brand.

# 6 Robustness Checks

In this section, we perform a series of robustness checks. First, we test the sensitivity of the baseline results to various assumptions about the seasonality parameters. Second, we test the sensitivity of the baseline results to the choice of the control state, Washington, by using Southern California as a control “state.” Third, using out-of-stock data for the products in our dataset, we test whether the recalls increased the probability that egg products were out-of-stock, thus causing a decrease in egg sales due to eggs not being available (instead of due to consumer responses to the recalls). Finally, we test the validity of our results by conducting placebo tests where we simulate the event taking place in another year in our data.

Table 8 in the appendix tests the sensitivity of the baseline results to various assumptions about the seasonality parameters. If there is a sales spike or drop in one of the pre-recall periods (2007, 2008 or 2009) due to another cause, our seasonality components may be biased. Columns (1) - (4) in Table 8 use the main specification (Equation 1) but estimate the effect of the egg recalls using only the years 2009 and 2010, and dropping the years 2007 and 2008 (half of the dataset). By using only one pre-treatment year, we do not control for the pre-recall trend. We find that the results for the overall eggs category, the traditional shell eggs class and the large traditional shell eggs subclass found in Tables 2 and 3 are still present two and three months after the recalls in Table 8 (all results show drops in egg sales) but the magnitudes are smaller. In particular, eggs sales drop by around 5 percent in the second and third month after the recalls when they are aggregated at the category level; they drop by around 5 percent in the second month after the recalls when they are aggregated at the traditional shell eggs class and by around 7 percent when they are aggregated at the large traditional shell eggs subclass level. The results for value added specialty eggs show a significant 9 percent drop in egg sales two months after the recalls. By comparison, the main specification shows a drop of around 6 percent but it is not significant. Columns (5) - (7) replicate the results from Table 2 at the category level only (all shell eggs) but exclude one of the control periods. Column (5) drops the year 2007, Column (6) drops 2008 and Column (7) drops 2009. Table 8 shows that excluding 2007 gives very similar results to the ones from the main specification; excluding 2008 gives similar but somewhat smaller results (sales drop by 5 to 7 percent compared to 7 to 9 percent in the main specification); and excluding 2009 gives similar but somewhat larger results (sales drop by 8 to 11 percent). Overall, the results show drops in egg sales after the recalls which are robust to assumptions about the seasonality components.

Our results have so far been based on the assumption that Washington is a suitable control for California and that they followed similar trends up to the event. We now test the sensitivity of the baseline results to this assumption. Table 9 in the appendix excludes data from Washington and uses stores in Southern California as controls. The rationale is that we may assume that stores in Southern California have trends similar to stores in Northern California. We find that, for all aggregations (category, class and the large traditional shell eggs subclass) and for one month after the event, the results are similar to those in the main specification. For non-specialty eggs, we find a significant 7 percent to 8 percent drop in egg purchases, depending on the aggregation level. The results are all significant at the 1% level. Results are no longer significant two and three months after the event. Column (3) shows that the recalls seem to have a positive effect on sales of value added specialty eggs but the results are not significant. Overall, Table 9 shows similar results to the ones from the main specification for one month after the recall. For the following two months, the effects seems to disappear. This is consistent with the results from Table 6, which show larger drops in sales in Southern California two and three months after the event.

A possible explanation for why egg sales dropped after the recalls is that the recalls caused a shortage of safe eggs and thus sales dropped because safe eggs were not available. To test this hypothesis, we obtain out-of-stock data which shows whether egg products were out-of-stock (not supplied) during the years 2008, 2009 and 2010 (data for the year 2007 were not available) in our stores. Data are aggregated at the UPC by month by store level. We estimate Equation 1 but change the dependent variable to an indicator variable for whether an egg product was out-of-stock. Table 10 in the appendix shows the results. Column (1) aggregates products at the category level (all shell eggs), Column (2) aggregates products at the class level "Traditional Shell Eggs", Column (3) aggregates products at the class level "Value Added Specialty Eggs", and Column (4) aggregates products at the large subclass level. Column (5) aggregates products at the chain brand level and Column (6) aggregates products at the "other brands" (non-chain brand) level. For the first two months after the recalls, all regressions in Table 10 show that the event not only did not increase the probability that egg products were out-of-stock, but actually decreased this probability. Columns (1), (2) and (4) show that the event significantly decreased the probability that eggs were out-of-stock from 2 to 7 percent during the first two months after the event. During the third month after event, the probability of being out-of-stock becomes positive and significant for the traditional eggs class, which shows an increase of around 5 percent. Column (3) shows that specialty eggs seem to have experienced a small decrease in the probability of being out-of-stock in the first two months after the recalls. Three months after the recalls, specialty eggs had an 8 percent significant decrease in the probability of being out-of-stock. Column (5) shows that the decrease in the probability of being out-of-stock was driven by the signature chain brand, which experienced a significant decrease of around 3 percent during the first two months after the recalls. During the third month after the recalls, the event seems to increase the out-of-stock probability but the results are not significant. Finally, Column (6) suggests that other (non-chain) brands also experienced a decrease in the probability of being out-of-stock after the recalls, but the results are not significant.

Finally, as a check of the validity of our results, we conduct a series of placebo tests, where we simulate the event period in another year in the data. Because the event occurred in 2010, we should not observe a significant negative change by using an incorrect year. Table 11 in the appendix uses the specification from Equation 1 and codes the event in the year 2007 (Column 1), 2008 (Column 2) or 2009 (Column 3) in order to test whether a placebo effect can be detected in another year. Egg sales are aggregated at the category level. Table 11 shows no significant effect of the event in 2007, a positive and significant effect in 2008 (around 6 to 10 percent), and no significant effect in 2009. Thus, this procedure does not find a significant negative effect in another year.

Overall, the robustness checks find results similar to the main specification and show that, in our national grocery chain, consumers responded to the egg recalls by decreasing egg purchases from 5 to 11 percent, depending on the specification and the number of months after the recalls.

# 7 Conclusion

Using data from a large scanner dataset that has detailed purchasing records from over 650 stores from a national grocery chain, this paper studies how consumer purchases reacted after two Iowa farms found Salmonella in their eggs and started the largest egg recall in U.S. history. Contaminated eggs were recalled through codes clearly labeled on egg boxes so that, after the recall, there were no contaminated eggs in stores. By comparing purchases in a "treated" state, California, and a "control" state, Washington, we test whether consumers reduced egg purchases. We find a statistically significant and robust decrease of around 7 to 9 percent in egg purchases following the recalls. The effect lasted at least three months. Given an overall price elasticity for eggs in U.S. households of around -0.1,[26] the largest overall sales reduction is comparable to an almost 100% increase in prices. These results show that, even when consumers

[26]This elasticity is reported in Krugman and Wells (2009). This is one elasticity from the literature and is not from our sample.

can precisely identify safe eggs at the box level, recalls can have meaningful effects. The analysis shows that, on average, consumers reacted by decreasing their overall egg purchases, rather than substituting to other types of eggs that may be perceived as having a lower probability of Salmonella.

We also find evidence of heterogeneous effects. Stores located in zip codes with an average educational attainment of at least one year of college had sales that were around 3 percent higher during the first two months after the recalls, relative to stores with an average educational attainment of less than one year of college. Stores located in zip codes with higher income had higher sales of specialty eggs, 2 to 4 percent higher for a $10,000 increase in the median income in the zip code. We also exploit the fact that, due to its distribution chain, only stores in the national grocery chain's Northern California division had contaminated eggs, while stores in the Southern California division did not. We find that stores in Southern California experienced decreased overall egg purchases as well. The drop in Southern California is half the magnitude of the drop in Northern California in the first month after the recalls. During the second and third months after the recalls, the drop in Southern California increases and becomes comparable to the drop in Northern California stores. In addition, we also find evidence of brand spillover effects. The drop in sales of non-affected brands is comparable to the drop in sales of the signature chain brand, which had contaminated eggs.

Consistent with previous literature on the effects of recalls, food scares and government warnings, our results show that consumers do respond to recalls, at least temporarily. On average, not only did consumers reduce their egg purchases, they also did not switch to unaffected alternatives. As a result, overall egg purchases dropped. In a setting where demand is rather inelastic and traceability is already high, these findings have policy implications for consumers, producers, and policymakers. Drops in sales directly affect the incentives that retailers face to assure safety through the supply chain. Further, given the evidence of spillovers and, assuming all non-recalled eggs were safe, the results show that producers of safe eggs were meaningfully affected. Thus, producers responsible for the outbreak did not bear all of the costs. When considering up-front investments in safety measures, it is possible that producers responsible for outbreaks do not completely internalize costs and thus under-invest in food safety, in a way that decreases the availability of safe products for consumers. This highlights the need for targeted information campaigns tailored to the outbreak and the most affected sub-groups, as well as the need for enforcement of existing safety regulations to prevent negative effects on consumers and producers alike.

