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How Much Does It Matter How Sick You Get? Consumers' Responses to Foodborne Disease Outbreaks of Different Severities

Fred Kuchler

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Abstract

Federal health and safety officials warned consumers away from cantaloupes in 2011 and again in 2012. The warnings occurred under similar market conditions but were for contamination by two different foodborne microorganisms that posed entirely different health risks. This unhappy natural experiment allows us to investigate whether consumers make food choices that account for the severity of pathogens and the associated health risks. A retail demand system for U.S. melons is estimated to account for ordinary price- and income-induced changes in demand. Remaining changes are attributed to warnings. After consumers were informed about the risk with the higher fatality rate, the demand for cantaloupes fell and consumers substituted other melons. No such shifts in demand were evident under the lower fatality risk, despite more illnesses attributed to it.

Keywords: comparative risks, demand, *Salmonella*, *Listeria*

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How Much Does It Matter How Sick You Get? Consumers' Responses to Foodborne Disease Outbreaks of Different Severities

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What Is the Issue?

When Federal health and safety officials recall a food product and warn consumers that the safety of that food has been compromised, do consumers understand that not all risks are alike? Or do all warnings induce the same market response because consumers cannot discriminate among pathogens and the associated risk? This case study suggests that consumers make some distinctions among pathogens and health risks. That is, larger health risks induce larger market responses.

If public health officials cannot communicate the difference between large and small food-related health risks to consumers, then public health agencies may have to focus on the larger risks, issuing more and bigger recalls and generating more publicity about specific hazards. And if consumers routinely overestimate small risks, fleeing from relatively harmless foods, public health officials might have to choose between releasing information that would protect specific subpopulations and withholding such information to avoid needless financial harm to all the businesses along the supply chain.

A unique situation provided an opportunity to empirically address whether consumers make systematic choices that take into account different health risks. Federal health and safety officials warned consumers away from cantaloupes in 2011 and again in 2012. The warnings occurred under similar market conditions, but the contaminants were different. The first recall was due to *Listeria monocytogenes* and the second from two *Salmonella* serotypes. Both cause gastrointestinal illnesses, but health outcomes from the two illnesses are very different. The Centers for Disease Control and Prevention estimates that *Salmonella* is the cause of 1 million illnesses in the United States, with 19,000 hospitalizations and 380 deaths every year. Most persons recover without treatment. In contrast, CDC estimates that approximately 1,600 illnesses and 260 deaths due to listeriosis occur annually in the United States. The *Listeria* outbreak in 2011 caused 147 illnesses, 33 deaths, and a 99-percent hospitalization rate among those who fell ill. It mostly afflicted the elderly, with 78 the median age of those who fell ill. In effect, the two foodborne health risks were entirely different. Any difference in response is likely the result of consumers treating the risks as different.

What Did the Study Find?

Empirical evidence points to consumers reacting after the 2011 recall. Consumers temporarily reduced purchases of cantaloupes, even after accounting for the influence of prices and income. Expenditures on cantaloupe were $3.9 million (6-7 percent) lower than normal, and cantaloupe purchases were 6.2 million pounds lower over a 4-week period. Evidence from retail market transactions indicates that consumers generally understood the message and knew that other

melons were safe: in the weeks after cantaloupe were implicated, purchases of watermelon increased 1.0 million pounds and purchases of honeydew increased 3.7 million pounds, leaving total expenditures on melons largely unchanged.

A year later, when Federal health and safety officials again recalled some cantaloupe, this time for *Salmonella* contamination, consumer response was more muted. Intensity of news media coverage appears to be associated with the differing consumer responses: the *Listeria* outbreak received substantially more coverage than the *Salmonella* one.

The differing retail market responses point to consumers recognizing that *Listeria monocytogenes* poses more profound risks than do the identified *Salmonella* serotypes. The listeriosis fatality rate is extraordinarily high among the elderly. Shifting melon demand indicates that some consumers took defensive actions to protect themselves. *Salmonella* did not pose as great a risk of death, and the *Salmonella* warning did not induce a measurable market response. As such, there is evidence that consumers were informed about these relative risks. As long as consumers are concerned about the various foodborne illness risks they face and are informed about the severity of those risks, it would follow that observed market responses can be attributed to news about changes in risks.

How Was the Study Conducted?

It is possible to empirically test whether consumers make reasoned choices when they find out that safety of a food has been compromised. Examining retail demand before and after information is released is a vehicle for doing so. When consumers are made aware that food safety has been compromised, a reasonable expectation is that demand will fall—quantity demanded falls even with prices unchanged. If consumers are making reasoned choices about the risk they find acceptable or unacceptable, the bigger risk ought to induce a bigger shift in retail demand. Separating out the weeks immediately after the first news about the *Listeria* and *Salmonella* outbreaks yields a quantitative measure of consumers' responses to the two outbreaks and can reveal whether and to what extent consumers' responses differed. Finding similar responses would suggest that consumers do not make reasoned decisions about risks. Finding a larger response to *Listeria* news would suggest that the higher lethality of *Listeria* matters to consumers and the news provided the information consumers rely on to make choices over risks they face.

The paired comparison of warnings about cantaloupe is ideal for determining how much relative foodborne illness risks matter to consumers. The two outbreaks occurred within a year's time under conditions that minimize the problems caused by confounding variables. Although the two farms identified as supplying contaminated melons were in different States, the market conditions under which the warnings were issued were similar. Further, the market conditions prevailing at the time of the warnings ensure that any direct impacts (the recalls) or indirect impacts (increased liability concerns) the warnings might have had on the supply chain were relatively small. Thus, the main differences between the market impacts of the two outbreaks were driven by changes on the demand side of the retail cantaloupe market.

To compare consumers' responses to the two warnings, a model of the retail demand for melons was estimated. The model takes the (linear approximate) Almost Ideal Demand System form. Treating the warnings as external shocks to retail demand, it is possible to estimate how much demand for major varieties of melons shifted following each warning. The two measured shifts were compared, given the different risk posed by *Salmonella* and by *Listeria*.