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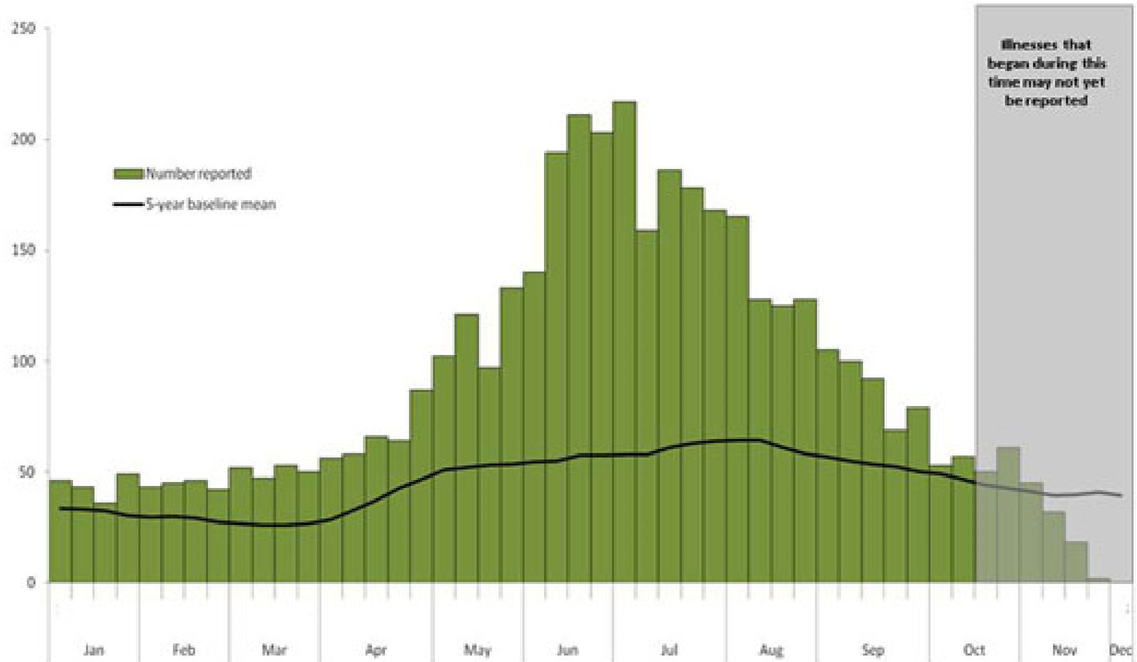
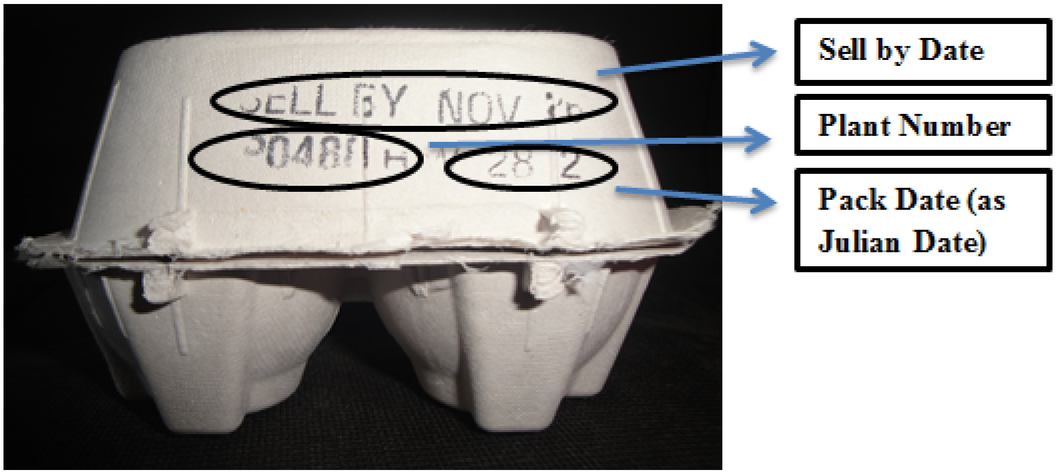
Figure 1: Epidemic Curve: Enteritidis Infections Matching PFGE Patterns



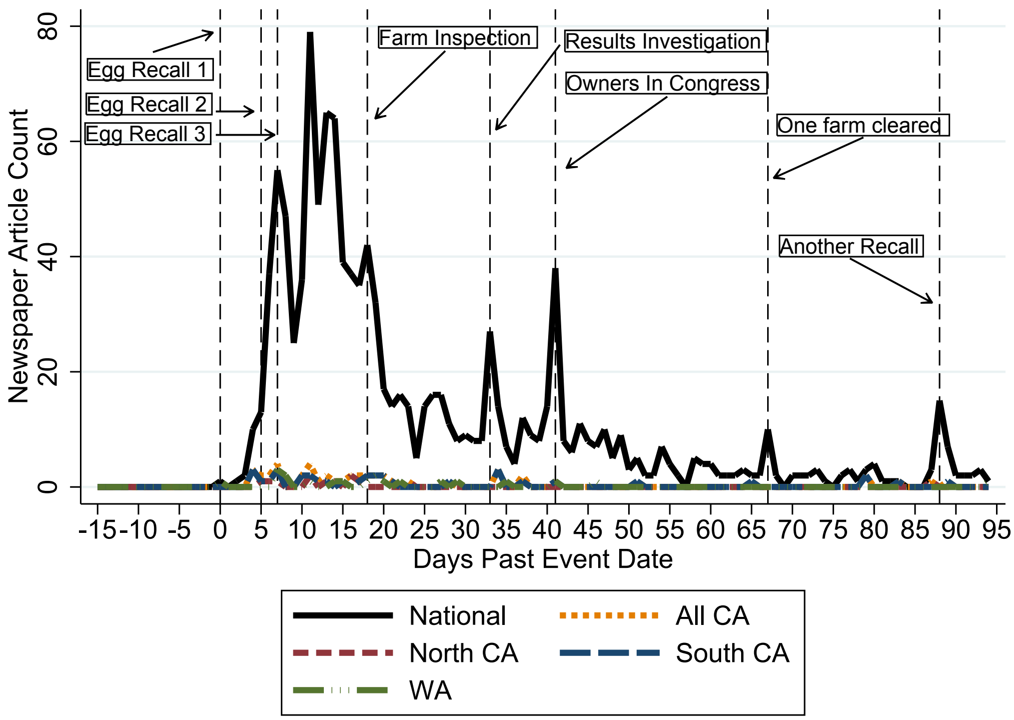

Source: CDC (last modified December 2010). Notes (from CDC): Figure shows the number of Salmonella Enteritidis cases matching PFGE (Pulsed-Field Gel Electrophoresis) patterns. PFGE patterns are used to identify bacteria. From May 1 to November 30, 2010, a total of 3,578 illnesses were reported. However, some cases from this period may not have been reported at that time, and some of these cases may not be related to the 2010 Salmonella egg outbreak. Based on the previous 5 years of reports, we would expect approximately 1,639 total illnesses to occur during this same period. This means there are approximately 1,939 reported illnesses that are likely to be associated with this outbreak.

Figure 2: Identifying Contaminated Eggs



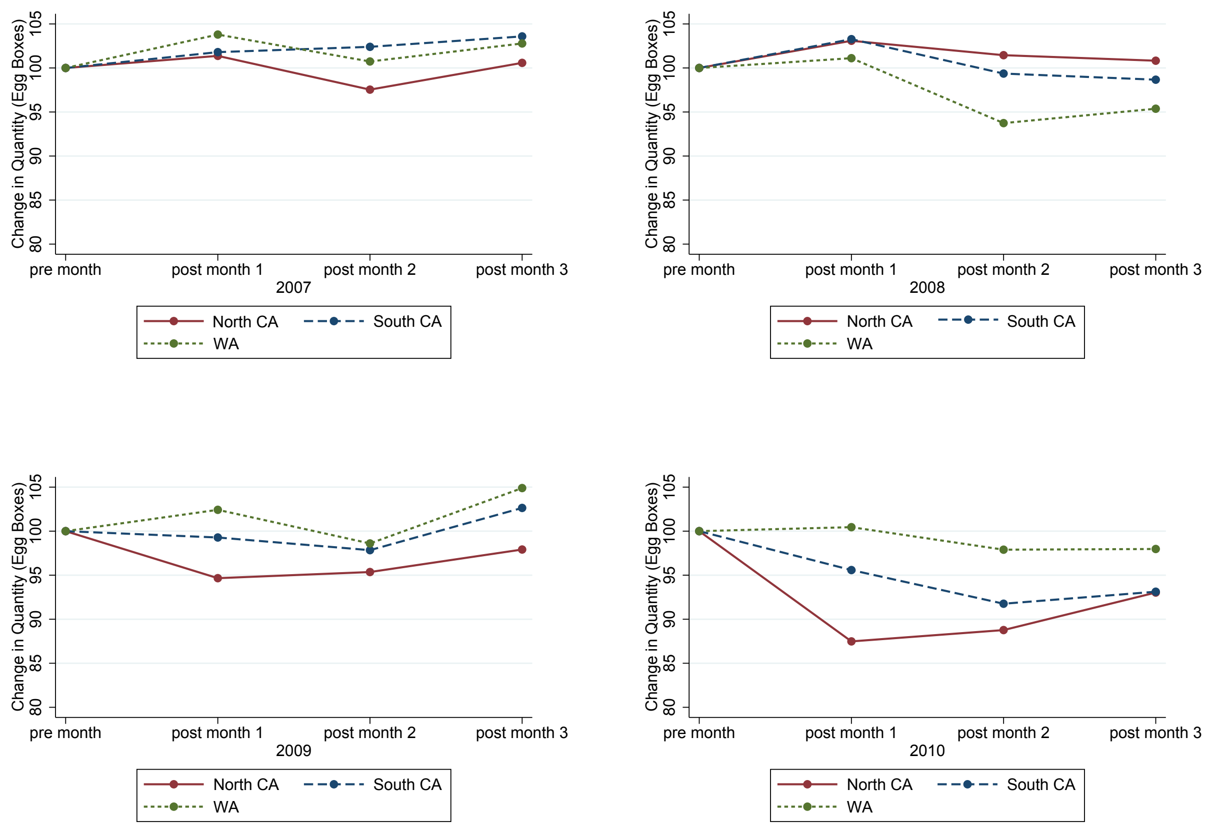

Notes: Egg cartons with the USDA grade shield on them have a "plant number" and a "pack date." The plant number is a number always preceded by the letter "P" that must be stamped or pre-printed on each carton. The pack date refers to the day that the eggs were washed, graded, and placed in the carton and is a three-digit code that represents the consecutive day of the year (the "Julian Date") starting with January 1 as 001 and ending with December 31 as 365. Plants that are not under USDA inspection are governed by the state laws where the eggs are packed and/or sold. Most states require a pack date (USDA).

Figure 3: Newspaper Coverage of the 2010 Salmonella Egg Outbreak



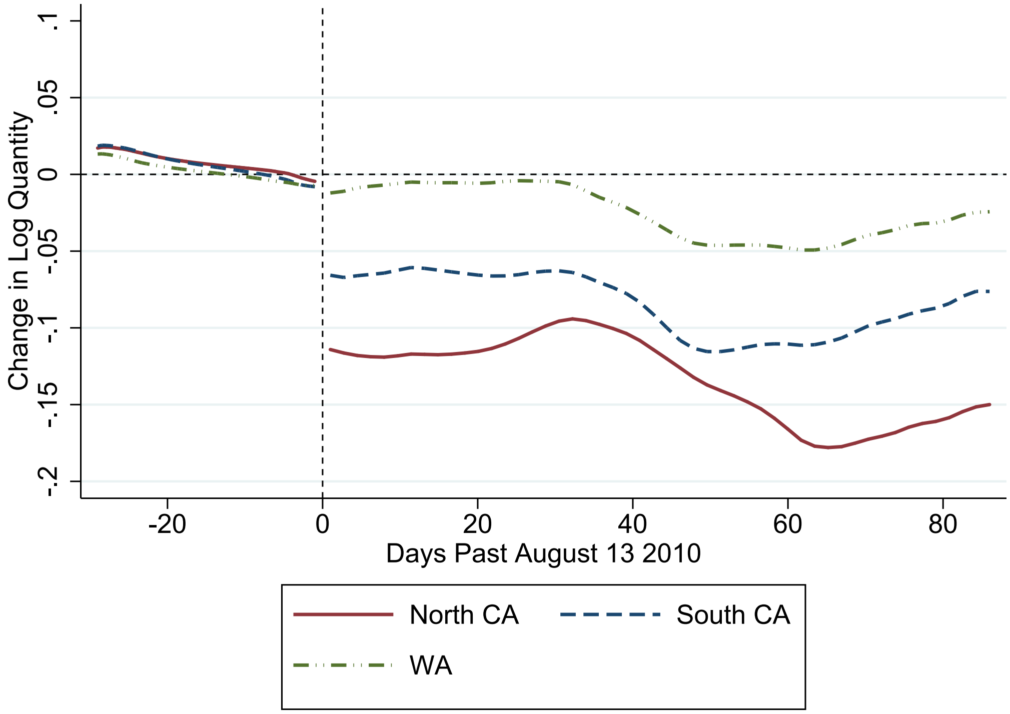

Notes: Figure displays the result of a Lexis-Nexis search that counts the number of articles in major newspapers that include the words "Salmonella" and "Eggs" on a given day for California (orange line), North California only (red line), South California only (blue line), Washington (green line), and all of the United States (black line). Day 0 corresponds to August 13, 2010 (the day of the first recall). Dashed vertical lines indicate major events linked to the outbreak, in particular the three egg recalls, the FDA farm inspection, the results of investigations, the day when the owners of both Iowa farms appeared before Congress, the day Hillandale farms was allowed to sell eggs again and the day of another egg recall by a new farm.

Figure 4: Evolution of Average Store Monthly Sales by Geographic Area and Year




Notes: Figure shows the evolution of store monthly average egg sales (in egg boxes sold) by month and geographic area (Northern California, Southern California and Washington) for all shell eggs during the 2007-2010 period, using the raw data and no controls. For each year (2007, 2008, 2009 and 2010), there is one month before the event (labeled "pre month" for pre-08/13) and up to three months after the event (labeled "post month 1", "post month 2", and "post month 3" for each month after August 13, the day of the first recall). Changes are percent changes with respect to the pre-event month and the pre-event month is normalized to 100 percent. The top left panel shows data for 2007, the top right panel for 2008, the bottom left panel for 2009, and the bottom right panel for 2010.

Figure 5: Daily Changes in Egg Purchases Following the Egg Recalls (All Shell Eggs)




Notes: Figure plots changes in log egg sales (in quantities of egg boxes sold) for all shell eggs for stores in Northern California (red line), Southern California (blue line), and Washington (green line). Day 0 is August 13, 2010, when the first egg recall took place. Changes in egg purchases control for day of the month fixed effects, price, store-by-category fixed effects and weekday fixed effects (e.g., sales are always higher on weekends). Residuals are smoothed using a locally weighted regression which uses Epanechnikov Kernel weights with a window of 10 days. Observations prior to the event date are demeaned.

Table 1: Descriptive Statistics

| | | | | | |
|---|---|---|---|---|---|
| PANEL A: SCANNER DATA | | | | | |
| Raw dataset (N=43,575,891 ) | | | | | |
| | Obs | Mean | Std. Dev. | Min | Max |
| Year | 10,416 | 2008.5 | 1.11 | 2007 | 2010 |
| Month | 10,416 | 8.5 | 4.60 | 1 | 16 |
| Store ID | 10,416 | 1,764.08 | 820.72 | 91 | 4,601 |
| Aggregation at the Category Level | | | | | |
| Quantity | 10,416 | 5,011.09 | 2,072.21 | 1,083 | 15,138 |
| Price | 10,416 | 3.72 | 0.74 | 2.15 | 5.67 |
| Aggregation at the Class Level | | | | | |
| Quantity-Traditional | 10,416 | 4,385.97 | 1,782.78 | 952 | 12,181 |
| Price-Traditional | 10,416 | 3.66 | 0.84 | 2.07 | 5.75 |
| Quantity-Specialty | 10,412 | 625.35 | 468.83 | 19 | 3,855 |
| Price-Specialty | 10,412 | 4.13 | 0.40 | 2.22 | 5.55 |
| Aggregation at the Subclass Level | | | | | |
| Quantity-Large | 10,416 | 3,883.56 | 1,656.1 | 727 | 11,339 |
| Price-Large | 10,416 | 3.66 | 0.89 | 2.03 | 5.81 |
| PANEL B: SOCIO-ECONOMIC DATA | | | | | |
| | Obs | Mean | Std. Dev. | Min | Max |
| College | 10,416 | 0.33 | 0.47 | 0 | 1 |
| Median Income | 10,416 | 5.52 | 1.92 | 2.00 | 14.54 |
| Household Size | 10,416 | 2.63 | 0.42 | 1.41 | 5.03 |
| PANEL C: BRAND AND OUT-OF-STOCK DATA | | | | | |
| | Obs | Mean | Std. Dev. | Min | Max |
| Chain Brand | 43,575,891 | 0.85 | 0.35 | 0 | 1 |
| Out-of-stock | 106,372 | 0.12 | 0.32 | 0 | 1 |