Proprietary data on food purchases from IRI, denoted InfoScan, were used to estimate retail demand for melons. Retail establishments across the United States and Puerto Rico provide IRI weekly records of all transactions (dollar expenditures and quantity), with a separate line for each item that crossed a store's scanner. The stores reporting include grocery stores, supermarkets, supercenters, convenience stores, drug stores, and liquor stores. Data were tallied on a weekly basis over 2009-2012, with 209 observations for each type of melon: cantaloupe, watermelon, mini seedless watermelon (including Mickey Lee/Sugarbaby), honeydew, and all others.

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Introduction

In September 2011, the U.S. Centers for Disease Control and Prevention (CDC) and the U.S. Food and Drug Administration (FDA) issued warnings to consumers to avoid particular types of cantaloupes because the fruit could cause gastrointestinal illness. Less than a year later, the agencies repeated their warnings about bacterial contamination of cantaloupes. The first warning was triggered by a listeriosis outbreak (from the bacterium *Listeria monocytogenes*) and the second by a salmonellosis outbreak (*Salmonella* serotypes Newport and Typhimurium). These two warnings, distinct but proximate in time and identifying cantaloupe as the disease vector, are a kind of unhappy natural experiment. The paired events make it possible to investigate whether consumers think that all gastrointestinal illnesses are alike, with consistent market responses. Or do consumers make food choices that differentiate among pathogens and relative health risks?

Consumers' responses to food safety warnings have been studied extensively. Swartz and Strand (1981) examined the impact of closing the James River (Virginia) to oyster harvesting (1975-1976) due to a kepone (pesticide) contamination. The market for oysters harvested elsewhere—and not contaminated by kepone—was also monitored. Retail oyster demand fell upon newspaper coverage of the kepone contamination, regardless of the oysters' provenance. Smith and colleagues (1988) examined the impact on milk sales in Oahu following recalls of milk contaminated with heptachlor (a pesticide). They categorized news stories as either negative (milk contains pesticide residues above legally permissible levels) or positive (milk is free of contamination) and, through econometric testing, found only negative news as relevant to milk consumption.

Shimshack and colleagues (2007) examined responses to an FDA advisory urging limits on fish consumption[1] for infants, small children, pregnant or nursing mothers, and women who may become pregnant. Using household purchase data from a cross-section of U.S. households, the authors concluded that information policies can be effective as canned fish consumption decreased after the advisory. But the response was not uniform across the population, and there were unintended consequences. College-educated consumers, especially those with young children, were primarily responsible for the overall reduction in fish consumption. But the less educated did not respond. Nonreaders of newspapers and magazines did not respond. Some nontargeted consumers, especially readers, reduced their consumption of fish as well.

[1] In 2004, FDA and EPA advised some consumers to avoid seafood high in mercury. That advice is now being revised (FDA, 2014). The new advice encourages pregnant women, those who may become pregnant, breastfeeding mothers, and young children to eat more fish and to eat a variety of fish that are lower in mercury. The nutritional value of fish is important during growth and development before birth, in early infancy for breastfed infants, and in childhood. Fish contain high-quality protein, many vitamins and minerals, and omega-3 fatty acids, and are mostly low in saturated fat.

Lloyd and colleagues (2006) examined the response in the UK to a ministerial announcement in Parliament suggesting a link between bovine spongiform encephalopathy (BSE, informally known as Mad Cow disease) and variant Creutzfeld–Jakob disease, which is invariably fatal. Retailers and producers were found to bear different impacts, with farm price affected twice as much as retail price. In sum, consumers' response to news about food safety lapses has been studied one pathogen/pesticide/toxin at a time. No one has compared consumer reactions to similar events with different levels of risk.

The paired comparison of warnings about cantaloupe is ideal for addressing how much relative foodborne illness risks matter to consumers. The two outbreaks occurred under conditions that minimize the problems caused by confounding variables. Although the two farms identified as supplying contaminated melons were in different States, the prevailing market conditions under which the warnings were issued were similar. Further, market conditions were such that any direct impacts (the recalls) or indirect impacts (increased liability concerns) on the supply chain were relatively small. As a result, the main difference between the market impacts of the two outbreaks were driven by changes on the *demand* side of the retail cantaloupe market.

To compare consumers' responses to the two warnings, a model of retail demand for melons in the United States was estimated. Treating the health warnings as external shocks to retail demand, it is then possible to measure how much demand for major varieties of melons shifted following each warning. This approach distinguishes between ordinary price-induced changes in purchasing behavior and warning-induced changes, on the assumption that consumers assign lower value to food when health officials warn that it is contaminated with potentially deadly pathogens. Results show that consumers temporarily reduced purchases of cantaloupe after the *Listeria* warning in 2011. They substituted honeydew and watermelon, leaving total expenditures on melons largely unchanged. There was no detectable impact of the *Salmonella* warning in 2012 on melon purchases.

Consumers apparently recognized that *Listeria monocytogenes* posed more severe risks than did the identified *Salmonella* serotypes. For some subpopulations, the listeriosis fatality rate is extraordinarily high, and some consumers took actions to protect themselves. *Salmonella* did not pose as great a risk of death, and the *Salmonella* warning did not induce a measurable market response. In other words, relative changes in retail demand indicate that consumers were informed about the degree of risk. As long as consumers are concerned about the various foodborne illness risks they face and are informed about the existence of those risks, it follows that observed market responses could be attributed to news about changes in risks.

Consumers do not need a deep understanding of microbiology for relative risks to influence their behavior. They do not have to conduct quantitative risk assessments or calculate the probability of illness from various foods for relative risks to influence their behavior. They do not have to communicate directly with health and safety officials. Instead, relative risks will influence consumers' behavior if consumers value avoiding illness and death and have limited time, energy, and resources to devote to risk management.

Given consumers' responsiveness, it makes sense that there would be an active market for risk information. Health and safety officials mostly communicate with consumers through news media. Various news sources likely compete to inform consumers about ascendant risks, translating information from health and safety officials.

Clearly, there are various ways to characterize consumers' retail purchase behavior following news about food safety being compromised. Here we posit consumers as rational, selecting the best bundle of foods given their income and prices, while simultaneously managing foodborne-illness risks. Such behavior requires information about changes in risks. As long as consumers can discriminate among news sources, the news business will compete to supply the news that consumers find useful.

The opposite view posits consumers as uncritical recipients of news, alarmed by whatever news they receive about a foodborne illness risk. In this case, there would be no reason to expect the volume of news coverage to be aligned with risks. There would be no reason to see consumers actively seeking information about food safety risks. And there would be no reason to see different market responses to different risks.

The tally of television and newspaper reports on the two cantaloupe events shows much more interest in the listeriosis outbreak. Consumers had risk-justified reasons to be interested in the listeriosis outbreak but not in the subsequent salmonellosis outbreak, which is corroborated by Internet search volume as well.

Given the information consumers received about relative risks, the different retail market impacts of the two cantaloupe outbreaks should not be surprising. The evidence does not prove that consumers are making optimal choices over foods and risks. Information conveyed by the news media about the microbiology of pathogens and the physiology of foodborne diseases is limited. But consumers are clearly making choices based on food safety information they want, and they are active in seeking that information.

Comparing Two Market Shocks

The two foodborne illness outbreaks in 2011-12 shared some attributes. In both cases, small and discrete participants in U.S. cantaloupe production were identified as the cause of disease. However, the human health impacts of the two outbreaks were very different, with more illnesses attributed to *Salmonella* but more deaths attributed to *Listeria*. The salmonellosis deaths and illnesses were spread across demographic groups, while listeriosis deaths and illnesses were concentrated among the elderly.

Small Shares of the Market Were Identified as Disease Vectors

The information pointing to a listeriosis outbreak and cantaloupes as the likely cause began to be assembled in early September 2011. On September 9, the Colorado Department of Public Health and Environment advised persons in Colorado at high risk for severe listeriosis to avoid eating cantaloupes. On September 12, CDC advised that persons throughout the mainland United States and at high risk for listeriosis—including older adults, persons with weakened immune systems, and pregnant women—to not eat cantaloupes from the Rocky Ford region of Colorado. The warning was quickly revised to specify Jensen Farms as the source of the contamination and issuer of a voluntary recall of its Rocky Ford cantaloupe (CDC, 2011).

Colorado cantaloupe shipments account for less than 1 percent of U.S. annual cantaloupe shipments (USDA, AMS, 2011). And Colorado farmers ship cantaloupes in July, August, and September, with only 7 percent of their annual shipments in September (2010 data, the most recent year prior to the cantaloupe recalls), so most of Colorado production was already through the supply chain before the warning was issued. By September, almost all cantaloupe shipments are from California.

Further, Jensen Farms' cantaloupes were labeled as such, enabling the recalled product to be easily identified and differentiated from other cantaloupe. Even if consumers had followed the initial advice to avoid all Colorado cantaloupe, the Colorado share of supply at the time of the outbreak was also small. That is, the vast majority of the cantaloupe market was immediately absolved of guilt.[2]

The *Salmonella* recall occurred under similar market conditions. The recall identified Chamberlin Farms Produce, Inc., of Owensville, Indiana, as the source of the multistate outbreak (CDC, October 5, 2012). The event began in August 2012. Indiana farmers ship cantaloupes in July (91 percent) and August (9 percent). Again, most of Indiana's cantaloupe production had been shipped before any information about the outbreak had been released. Indiana shipments account for 1.4 percent of U.S. shipments and less than 1 percent of August shipments, which are mostly from California (USDA, AMS, 2011).

Different Pathogens, Different Consequences

Health professionals make clear distinctions among gastrointestinal illnesses. Most persons infected with *Salmonella* develop diarrhea, fever, and abdominal cramps 12 to 72 hours after infection. The

[2] Writing soon after the *Listeria* warning, Thornsbury and Calvin (2011) explained that most of the direct cost of the outbreak would fall on Jensen Farms in lost sales, recall expenses, cleanup/sanitation expenses, and potential lawsuits or other legal settlements. Shaken buyer confidence might compromise sales and revenue (demand) of other producers.

illness usually lasts 4 to 7 days, and most persons recover without treatment. However, in some cases the diarrhea may be so severe that the patient needs to be hospitalized. In these patients, the *Salmonella* infection may spread from the intestines to the blood stream, which can cause death. The elderly, infants, and those with impaired immune systems are more likely to have a severe illness (CDC, August 28, 2014).

Listeria primarily affects older adults, pregnant women, newborns, and adults with weakened immune systems. A person with listeriosis usually has fever and muscle aches, sometimes preceded by diarrhea or other gastrointestinal symptoms. Almost everyone diagnosed with listeriosis has invasive infection, in which the bacteria spread beyond the gastrointestinal tract. In older adults and people with compromised immune systems, septicemia and meningitis are the most common clinical presentations. Pregnant women may experience a fever, fatigue, and aches, followed by fetal loss or newborns with bacteremia and meningitis. People with healthy immune systems may suffer acute febrile gastroenteritis or present no symptoms at all (CDC July 29, 2014).

USDA's Economic Research Service provides estimates of the economic burden of foodborne illnesses, a proxy for society's willingness to pay to reduce the risk of disease. Recently, ERS released new estimates for 15 leading pathogens (Hoffmann et al., 2015), which together account for over 95 percent of the illnesses, hospitalizations, and deaths from foodborne illnesses in the United States that can be tied to identifiable pathogens. These pathogens impose at least $15.2 billion ($2013) in economic burden each year.

Salmonella and *Listeria monocytogenes* elicit very different economic burdens. *Salmonella* creates the largest total economic burden at $3.7 billion annually. In this ranking, *Listeria monocytogenes* ranks third (behind *Toxoplasma gondii*) at $2.8 billion. However, the per-case burden is strikingly different. *Listeria monocytogenes* tops the list at $1.8 million per case, while each case of *Salmonella* costs less than $3,600, on average.[3]

CDC describes *Salmonella* as causing 1 million illnesses in the United States each year (CDC, August 28, 2014). The agency estimates that the *Salmonella* illnesses result in 380 deaths annually, implying a fatality rate of 0.00038 per illness. Less than 2 percent of those who fall ill require hospitalization. Many milder cases are not diagnosed or reported. Most recover without treatment. So, many Americans likely had direct experience with salmonellosis before 2012, with only minor consequences.