Notes: Quantities are in egg boxes and prices are in USD. Panel A displays descriptive statistics for the scanner dataset. Quantity and price data are presented for the category aggregation level, the traditional eggs class, the value added specialty eggs class, and the large traditional eggs subclass. Panel B displays socio-economic characteristics: "College" is an indicator variable that is equal to one if the average attainment level of the zip code in which the store is located is equal to at least one year of college, "Median Income" is the median income of the zip code in which the store is located (in $10,000 increments) and "Household Size" is the average household size of the zip code in which the store is located. Panel C displays signature chain brand and out-of-stock data. "Chain Brand" is an indicator variable that is equal to one if the brand of an egg product is the signature chain brand. "Out-of-stock" is an indicator variable that is equal to one if an egg product was out-of-stock (not supplied). Out-of-stock data are aggregated at the UPC by month by store level. Socio-economic data are from the 2000 U.S. Census. Time, store and demographic variables show the number of observations when data are aggregated at the store by month by category level.

Table 2: Abnormal Monthly Changes for Egg Purchases Following the Egg Recalls

| | (1) | (2) | (3) |
|---|---|---|---|
| | Log Q | Log Q | Log Q |
| Event N1 | -0.00158 | -0.0163 | 0.0307 |
| | (0.0140) | (0.0160) | (0.0229) |
| Event N2 | 0.0168 | 0.00455 | 0.0359* |
| | (0.0151) | (0.0161) | (0.0190) |
| Event N3 | -0.0321** | -0.0307* | -0.0583*** |
| | (0.0148) | (0.0169) | (0.0212) |
| Log Price | -0.242*** | -0.119 | -0.903** |
| | (0.0737) | (0.0934) | (0.358) |
| Event * CA N1 | -0.0757** | -0.0812** | -0.0282 |
| | (0.0308) | (0.0351) | (0.0655) |
| Event * CA N2 | -0.0949*** | -0.0969*** | -0.0655 |
| | (0.0246) | (0.0294) | (0.0536) |
| Event * CA N3 | -0.0714*** | -0.0541* | -0.0799 |
| | (0.0251) | (0.0311) | (0.100) |
| Constant | 8.750*** | 8.467*** | 7.406*** |
| | (0.0951) | (0.119) | (0.502) |
| Aggregation | Category | Class | Class |
| Agg. Type | Shell Eggs | Traditional | Specialty |
| Observations | 10,416 | 10,416 | 10,412 |
| R-squared | 0.983 | 0.981 | 0.974 |

Notes: Table tests for abnormal monthly changes in egg purchases following the egg recalls. Column (1) aggregates sales at the category level (all shell eggs). Column (2) aggregates sales at the class level "Traditional Shell Eggs" and Column (3) aggregates sales at the class level "Value Added Specialty Eggs." The number of observations for Column (3) is lower than for the traditional eggs class and overall shell eggs category because not all stores sell value added specialty eggs. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 3: Abnormal Monthly Changes for Egg Purchases Following the Egg Recalls by Subclass

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | Log Q | Log Q | Log Q | Log Q | Log Q | Log Q | Log Q |
| Event N1 | -0.0111 | 0.143*** | -0.0757** | -0.0686 | -0.000844 | -0.00999 | 0.224*** |
| | (0.0176) | (0.0215) | (0.0332) | (0.0620) | (0.0525) | (0.0651) | (0.0681) |
| Event N2 | 0.00896 | 0.265*** | -0.118*** | 0.0130 | -0.0470 | 0.0358 | 0.332*** |
| | (0.0181) | (0.0269) | (0.0216) | (0.0512) | (0.0527) | (0.0474) | (0.0560) |
| Event N3 | -0.0244 | 0.223*** | -0.271*** | -0.179** | -0.0793 | -0.157* | 0.349*** |
| | (0.0190) | (0.0218) | (0.0323) | (0.0848) | (0.0586) | (0.0818) | (0.0684) |
| Log Price | -0.206** | -1.131*** | 0.340 | -0.0274 | -1.660*** | -0.544 | -5.772*** |
| | (0.0881) | (0.204) | (0.269) | (0.389) | (0.590) | (0.401) | (1.055) |
| Event * CA N1 | -0.0932** | 0.0265 | 0.00558 | -0.00112 | 0.0247 | -0.137 | -0.0247 |
| | (0.0372) | (0.0588) | (0.0857) | (0.154) | (0.134) | (0.113) | (0.208) |
| Event * CA N2 | -0.119*** | 0.0271 | 0.0576 | -0.00479 | 0.0476 | -0.237* | -0.520* |
| | (0.0279) | (0.0483) | (0.107) | (0.146) | (0.119) | (0.126) | (0.294) |
| Event * CA N3 | -0.112*** | 0.0545 | 0.333* | 0.137 | -0.0825 | 0.0310 | -0.181 |
| | (0.0301) | (0.0718) | (0.176) | (0.163) | (0.198) | (0.129) | (0.226) |
| Constant | 8.452*** | 6.945*** | 4.562*** | 4.871*** | 7.842*** | 5.241*** | 11.12*** |
| | (0.112) | (0.276) | (0.344) | (0.472) | (0.877) | (0.547) | (1.365) |
| Aggregation | Subclass | Subclass | Subclass | Subclass | Subclass | Subclass | Subclass |
| Class | Traditional | Traditional | Traditional | Specialty | Specialty | Specialty | Specialty |
| Subclass | Large | Extra Large | Jumbo | Brown | Organic | Cage Free | Nutrient |
| Market Share | 75% | 7% | 4% | 3% | 7% | 3% | 1% |
| Observations | 10,416 | 10,345 | 10,138 | 8,314 | 10,358 | 9,942 | 8,494 |
| R-squared | 0.981 | 0.961 | 0.893 | 0.904 | 0.942 | 0.902 | 0.847 |

Notes: Table tests for abnormal monthly changes of egg purchases by subclass. Log Price is the log of the average price of the corresponding subclass level. The number of observations are different in all regressions because not all stores sell all subclass types. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. "Nutrient" in Column (7) refers to the nutrient-enhanced subclass. Market share is the average market share of sales of the subclass in the sample in the year 2009. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 4: Price Response and Abnormal Monthly Changes Without Price

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Log P | Log P | Log P | Log P | Log Q | Log Q | Log Q | Log Q |
| Event N1 | 0.0834*** | 0.0925*** | 0.0151 | 0.0947** | -0.0217 | -0.0273* | 0.0171 | -0.0307 |
| | (0.0313) | (0.0347) | (0.0114) | (0.0364) | (0.0152) | (0.0155) | (0.0252) | (0.0186) |
| Event N2 | 0.0674*** | 0.0777*** | -0.00695 | 0.0839*** | 0.000574 | -0.00468 | 0.0422* | -0.00835 |
| | (0.00659) | (0.00687) | (0.0118) | (0.00680) | (0.0147) | (0.0147) | (0.0221) | (0.0168) |
| Event N3 | 0.00816 | 0.0127 | -0.00945 | 0.0151 | -0.0341* | -0.0322 | -0.0498* | -0.0276 |
| | (0.0340) | (0.0376) | (0.0155) | (0.0397) | (0.0202) | (0.0199) | (0.0293) | -0.0244 |
| Event * CA N1 | -0.0129 | -0.0114 | -0.00952 | -0.00810 | -0.0726** | -0.0798** | -0.0196 | -0.0915** |
| | (0.0402) | (0.0463) | (0.0168) | (0.0482) | (0.0325) | (0.0358) | (0.0723) | (0.0391) |
| Event * CA N2 | -0.0106 | -0.00956 | 0.00385 | -0.00699 | -0.0923*** | -0.0957*** | -0.0690 | -0.118*** |
| | (0.0229) | (0.0279) | (0.0145) | (0.0318) | (0.0225) | (0.0279) | (0.0571) | (0.0253) |
| Event * CA N3 | -0.108* | -0.119* | -0.0368* | -0.124* | -0.0452 | -0.0399 | -0.0467 | -0.0861** |
| | (0.0555) | (0.0664) | (0.0219) | (0.0722) | (0.0289) | (0.0327) | (0.120) | (0.0363) |
| Constant | 1.266*** | 1.240*** | 1.409*** | 1.236*** | 8.444*** | 8.319*** | 6.133*** | 8.197*** |
| | (0.00627) | (0.00730) | (0.00377) | (0.00793) | (0.00577) | (0.00785) | (0.0227) | (0.00737) |
| Aggregation | Category | Class | Class | Subclass | Category | Class | Class | Subclass |
| Agg. Type | Shell Eggs | Traditional | Specialty | Large | Shell Eggs | Traditional | Specialty | Large |
| Observations | 10,416 | 10,416 | 10,412 | 10,416 | 10,416 | 10,416 | 10,412 | 10,416 |
| R-squared | 0.982 | 0.982 | 0.949 | 0.982 | 0.983 | 0.981 | 0.973 | 0.981 |