CDC's historical outbreak numbers confirm these fatality estimates. Prior to the 2012 cantaloupe outbreak, CDC conducted 37 *Salmonella* outbreak investigations, with the first in 2006 (CDC, August 21, 2014). Among these investigations, a total of 6,565 illnesses were identified. Based on CDC's implied fatality rate, the expected number of associated deaths is 2.5. Across the 37 outbreak investigations, reports confirmed 2 deaths, 1 attributed to ground turkey and another from exposure at a microbiology lab.[4]

[3] FDA also estimates U.S. costs of foodborne illness by pathogen (Minor et al., forthcoming). FDA analysis differs in having less detailed health outcomes, but adds monetized quality-adjusted life years lost to illness and death and covers a wider range of pathogens. Even so, results from USDA and FDA are similar. For example, *Salmonella* ranks first in total cost among pathogens in both analyses.

[4] Two other outbreak reports raise the possibility of additional deaths attributable to *Salmonella*, noting that the pathogen may have contributed to these deaths.

CDC's tally of the 2012 *Salmonella* outbreak from cantaloupe included 261 illnesses, 3 deaths, and 94 hospitalizations (CDC, October 5, 2012). The *Listeria* event 1 year earlier caused 147 illnesses, 33 deaths, and a 99-percent hospitalization rate[5] among those who fell ill (CDC, August 27, 2012). One miscarriage was reported. The 2011 *Listeria* outbreak mostly afflicted the elderly, with 78 the median age of those who fell ill.

The 2012 listeriosis outbreak surprised health professionals. USDA's Food Safety and Inspection Service (FSIS) describes *Listeria* as a problem that emerged in the 1980s with processed meat, with outbreaks from hot dogs and deli meats during the 1990s (USDA, FSIS, 2013). The 2012 outbreak was the first listeriosis outbreak associated with melon (Jackson et al., 2011). In sum, many of the attributes of the listeriosis outbreak were unique: the pathogen had found a new way into the food supply, had an especially high fatality rate, and was especially hazardous for the elderly and pregnant women.

Risk analysts often judge consumers' first reactions to a new and potentially serious risk as overreactions, although typically shortlived (Sandman, 2005). Given that the listeriosis risk was new and surprising, risk analysts could have accurately predicted that listeriosis sourced from cantaloupe would generate a larger market outcome than would salmonellosis from cantaloupe.

[5] Among the 145 ill persons with available information on whether they were hospitalized, 143 were hospitalized.

Media Attention and Consumers' Interest Focused on *Listeria*

It is not surprising that the news media devoted more coverage to the listeriosis outbreak than to the salmonellosis outbreak, given consumers' greater familiarity with salmonellosis and its lower fatality rate. Two news archives were consulted to measure relative interest in the two outbreaks. The Vanderbilt Television News Archive compiles news broadcasts from U.S. national television networks.[6] NewsBank, Inc., has a searchable database populated with the complete electronic editions of magazines and newspapers from around the world.

The Vanderbilt Television News Archive (VTNA) archive is a searchable database of news abstracts and broadcast descriptions. The VTNA has been recording, preserving, and providing access to television news broadcasts of the national networks since August 5, 1968. The archive began with three networks—ABC, CBS, and NBC—and added coverage of CNN in 1995 and FoxNews in 2004.

A search of the VTNA for reports discussing the 2011/12 listeriosis and salmonellosis outbreaks during evening news broadcasts returned 11 reports on the listeriosis outbreak beginning on September 14, 2011, and ending on October 19, 2011.[7] Six reports came from ABC, three from NBC, and one report each from CBS and CNN for a total coverage time of 19.5 minutes.[8]

There were fewer reports about the *Salmonella* outbreak. ABC reported on the outbreak due to cantaloupe on August 17 and August 18, 2012. The second report also discussed the previous year's *Listeria* outbreak. NBC reported on the salmonellosis outbreak on August 18, 2012. Total coverage time for the three reports was 2 minutes. Four networks covered the listeriosis outbreak, versus two for the salmonellosis outbreak. Reports on the listeriosis outbreak spanned 35 days while the salmonellosis outbreak was covered for 2 days.

Clearly, consumers do not get all their news and information from television broadcasts.[9] NewsBank's periodicals database dates to 1977. Our search for reports on the listeriosis and salmonellosis outbreaks was confined to the 2,273 U.S. newspapers included in the database as of June 2014. The daily count of newspaper articles begins on September 9, 2011, with four newspaper articles that included the words "cantaloupe" and "*Listeria*." While the outbreak was reported immediately after the FDA warnings and recall, it was several weeks before newspaper coverage peaked. NewsBank shows a total of 88 reports during the first week (September 9-September 14), 110 the following week, 138 the week after, and 240 during the week of September 30-October 5 (fig. 1). Weekly totals dropped into double digits by the end of October but did not consistently drop to single digits until the end of December. The listeriosis outbreak continued to be reported over at least 28 weeks.

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[6] http://tvnews.vanderbilt.edu

[7] The keyword search was conducted searching with keywords "*Listeria*," "*Salmonella*," and "cantaloupe."

[8] The total includes a 6-minute segment on ABC Nightline that discussed food safety and the listeriosis outbreak.

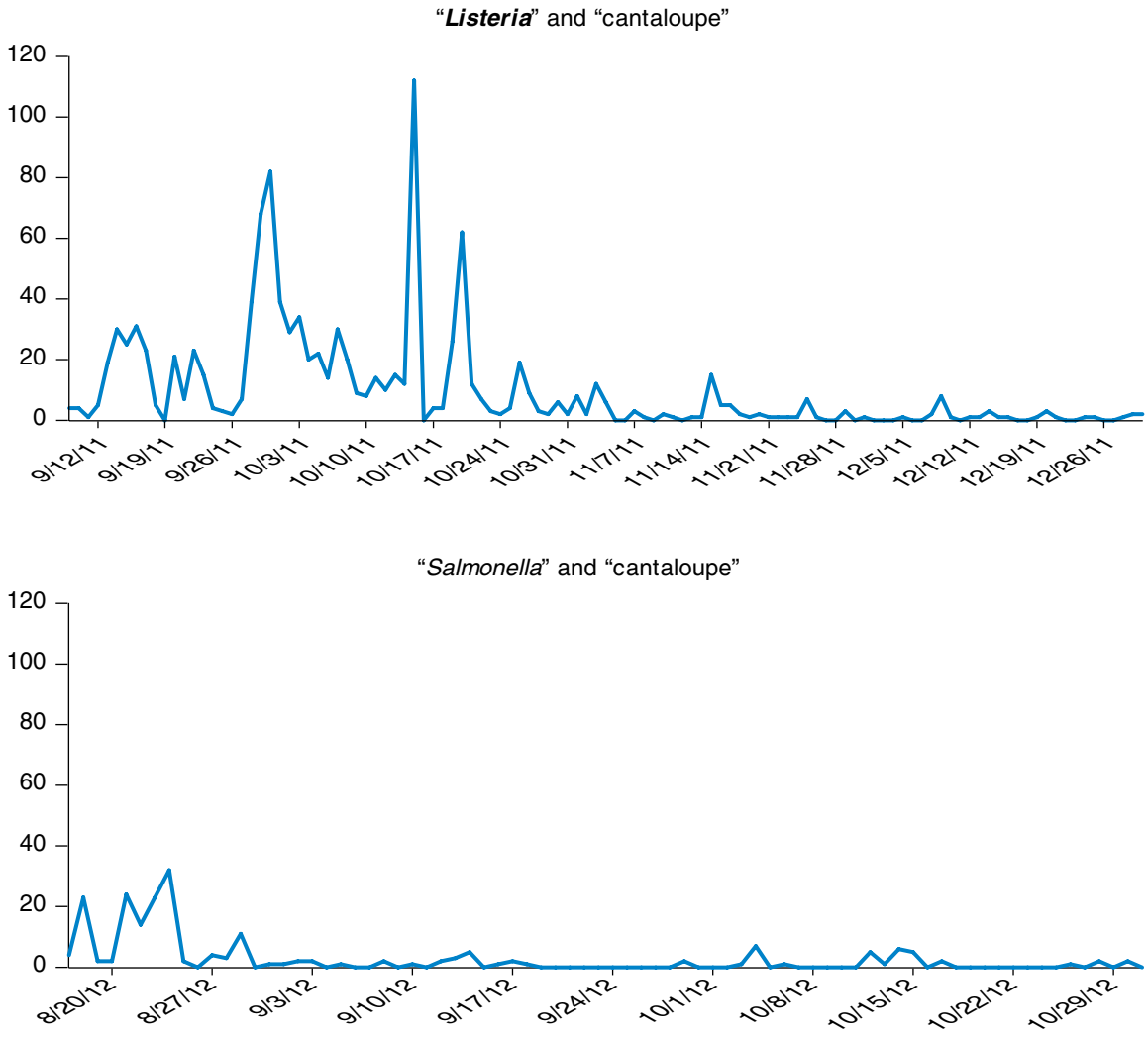
[9] The Media Insight Project (2014), an initiative of the American Press Institute and the Associated Press-National Opinion Research Center for Public Affairs Research, reported results of a recent poll on how American get their news. They found that Americans followed the news largely using four different devices or technologies. The most frequently used devices include television (87 percent), laptops/computers (69 percent), radio (65 percent), and print newspapers or magazines (61 percent).

In comparison, the salmonellosis outbreak received much less attention for a much shorter time from newspapers. The first 7 days of *Salmonella* news coverage totaled 92 reports. The second week (August 24-August 30, 2012) totaled 50 news stories. But most successive weeks totaled in single digits (fig. 1).

Google Trends, a public Web facility of Google Inc., allows users to determine how often a particular search term is entered relative to the total search volume across regions of the world and in various languages. We examined how often Internet users searched for the individual terms *"Listeria," "Salmonella,"* and "cantaloupe," with results specific to the United States and in English.

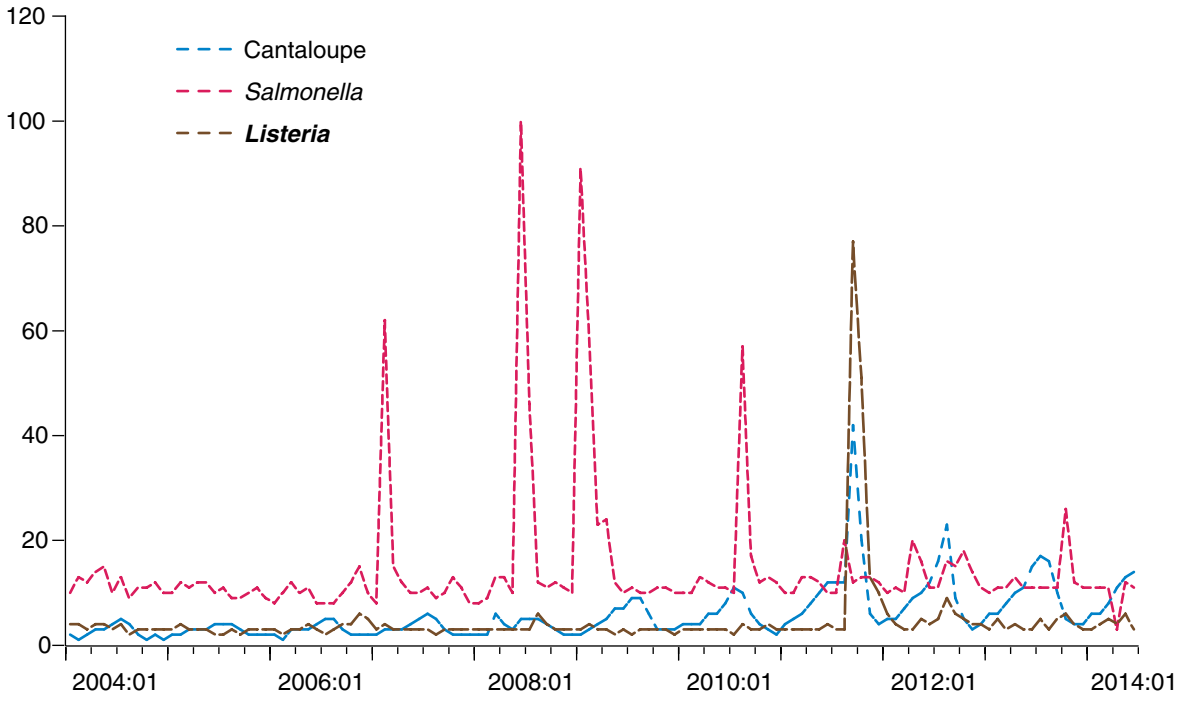
The Google Trends data begin in January 2004. The Internet search series for "cantaloupe" shows there is an annual cycle of interest, peaking in mid-summer when cantaloupe purchases are highest (fig. 2). Cantaloupe queries spiked in September 2011, along with the *Listeria* series, which is not

Figure 1
Daily count of newspaper stories mentioning "cantaloupe," *"Salmonella,"* and "*Listeria*"



Source: Newsbank, Inc. June 2014.