Notes: Columns (1) - (4) test whether stores adjusted prices in response to the egg recalls and have the log of price as the dependent variable. Columns (5) - (8) report the abnormal monthly changes for egg purchases following the egg recalls without controlling for price and have the log of quantity as the dependent variable. The number of observations for Columns (3) and (6) are lower than for the other columns because not all stores sell value added specialty eggs. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level has two separate classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level presented in this table only includes large traditional shell eggs. Log price is the log of the average price of the corresponding aggregation level. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 5: Abnormal Monthly Changes for Egg Purchases Following the Egg Recalls by Demographics

| | (1)<br>Log Q | (2)<br>Log Q | (3)<br>Log Q | (4)<br>Log Q |
|---|---|---|---|---|
| Log Price | -0.228*** | -0.108 | -0.976*** | -0.195** |
| | (0.0754) | (0.0941) | (0.349) | (0.0888) |
| Event * CA N1 | -0.0870*** | -0.0963*** | -0.00415 | -0.109*** |
| | (0.0312) | (0.0347) | (0.0600) | (0.0369) |
| Event * CA N1 * College | 0.0310** | 0.0421*** | -0.0564* | 0.0524*** |
| | (0.0117) | (0.0123) | (0.0312) | (0.0152) |
| Event * CA N1 * Med Inc | -0.00471 | -0.00802** | 0.0179* | -0.00884* |
| | (0.00407) | (0.00397) | (0.00938) | (0.00473) |
| Event * CA N1 * HH Size | -0.0139 | -0.00799 | -0.0568 | -0.00703 |
| | (0.0178) | (0.0169) | (0.0392) | (0.0178) |
| Event * CA N2 | -0.107*** | -0.113*** | -0.0381 | -0.137*** |
| | (0.0250) | (0.0287) | (0.0477) | (0.0272) |
| Event * CA N2 * College | 0.0339*** | 0.0382*** | -0.0126 | 0.0435*** |
| | (0.00874) | (0.00991) | (0.0247) | (0.0112) |
| Event * CA N2 * Med Inc | -0.000655 | -0.00482 | 0.0443*** | -0.00708 |
| | (0.00461) | (0.00469) | (0.00820) | (0.00479) |
| Event * CA N2 * HH Size | -0.0160 | -0.00774 | -0.123*** | -0.0116 |
| | (0.0147) | (0.0131) | (0.0345) | (0.0156) |
| Event * CA N3 | -0.0773*** | -0.0597* | -0.0823 | -0.117*** |
| | (0.0263) | (0.0316) | (0.0870) | (0.0309) |
| Event * CA N3 * College | 0.00888 | 0.00246 | 0.0458 | -0.00200 |
| | (0.0103) | (0.0139) | (0.0411) | (0.0169) |
| Event * CA N3 * Med Inc | -0.00267 | -0.00565 | 0.0344** | -0.00927 |
| | (0.00560) | (0.00576) | (0.0137) | (0.00703) |
| Event * CA N3 * HH Size | -0.0315* | -0.0229 | -0.126** | -0.0179 |
| | (0.0178) | (0.0153) | (0.0476) | (0.0178) |
| Constant | 8.733*** | 8.453*** | 7.509*** | 8.438*** |
| | (0.0973) | (0.120) | (0.489) | (0.113) |
| Aggregation | Category | Class | Class | Subclass |
| Agg. Type | Shell Eggs | Traditional | Specialty | Large |
| Observations | 10,416 | 10,416 | 10,412 | 10,416 |
| R-squared | 0.984 | 0.982 | 0.974 | 0.982 |

Notes: Table tests for heterogeneous effects by socio-economic groups. Column (1) shows results for the category aggregation level (all shell eggs); Column (2) shows results for the "Traditional Shell Eggs" class aggregation level; Column (3) shows results for the "Value Added Specialty Eggs" class aggregation level; and Column (4) shows results for the "Large Traditional Shell Eggs" subclass aggregation level. The number of observations for Column (3) is lower than for the other columns because not all stores sell value added specialty eggs. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. "College" is an indicator variable that is equal to one if the average attainment level of the zip code in which the store is located is equal to at least one year of college, "MedInc" is the demeaned median income of the zip code in which the store is located (in $10,000 increments) and "HH Size" is the demeaned average household size of the zip code in which the store is located. Socio-economic data are from the 2000 U.S. Census. To avoid clutter, only results with the interaction "Event * CA" are presented (results with the "Event" only are not presented but were included in the regressions). Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 6: Abnormal Monthly Changes for Egg Purchases Following the Egg Recalls by Californian Geographical Divisions

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Log Q | Log Q | Log Q | Log Q |
| Event N1 | 0.0152 | -0.0143 | 0.0287 | -0.0136 |
| | (0.0149) | (0.0160) | (0.0231) | (0.0183) |
| Event N2 | 0.0148 | 0.00622 | 0.0369* | 0.00683 |
| | (0.0118) | (0.0163) | (0.0193) | (0.0185) |
| Event N3 | -0.0228* | -0.0304* | -0.0570** | -0.0248 |
| | (0.0117) | (0.0164) | (0.0221) | (0.0196) |
| Log P | -0.213** | -0.140 | -0.765* | -0.181* |
| | (0.0845) | (0.0982) | (0.389) | (0.0991) |
| Event * Northern CA N1 | -0.143*** | -0.123*** | -0.00258 | -0.136*** |
| | (0.00500) | (0.0250) | (0.0249) | (0.0274) |
| Event * Northern CA N2 | -0.106*** | -0.110*** | -0.0635*** | -0.128*** |
| | (0.00362) | (0.0205) | (0.0226) | (0.0219) |
| Event * Northern CA N3 | -0.0902*** | -0.0699** | -0.0348 | -0.101*** |
| | (0.0173) | (0.0300) | (0.0352) | (0.0330) |
| Event * Southern CA N1 | -0.0622*** | -0.0433 | -0.0493 | -0.0532* |
| | (0.0200) | (0.0262) | (0.0858) | (0.0277) |
| Event * Southern CA N2 | -0.0842*** | -0.0853*** | -0.0684 | -0.110*** |
| | (0.0175) | (0.0255) | (0.0757) | (0.0254) |
| Event * Southern CA N3 | -0.0725*** | -0.0443 | -0.112 | -0.116*** |
| | (0.0203) | (0.0311) | (0.131) | (0.0344) |
| Constant | 8.713*** | 8.493*** | 7.212*** | 8.421*** |
| | (0.108) | (0.124) | (0.549) | (0.124) |
| Aggregation | Category | Class-Traditional | Class-Specialty | Subclass-Large |
| Observations | 10,416 | 10,416 | 10,412 | 10,416 |
| R-squared | 0.983 | 0.981 | 0.976 | 0.982 |

Notes: Table tests for heterogeneous effects by geographic divisions (only Northern California stores had contaminated eggs). Column (1) shows results for the category aggregation level (all shell eggs); Column (2) shows results for the "Traditional Shell Eggs" class aggregation level; Column (3) shows results for the "Value Added Specialty Eggs" class aggregation level; and Column (4) shows results for the "Large Traditional Shell Eggs" subclass aggregation level. The number of observations for Column (3) is lower than for the other columns because not all stores sell value added specialty eggs. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 7: Abnormal Monthly Changes for Egg Purchases by Brands Following the Egg Recalls

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | Log Q | Log Q | Log Q | Log Q | Log Q | Log Q | Log Q | Log Q |
| Event N1 | 0.00240 | -0.0203 | -0.0105 | -0.0261* | 0.0672* | 0.00193 | -0.00419 | -0.0366** |
| | (0.0115) | (0.0128) | (0.0128) | (0.0137) | (0.0356) | (0.0154) | (0.0139) | (0.0171) |
| Event N2 | 0.0223* | 0.000212 | 0.0111 | -0.00211 | 0.0580** | -0.00548 | 0.0162 | -0.00687 |
| | (0.0128) | (0.0125) | (0.0135) | (0.0142) | (0.0245) | (0.0205) | (0.0146) | (0.0172) |
| Event N3 | -0.0236* | -0.0280 | -0.0236* | -0.0131 | -0.0612*** | -0.129*** | -0.0160 | 0.0182 |
| | (0.0123) | (0.0178) | (0.0139) | (0.0183) | (0.0205) | (0.0342) | (0.0154) | (0.0235) |
| Log Price | -0.230*** | -0.0243 | -0.148** | 0.104 | -0.596*** | -1.088* | -0.258*** | 0.22 |
| | (0.0502) | (0.107) | (0.0716) | -0.152 | (0.168) | (0.598) | (0.0700) | (0.222) |
| Event * CA N1 | -0.0809*** | -0.0770*** | -0.0881*** | -0.0877*** | -0.0171 | -0.0325 | -0.0995*** | -0.0274 |
| | (0.0270) | (0.0257) | (0.0303) | (0.0308) | (0.0437) | (0.0445) | (0.0323) | (0.0252) |
| Event * CA N2 | -0.100*** | -0.0897*** | -0.103*** | -0.0996*** | -0.0550* | -0.0359 | -0.124*** | 0.0311 |
| | (0.0203) | (0.0180) | (0.0243) | (0.0258) | (0.0322) | (0.0395) | (0.0229) | (0.0229) |
| Event * CA N3 | -0.0831*** | -0.0437* | -0.0683** | -0.0568* | -0.130** | 0.0182 | -0.124*** | 0.0427 |
| | (0.0210) | (0.0246) | (0.0262) | (0.0290) | (0.0621) | (0.0766) | (0.0250) | (0.0313) |
| Constant | 8.884*** | 8.652*** | 8.655*** | 8.304*** | 7.392*** | 8.225*** | 8.682*** | 7.999*** |
| | (0.0634) | (0.153) | (0.0907) | (0.215) | (0.212) | (0.867) | (0.0881) | (0.303) |
| Aggregation | Category | Category | Class | Class | Class | Class | Subclass | Subclass |
| Agg. Type | Shell Eggs | Shell Eggs | Traditional | Traditional | Specialty | Specialty | Large | Large |
| Brand | Chain | Other | Chain | Other | Chain | Other | Chain | Other |
| Observations | 37,200,042 | 6,375,849 | 35,226,053 | 2,300,952 | 1,973,989 | 4,074,897 | 32,041,792 | 551,517 |
| R-squared | 0.983 | 0.981 | 0.980 | 0.979 | 0.983 | 0.978 | 0.980 | 0.973 |

Notes: Table tests whether non-chain brands ("other brands") were affected in response to the egg recalls. Columns (1), (3), (5) and (7) show results for the chain brand (which had contaminated eggs) and Columns (2), (4), (6) and (8) show results for non-chain brands (which did not have contaminated eggs). All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level has two separate classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level includes large traditional shell eggs only. Log price is the log of the average price of the corresponding aggregation level. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

# 8 Appendix: Supplementary Tables

Table 8: Sensitivity of Abnormal Changes in Egg Purchases to Assumptions about Seasonality Estimates

| | (1) Log Q | (2) Log Q | (3) Log Q | (4) Log Q | (5) Log Q | (6) Log Q | (7) Log Q |
|---|---|---|---|---|---|---|---|
| Event N1 | -0.0122** | -0.0194*** | -0.00543 | -0.0179*** | 0.0149 | -0.0175** | -0.00156 |
| | (0.00534) | (0.00587) | (0.00964) | (0.00540) | (0.0154) | (0.00740) | (0.0195) |
| Event N2 | 0.0172* | -0.00172 | 0.0744*** | 0.0000 | 0.0434*** | -0.00751 | 0.0167 |
| | (0.00906) | (0.0107) | (0.00877) | (0.00886) | (0.0137) | (0.0104) | (0.0209) |
| Event N3 | -0.0453*** | -0.0547*** | -0.0565*** | -0.0481*** | -0.0204 | -0.0548*** | -0.0202 |
| | (0.0112) | (0.0128) | (0.0145) | (0.0119) | (0.0143) | (0.00868) | (0.0200) |
| Log P | -0.329*** | -0.180 | -0.199 | -0.295*** | -0.368*** | -0.191** | -0.182** |
| | (0.108) | (0.112) | (0.222) | (0.0872) | (0.0748) | (0.0799) | (0.0827) |
| Event * CA N1 | -0.0211 | -0.0299 | 0.0146 | -0.0348 | -0.0756** | -0.0512* | -0.0989*** |
| | (0.0302) | (0.0343) | (0.0477) | (0.0348) | (0.0329) | (0.0302) | (0.0325) |
| Event * CA N2 | -0.0598*** | -0.0539* | -0.0950** | -0.0745*** | -0.0980*** | -0.0705*** | -0.113*** |
| | (0.0215) | (0.0267) | (0.0367) | (0.0238) | (0.0251) | (0.0234) | (0.0278) |
| Event * CA N3 | -0.0576** | -0.0222 | -0.111 | -0.0799*** | -0.0812*** | -0.0513** | -0.0812*** |
| | (0.0274) | (0.0336) | (0.0796) | (0.0280) | (0.0270) | (0.0224) | (0.0274) |
| Constant | 8.785*** | 8.481*** | 6.458*** | 8.505*** | 8.883*** | 8.668*** | 8.698*** |
| | (0.117) | (0.115) | (0.311) | (0.0874) | (0.0899) | (0.0986) | (0.109) |
| Aggregation | Category | Class | Class | Subclass | Category | Category | Category |
| Agg. Type | Shell Eggs | Traditional | Specialty | Large | Shell Eggs | Shell Eggs | Shell Eggs |
| Excluded | 2007-2008 | 2007-2008 | 2007-2008 | 2007-2008 | 2007 | 2008 | 2009 |
| Observations | 5,208 | 5,208 | 5,206 | 5,208 | 7,812 | 7,812 | 7,812 |
| R-squared | 0.984 | 0.982 | 0.980 | 0.983 | 0.984 | 0.983 | 0.983 |

Notes: Table tests for sensitivity of abnormal monthly changes in egg purchases to assumptions about the seasonality estimates. Columns (1) - (4) include only one pre-recall year and exclude data for the years 2007 and 2008. Columns (5) - (7) exclude data from each of the pre-recall years. The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level includes two classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level includes large traditional shell eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 9: Sensitivity of Abnormal Changes in Egg Purchases to the Control State

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Log Q | Log Q | Log Q | Log Q |
| Event N1 | -0.0568*** | -0.0739*** | -0.0199 | -0.0849*** |
| | (0.0168) | (0.0246) | (0.0833) | (0.0240) |
| Event N2 | -0.0796*** | -0.0966*** | -0.0298 | -0.122*** |
| | (0.0159) | (0.0234) | (0.0732) | (0.0210) |
| Event N3 | -0.0898*** | -0.0695*** | -0.170 | -0.137*** |
| | (0.0156) | (0.0232) | (0.128) | (0.0247) |
| Log P | -0.0645 | 0.0724 | -0.849 | 0.0342 |
| | (0.110) | (0.143) | (0.503) | (0.137) |
| Event N1 * Northern CA | -0.0689*** | -0.0816*** | 0.0462 | -0.0840*** |
| | (0.0226) | (0.0286) | (0.0838) | (0.0297) |
| Event N2 * Northern CA | -0.0176 | -0.0183 | 0.000746 | -0.0134 |
| | (0.0192) | (0.0251) | (0.0781) | (0.0235) |
| Event N3 * Northern CA | 0.00857 | 0.0106 | 0.0719 | 0.0556 |
| | (0.0247) | (0.0429) | (0.141) | (0.0466) |
| Constant | 8.551*** | 8.236*** | 7.471*** | 8.168*** |
| | (0.145) | (0.186) | (0.726) | (0.176) |
| Aggregation | Category | Class | Class | Subclass |
| Agg. Type | Shell Eggs | Traditional | Specialty | Large |
| Control "State" | Southern CA | Southern CA | Southern CA | Southern CA |
| Observations | 7,808 | 7,808 | 7,804 | 7,808 |
| R-squared | 0.985 | 0.983 | 0.974 | 0.983 |