Figure 2
Monthly Web searches for "cantaloupe," "*Salmonella*," and "*Listeria*"



Source: Google Trends. Search tallies are relative indicators, relative to *Salmonella* count in June 2008, (highest peak) which was normalized to be equal to 100.

much Googled throughout the entire reporting period except for September 2011 and several months following. The *Salmonella* series displays four large spikes, coincident with FDA's February 2007 warning to avoid Peter Pan and some Great Value peanut butter products, the June 2008 warning to avoid tomatoes and other raw vegetables, regulatory actions taken in January and February 2009 regarding King Nut peanut butter and its investigation of the Peanut Corporation of America (PCA), and FDA's August 2010 egg recall.

The 2008 *Salmonella* contamination of tomatoes and other raw vegetables sickened 1,425 people—the largest number CDC has reported for any *Salmonella* outbreak. Arnade and colleagues (2013) found that consumers temporarily reduced purchases of tomatoes identified as contaminated, responding to the volume and timing of news coverage that repeated the warnings. The *Salmonella* contamination of Peter Pan and Great Value peanut butter sickened 425 individuals. Bakhtavoryan and colleagues (2012) examined retail demand for peanut butter before and after the Peter Pan recall and concluded that the brand did recover, though overall peanut butter demand underwent a structural change. Wittenberger and Dohlman (2010) examined the warning about foods containing PCA peanut products and found that consumer purchases slowed as the scope of the recalls spread. In effect, spikes in Internet search volume indicate likely reductions in retail food demand. As such, consumers were well acquainted with *Salmonella* warnings before the 2012 cantaloupe outbreak.

With a low fatality rate, searches for *Salmonella* were unlikely to continue indefinitely. Clearly, newspapers had many more risky issues to report and consumers had more substantive risks to negotiate. *Salmonella* contaminating a small portion of the cantaloupe supply might have rationally been ignored by consumers and the news media.

It is possible to empirically test whether consumers make reasoned choices when they find out that safety of a food has been compromised. Examining retail demand before and after information is released is a vehicle for doing so. When consumers are made aware that food safety has been compromised, a reasonable expectation is that demand will fall—quantity demanded falls even with prices unchanged. If consumers are making reasoned choices about the risk they find acceptable or unacceptable, the bigger risk ought to induce a bigger shift in retail demand. The next section examines retail demand for melons, separating out the weeks immediately after the first news about the *Listeria* and *Salmonella* outbreaks. The estimates yield a quantitative measure of consumers' responses to the two outbreaks and can reveal whether and to what extent consumers' responses differed. Finding similar responses would suggest that consumers do not make reasoned decisions about risks. Finding a larger response to *Listeria* news would suggest that the higher lethality of *Listeria* matters to consumers and that the news provided the information consumers rely on to make choices over risks they face.

Modeling Consumers' Purchase Behavior After Health Warnings

Knowing that Colorado farmers typically account for a small share of the U.S. cantaloupe supply after September (i.e., the date of the Jensen Farms' listeriosis-induced recall) means that other producers had to do little to accommodate the recall. There would have been no reason for retailers to find other sources of supply. As the product was branded, retailers that had Jensen Farms' products could easily remove them from the supply chain. Complex trace-back procedures, examining purchase and sales records, were unnecessary since the recall did not raise liability concerns for most suppliers. The *Salmonella* recall occurred under similar market conditions.

The recalls and warnings might have affected the supply side of the cantaloupe market if the recalls significantly reduced supply or if the warnings created financial incentives for suppliers to restrict supply. In either case, the quantity marketed would be, from the perspective of consumers' demand, exogenous. That is, the quantity supplied might be determined by suppliers rather than by consumers, as a function of relative prices. As such, demand analysis alone would be insufficient to capture market impacts.

But the recalled quantities were a fraction of the quantity produced. As most of the supply following each warning came from California and Arizona (and not from Colorado or Indiana), brands other than those implicated were not at risk. Thornsbury and Calvin (2011) cite early evidence that prices received by all cantaloupe farmers fell after the recall announcement. Given time, those prices might influence supply decisions, but the announcement was a surprise and thus unlikely to affect supply decisions for several months. Because the warnings created no financial incentives for suppliers other than those identified as having sold contaminated fruit, there were no incentives to restrict supply. In sum, the behavior of cantaloupe suppliers (responses to relative prices) ought not to have been affected by the warnings and recalls; the economic impacts were mostly limited to the demand for melons. But how far did demand fall and for how long?

Here, the linear approximate Almost Ideal Demand System (AIDS) was used to account for consumers' retail behavior (Deaton and Muellbauer, 1980). AIDS models specify budget shares of various goods (or a separable group of goods[10]) in a household's total expenditure as a function of prices and total expenditure (group expenditure). Demand for five types of melons was modeled using weekly retail point-of-sale store scanner data (described in greater detail in the next section). The typical share equation of the AIDS model is**:**

$$S_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \, ln(P_j) + \beta_i ln\left(\frac{E}{PI}\right) + \varepsilon_i$$

[10] Here, melons are considered to be a separable group. It is unlikely that there are other fresh fruits for which their prices would substantially affect consumers' expenditure allocations among melons. Melons are physically larger than all other fruit, so the way in which they are used and prepared has to be different from, say, blueberries. It is also unlikely that there are processed melon products that would substantially affect consumers' expenditure allocations among melons (fresh). Unlike many other fruits, melons are nonacidic and therefore not routinely canned. Freezing does change texture, so frozen products are substitutable with fresh only in particular uses.

where S_i represent the expenditure share of the i^{th} melon variety in total melon expenditures, here denoted as a budget share; P_j is the price of the j^{th} melon variety, and γ_{ij} is the corresponding coefficient representing the influence of natural logarithm of the j^{th} melon price on the budget share of the i^{th} melon variety. The term denoted E represents aggregate expenditures on melons. The linear approximate AIDS model estimated deflates expenditures by the Stone price index, *PI*, the log of which is the sum of share-weighted log prices. The term β_i represents the influence of price-deflated expenditures on the i^{th} budget share. Symmetry and homogeneity conditions are imposed by setting $\gamma_{ij} = \gamma_{ij}$ for all i and j, and $\Sigma_j \gamma_{ij} = 0$, respectively. Adding-up requires $\Sigma_i \gamma_{ij} = 0$, $\Sigma_i \alpha_i = 1$, and $\Sigma_i \beta_i = 0$.