Notes: Table tests for sensitivity of results to the control state. All regressions use Southern California as a control "state" and Northern California as a treatment "state". The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level includes two classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level includes large traditional shell eggs only. The number of observations for Column (3) is lower than for the other columns because not all stores sell value added specialty eggs. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 10: Product Out-of-Stock (OOS) Status Following the Egg Recalls

| | (1) OOS | (2) OOS | (3) OOS | (4) OOS | (5) OOS | (6) OOS |
|---|---|---|---|---|---|---|
| Event N1 | 0.0530*** | 0.0498*** | 0.0590** | 0.0718*** | 0.0472*** | 0.0649*** |
| | (0.0139) | (0.00949) | (0.0251) | (0.00919) | (0.00919) | (0.0230) |
| Event N2 | 0.0708*** | 0.0689*** | 0.0728*** | 0.0598*** | 0.0493*** | 0.0996*** |
| | (0.0107) | (0.0112) | (0.0235) | (0.0142) | (0.00626) | (0.0229) |
| Event N3 | 0.0956*** | 0.00452 | 0.226*** | 0.00290 | 0.0289*** | 0.200*** |
| | (0.0132) | (0.0129) | (0.0217) | (0.0127) | (0.00839) | (0.0270) |
| Log Price | -0.106 | -0.125** | -0.0311 | -0.1000*** | -0.146*** | -0.101 |
| | (0.0985) | (0.0524) | (0.0947) | (0.0314) | (0.0513) | (0.162) |
| Event * CA N1 | -0.0403* | -0.0431*** | -0.0380 | -0.0747*** | -0.0357** | -0.0439 |
| | (0.0207) | (0.0131) | (0.0351) | (0.0120) | (0.0161) | (0.0333) |
| Event * CA N2 | -0.0242** | -0.0427*** | -0.000372 | -0.0531*** | -0.0338*** | -0.00920 |
| | (0.0112) | (0.0126) | (0.0236) | (0.0184) | (0.0116) | (0.0242) |
| Event * CA N3 | 0.000300 | 0.0547*** | -0.0784** | 0.00332 | 0.0181 | -0.0384 |
| | (0.0206) | (0.0144) | (0.0362) | (0.0164) | (0.0139) | (0.0436) |
| Constant | 0.243* | 0.274*** | 0.130 | 0.246*** | 0.310*** | 0.219 |
| | (0.137) | (0.0719) | (0.135) | (0.0440) | (0.0680) | (0.240) |
| Aggregation | Category | Class | Class | Subclass | Chain Brand | Other Brands |
| Agg. Type | Shell Eggs | Traditional | Specialty | Large | Chain Brand | Other Brands |
| Observations | 106,372 | 59,786 | 46,586 | 33,108 | 59,293 | 47,079 |
| R-squared | 0.169 | 0.168 | 0.245 | 0.189 | 0.186 | 0.215 |

Notes: Table tests for changes in out-of-stock status following the three egg recalls. Data are aggregated at the UPC by month by store level. Column (1) aggregates products at the category level (all shell eggs). Column (2) aggregates products at the class level "Traditional Shell Eggs", Column (3) aggregates products at the class level "Value Added Specialty Eggs" and Column (4) aggregates products at the "Large" subclass level. Column (5) aggregates products at the chain brand level and Column (6) aggregates products at the "other brands" (non-chain brand) level. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Out-of-stock data are available for the years 2008, 2009 and 2010 only. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 11: Testing of Abnormal Monthly Changes for Egg Purchases Following the Egg Recalls Using Placebo Tests

| | (1) | (2) | (3) |
|---|---|---|---|
| | Log Q | Log Q | Log Q |
| Event N1 | 0.0173 | -0.0213* | 0.0159 |
| | (0.0105) | (0.0121) | (0.0122) |
| Event N2 | 0.0408*** | -0.0590*** | 0.00584 |
| | (0.0129) | (0.0111) | (0.0152) |
| Event N3 | 0.0383*** | -0.0566*** | 0.0432** |
| | (0.0133) | (0.0158) | (0.0177) |
| Log P | -0.244*** | -0.102 | -0.189* |
| | (0.0882) | (0.0986) | (0.102) |
| Event * CA N1 | 0.0274 | 0.0839*** | -0.0394 |
| | (0.0256) | (0.0228) | (0.0275) |
| Event * CA N2 | 0.0199 | 0.100*** | -0.0173 |
| | (0.0264) | (0.0225) | (0.0268) |
| Event * CA N3 | 0.0296 | 0.0687*** | -0.0210 |
| | (0.0273) | (0.0257) | (0.0311) |
| Constant | 8.753*** | 8.574*** | 8.683*** |
| | (0.111) | (0.125) | (0.129) |
| Aggregation | Category | Category | Category |
| Placebo Year | 2007 | 2008 | 2009 |
| Observations | 10,416 | 10,416 | 10,416 |
| R-squared | 0.982 | 0.982 | 0.982 |

Notes: Table tests for abnormal monthly changes in egg purchases following the recalls using placebo tests. All columns show sales at the category level (all shell eggs). Column (1) uses the year 2007 as a placebo year, Column (2) uses the year 2008 as a placebo year, and Column (3) uses the year 2009 as a placebo year. Log price is the log of the average category price. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 12: Abnormal Monthly Changes for Egg Purchases in Southern California Following the Egg Recalls

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Log Q | Log Q | Log Q | Log Q |
| Event N1 | -0.00208 | -0.0156 | 0.0305 | -0.0159 |
| | (0.0145) | (0.0170) | (0.0236) | (0.0194) |
| Event N2 | 0.0165 | 0.00511 | 0.0360* | 0.00471 |
| | (0.0155) | (0.0169) | (0.0194) | (0.0192) |
| Event N3 | -0.0321** | -0.0306* | -0.0582*** | -0.0252 |
| | (0.0150) | (0.0168) | (0.0217) | (0.0203) |
| Log P | -0.236*** | -0.126 | -0.889* | -0.156 |
| | (0.0871) | (0.113) | (0.518) | (0.116) |
| Event * Southern CA N1 | -0.0434** | -0.0431 | -0.0501 | -0.0530* |
| | (0.0199) | (0.0261) | (0.0854) | (0.0275) |
| Event * Southern CA N2 | -0.0842*** | -0.0854*** | -0.0650 | -0.110*** |
| | (0.0207) | (0.0253) | (0.0762) | (0.0250) |
| Event * Southern CA N3 | -0.0640*** | -0.0438 | -0.113 | -0.115*** |
| | (0.0227) | (0.0310) | (0.130) | (0.0343) |
| Constant | 8.588*** | 8.339*** | 7.153*** | 8.233*** |
| | (0.107) | (0.136) | (0.742) | (0.137) |
| Aggregation | Category | Class-Traditional | Class-Specialty | Subclass-Large |
| Treatment State | South CA | South CA | South CA | South CA |
| Control State | WA | WA | WA | WA |
| Excluded | North CA | North CA | North CA | North CA |
| Observations | 6,672 | 6,672 | 6,668 | 6,672 |
| R-squared | 0.981 | 0.979 | 0.964 | 0.979 |

Notes: Table tests for abnormal monthly changes in egg purchases in Southern California. Observations from Northern California are dropped and Washington is the control state. The "Category" aggregation level includes one category (shell eggs); the "Class" aggregation level includes two classes (traditional shell eggs and value added specialty eggs); and the "Subclass" aggregation level includes large traditional shell eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 13: Single Differences Estimates of Abnormal Changes in Egg Purchases

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Log Q | Log Q | Log Q | Log Q |
| Event N1 | -0.117*** | -0.0603*** | 0.0120 | 0.00742 |
| | (0.00819) | (0.00672) | (0.00879) | (0.00857) |
| Event N2 | -0.0921*** | -0.0833*** | 0.0278*** | 0.0241*** |
| | (0.00726) | (0.00677) | (0.00861) | (0.00843) |
| Event N3 | -0.101*** | -0.0879*** | -0.0308*** | -0.0312*** |
| | (0.0124) | (0.00637) | (0.00826) | (0.00817) |
| Log P | -0.184*** | -0.0119 | -0.405*** | -0.349*** |
| | (0.0618) | (0.0392) | (0.0363) | (0.0311) |
| Event * Northern CA N1 | | | | -0.112*** |
| | | | | (0.0106) |
| Event * Northern CA N2 | | | | -0.109*** |
| | | | | (0.0107) |
| Event * Northern CA N3 | | | | -0.0982*** |
| | | | | (0.0120) |
| Constant | 8.948*** | 8.269*** | 8.839*** | 9.011*** |
| | (0.0846) | (0.0492) | (0.0414) | (0.0397) |
| Aggregation | Category | Category | Category | Category |
| Treatment State | North CA | South CA | WA | North CA |
| Control State | Past North CA | Past South CA | Past WA | WA |
| Excluded State | WA, South CA | WA, North CA | North CA, South CA | South CA |
| Observations | 3,744 | 4,064 | 2,608 | 6,352 |
| R-squared | 0.977 | 0.982 | 0.978 | 0.981 |

Notes: Table shows results from several single differences estimates. Column (1) looks at the effect of the recalls in Northern California only, comparing observations before and after the recalls. It excludes data from Washington and Southern California. Column (2) repeats the same analysis as Column (1) but studies the effect of the recalls in Southern California only. Column (3) repeats the same analysis for Washington and Column (4) studies the effect of the recalls in Northern California, using Washington as a control. All columns aggregate sales at the category level (all shell eggs). Log price is the log of the average category price. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 14: Sensitivity of Abnormal Changes in Egg Purchases to Store Aggregation and Post-Event Months

| | (1) Log Q | (2) Log Q | (3) Log Q | (4) Log Q | (5) Log Q | (6) Log Q | (7) Log Q | (8) Log Q |
|---|---|---|---|---|---|---|---|---|
| Event N1 | 0.00243 | -0.0109 | 0.0223 | -0.00502 | -0.00639 | -0.0159 | 0.0306** | -0.0215* |
| | (0.0113) | (0.0130) | (0.0156) | (0.0141) | (0.0124) | (0.0125) | (0.0149) | (0.0123) |
| Event N2 | 0.0209 | 0.0105 | -0.00241 | 0.0163 | | | | |
| | (0.0126) | (0.0136) | (0.0174) | (0.0150) | | | | |
| Event N3 | -0.0269** | -0.0245* | -0.0943*** | -0.0176 | | | | |
| | (0.0122) | (0.0140) | (0.0134) | (0.0157) | | | | |
| Log P | -0.264*** | -0.149** | -0.976*** | -0.253*** | -0.184 | -0.123 | -0.891*** | -0.097 |
| | (0.0581) | (0.0735) | (0.285) | (0.0658) | (0.1530) | (0.1350) | (0.1950) | (0.1210) |
| Event N1 * CA | -0.0812*** | -0.0881*** | -0.0254 | -0.0979*** | -0.0750** | -0.0812** | -0.0281 | -0.0923** |
| | (0.0263) | (0.0301) | (0.0415) | (0.0323) | (0.0348) | (0.0384) | (0.0237) | (0.0403) |
| Event N2 * CA | -0.0988*** | -0.103*** | -0.0283 | -0.122*** | | | | |
| | (0.0200) | (0.0245) | (0.0358) | (0.0235) | | | | |
| Event N3 * CA | -0.0796*** | -0.0671** | -0.0322 | -0.123*** | | | | |
| | (0.0206) | (0.0264) | (0.0660) | (0.0252) | | | | |
| Constant | 8.938*** | 8.656*** | 8.020*** | 8.676*** | 8.677*** | 8.472*** | 7.389*** | 8.317*** |
| | (0.0752) | (0.0937) | (0.399) | (0.0833) | (0.1930) | (0.1670) | (0.2720) | (0.1490) |
| Aggregation | Category | Class | Class | Subclass | Category | Class | Class | Subclass |
| Agg. Type | Shell Eggs | Traditional | Specialty | Large | Shell Eggs | Traditional | Specialty | Large |
| Observations | 43,575,891 | 37,527,005 | 6,048,886 | 32,593,309 | 5,208 | 5,208 | 5,206 | 5,208 |
| R-squared | 0.982 | 0.980 | 0.979 | 0.980 | 0.993 | 0.992 | 0.994 | 0.992 |

Notes: Table tests for sensitivity of results to the aggregation at the store level and months after the event. Columns (1) - (4) use the raw dataset and do not aggregate sales at the store level. Columns (5) - (8) include only one month after the event. The “Category” aggregation level includes one category (shell eggs); the “Class” aggregation level includes two classes (traditional shell eggs and value added specialty eggs); and the “Subclass” aggregation level includes large traditional shell eggs only. Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. Standard errors are clustered at the division by month level.

Table 15: Sensitivity of Abnormal Changes in Egg Purchases to Clustering

| | (1) Log Q | (2) Log Q | (3) Log Q | (4) Log Q | (5) Log Q | (6) Log Q | (7) Log Q | (8) Log Q |
|---|---|---|---|---|---|---|---|---|
| Event N1 | -0.00158 | -0.00158 | -0.0163 | -0.0163* | 0.0307 | 0.0307* | -0.0111 | -0.0111 |
| | (0.0140) | (0.00831) | (0.0160) | (0.00873) | (0.0229) | (0.0183) | (0.0176) | (0.00907) |
| Event N2 | 0.0168 | 0.0168** | 0.00455 | 0.00455 | 0.0359* | 0.0359** | 0.00896 | 0.00896 |
| | (0.0151) | (0.00824) | (0.0161) | (0.00867) | (0.0190) | (0.0183) | (0.0181) | (0.00903) |
| Event N3 | -0.0321** | -0.0321*** | -0.0307* | -0.0307*** | -0.0583*** | -0.0583*** | -0.0244 | -0.0244*** |
| | (0.0148) | (0.00810) | (0.0169) | (0.00852) | (0.0212) | (0.0183) | (0.0190) | (0.00888) |
| Log Price | -0.242*** | -0.242*** | -0.119 | -0.119*** | -0.903** | -0.903*** | -0.206** | -0.206*** |
| | (0.0737) | (0.0222) | (0.0934) | (0.0206) | (0.358) | (0.0620) | (0.0881) | (0.0198) |
| Event * CA N1 | -0.0757** | -0.0757*** | -0.0812** | -0.0812*** | -0.0282 | -0.0282 | -0.0932** | -0.0932*** |
| | (0.0308) | (0.00936) | (0.0351) | (0.00984) | (0.0655) | (0.0211) | (0.0372) | (0.0103) |
| Event * CA N2 | -0.0949*** | -0.0949*** | -0.0969*** | -0.0969*** | -0.0655 | -0.0655*** | -0.119*** | -0.119*** |
| | (0.0246) | (0.00936) | (0.0294) | (0.00984) | (0.0536) | (0.0211) | (0.0279) | (0.0103) |
| Event * CA N3 | -0.0714*** | -0.0714*** | -0.0541* | -0.0541*** | -0.0799 | -0.0799*** | -0.112*** | -0.112*** |
| | (0.0251) | (0.00966) | (0.0311) | (0.0101) | (0.100) | (0.0212) | (0.0301) | (0.0105) |
| Constant | 8.750*** | 8.750*** | 8.467*** | 8.467*** | 7.406*** | 7.406*** | 8.452*** | 8.452*** |
| | (0.0951) | (0.0281) | (0.119) | (0.0256) | (0.502) | (0.0873) | (0.112) | (0.0246) |
| Aggregation | Category | Category | Class | Class | Class | Class | Subclass | Subclass |
| Agg. Type | Shell Eggs | Shell Eggs | Traditional | Traditional | Specialty | Specialty | Large | Large |
| Clustering | Yes | No | Yes | No | Yes | No | Yes | No |
| Observations | 10,416 | 10,416 | 10,416 | 10,416 | 10,412 | 10,412 | 10,416 | 10,416 |
| R-squared | 0.983 | 0.983 | 0.981 | 0.981 | 0.974 | 0.974 | 0.981 | 0.981 |

Notes: Table shows results from tables 2 and 3 with and without clustering. Columns (1), (3), (5) and (7) cluster standard errors, while Columns (2), (4), (6) and (8) do not cluster standard errors. Columns (1) and (2) aggregate sales at the category level (all shell eggs), Columns (3) and (4) aggregate sales at the class level "Traditional Shell Eggs", Columns (5) and (6) aggregate sales at the class level "Value Added Specialty Eggs", and Columns (7) and (8) aggregate results at the subclass level "Large Traditional Shell Eggs." Log price is the log of the average price of the corresponding aggregation level. All regressions include store-by-year fixed effects as well as month fixed effects to account for seasonal purchasing patterns. Robust standard errors are in parentheses. Three asterisks (***) indicate significance at the 1% level, two asterisks (**) indicate significance at the 5% level, and a single asterisk (*) indicates significance at the 10% level. When clustered, standard errors are clustered at the division by month level.