For estimation, one share equation is dropped from the system to avoid singularity, but the dropped equation's parameters are recovered using the symmetry, homogeneity, and adding-up conditions. Uncompensated own-price elasticities (η_{ii}) and cross-price elasticities (η_{ij}), as well as conditional expenditure elasticities (η_i) can be calculated as $\eta_{ii} = -1 + \frac{\gamma_{ii}}{S_i} - \beta_i, \eta_{ij} = \frac{\gamma_{ij}}{S_i} - \beta_i \frac{S_j}{S_i}$, and $\eta_i = 1 + \frac{\beta_i}{S_i}$.

Market Impacts of the Announcements

To estimate the duration and magnitude of market impacts from the announcements, a set of dummy variables was added to the share equations, with a separate dummy variable for each week that might have shown an influence from the announcements. Each dummy variable was equal to 1 for a particular week and 0 elsewhere. For consistency with retail market data used in estimation, weeks are defined as Sunday through the following Saturday.

Each of the five budget share equations included 11 weekly dummy variables for the *Listeria* event and 11 weekly dummy variables for the *Salmonella* event. *Listeria* dummy variables were defined as follows.

$D_1 = \left\{ \begin{array}{l} 1, \text{ for week beginning September 4, 2011} \\ 0, \text{ all other weeks} \end{array} \right\}$

$D_2 = \left\{ \begin{array}{l} 1, \text{ for the week beginning September 11, 2011} \\ 0, \text{ all other weeks} \end{array} \right\}$

...

$D_{11} = \left\{ \begin{array}{l} 1, \text{ for week beginning November 13, 2011} \\ 0, \text{ all other weeks} \end{array} \right\}$

Dummy variables for the *Salmonella* outbreak were defined similarly, with the first variable equal to 1 for the week beginning August 12, 2012.

For the *Listeria* event, the first dummy variable was equal to 1 in the week beginning September 4, 2011. The CDC timeline of events indicates that on September 5, the Colorado Department of Public Health and Environment collected cantaloupes from the home of an ill person for *Listeria* testing. Newspaper reports about cantaloupes and *Listeria* first appeared on September 9. The last week modeled was the week beginning November 13, 2011, 4 weeks after FDA announced the findings of its environmental assessment of Jensen Farms. That is, dummy variables allowed for the last formal statement by health and safety officials to have impacts beyond its release date. News media coverage of the outbreak also influenced the date of the terminal dummy variable. Television news coverage of the event ended more than 3 weeks earlier, after which the volume of newspaper articles

on the event dipped considerably. Later articles on the *Listeria* event began to describe the event as one among many that new food safety regulations might address.

The dummy variables for the *Salmonella* event began with the week that started on August 12, 2012. The first four U.S. newspaper reports mentioning the event were on August 17, the same day that CDC made its initial announcement. CDC announced that it was collaborating with public health officials in several States and the FDA to investigate a multistate outbreak of *Salmonella* Typhimurium infections. Evidence pointed to cantaloupe grown in southwestern Indiana as a likely source of the outbreak. For symmetry with the *Listeria* dummy variables, 10 additional dummy variables were included in each share equation. The last such dummy variable identified the week beginning on October 21, 2012, by which time most newspaper reports about *Salmonella* and cantaloupe had mostly ceased.

Data Description

Proprietary data on food purchases from IRI, denoted InfoScan, were used to estimate retail demand for melons. Retail establishments—grocery stores, supermarkets, supercenters, convenience stores, drug stores, and liquor stores—across the United States and Puerto Rico provide IRI each week with a record of all transactions (revenue and quantity purchased). Some retailers provide data for a particular brick-and-mortar location, while others provide data for stores within a market area, keeping the store location of each transaction undisclosed. Each retailer defines geographic areas as they choose. Over 2009-12, the data were derived from scanner records of 43,554 (2009) to 46,021 (2012) individual stores and 130 (2009) to 131 (2012) market areas. Store revenue was used to reflect consumer expenditures. Summing the quantities (expenditures) from the individual store and market area data indicates the total U.S. weekly quantity purchased (expenditures). Then, weekly prices are constructed as unit values.

To maintain a consistent sample of stores across time, data from 2008 were excluded. Walmart was included in the sample at the beginning of 2009, greatly increasing average expenditures and quantities purchased and reducing average prices from that point onward.

IRI data include purchase information on 30 varieties of melons.[11] This level of detail is unnecessary for a focus on cantaloupe. Thus, information was consolidated into five melon varieties: cantaloupe, watermelon, mini seedless watermelon (including Mickey Lee/Sugarbaby), honeydew, and all others. Clearly, watermelon is the largest share of the melon market whether measured in expenditures, pounds, or budget share (table 1). The "all other" variety of melons is composed almost entirely of specialty varieties that are purchased in small quantities at prices substantially higher than the better known varieties.

Table 1
Descriptive statistics for weekly melon purchases 2009-2012

		Expenditures (million $)	Quantity (million pounds)	Price[1] ($/pound)	Budget share[2]
Cantaloupe	Mean	8.0	14.2	0.62	0.36
	Std. dev.	3.9	8.4	0.13	0.09
Watermelon	Mean	13.0	31.8	0.76	0.41
	Std. dev.	12.4	38.4	0.35	0.14
Mini seedless watermelon	Mean	2.1	2.9	0.73	0.09
	Std. dev.	1.1	1.7	0.06	0.02
Honeydew	Mean	1.4	1.6	0.95	0.07
	Std. dev.	0.5	0.8	0.13	0.02
All others	Mean	1.4	0.6	2.65	0.07
	Std. dev.	0.4	0.3	0.51	0.03

[1] The price variable is a unit value, calculated as expenditures/quantity each week. These calculated prices were used to estimate the demand model, and the average of these weekly unit values is presented here. For each melon variety, the mean of the weekly unit values is always higher than the mean of expenditures/mean of quantity. That follows as the mean of the weekly unit values is not weighted by quantity purchased.

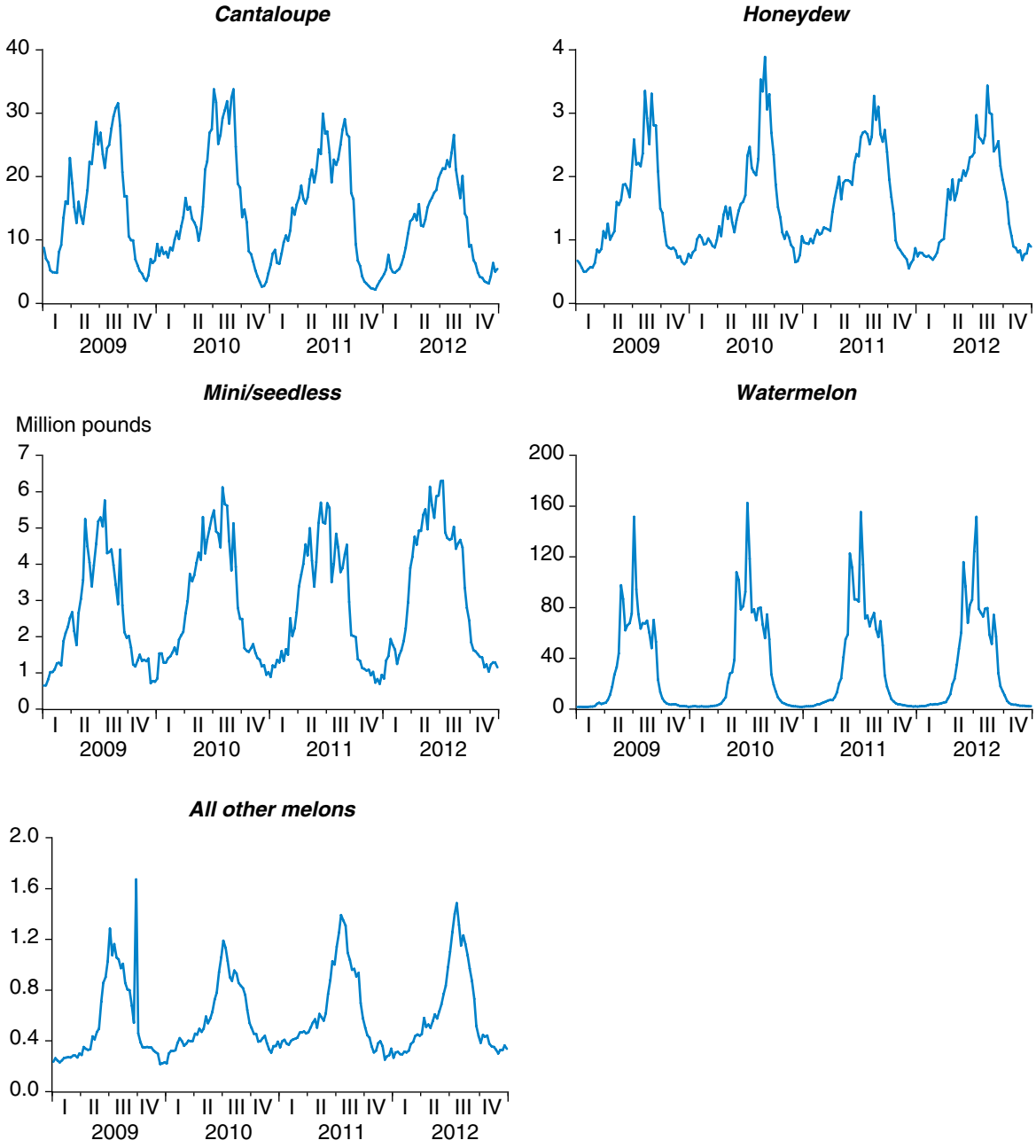
[2] Budget shares are expenditures on a particular item as a share of all expenditures on the group.

Source: USDA/Economic Research Service computations using IRI InfoScan data, 2009-2012.

[11] Canary, Cantaloupe, Casaba, Charentais, Cinnebar, Crenshaw, French Afternoon, French Breakfast, Galia, Golden Honeydew, Honeydew, Mayan, Mickey Lee/Sugarbaby, Mixed, Muskmellon, Orangeflesh, Other, Other Watermelon, Pepino, Persian, Pieldesapo, Prince, Santa Claus, Santicoy, Sharlin, Spanish, Temptation, Watermelon, Watermelon Mini, and Yellow Watermelon.

Impacts of the warnings are hypothesized to be shortlived. To identify impacts, data have to be reported frequently. As such, means and standard deviations calculated across the entire 4-year time period do not convey one of the major attributes of the data: pronounced annual cycles. In recent years, melon purchases have occurred year round. However, peak quantities purchased of watermelons (approximately 160 million pounds per week) are two orders of magnitude higher than trough quantities purchased (1.6 million pounds per week), whereas cantaloupe averages between 5 and 35 million per week (fig. 3). Prices move in largely the opposite pattern, with lowest prices in the middle of the third quarter (summer) each year, when the supply of melons is greatest.

Figure 3
Quantities of various melons purchased weekly in the United States



Source: IRI InfoScan data, 2009-2012.

Results

Estimating Retail Melon Demands

Table 2 shows results of the AIDS model estimated with melon data from IRI. A seemingly unrelated regression procedure was used to estimate the model (EViews 8). Budget share equations were estimated for cantaloupe, honeydew, mini/seedless, watermelon, and all other melons using 209 weekly observations. Coefficients and t-statistics for the "all other" melons equation, the equation dropped from the system estimation, were calculated using adding-up, symmetry, and homogeneity. Initial estimation showed evidence of first-order autocorrelation in residuals. A first-order autocorrelation term on the errors was added to each equation. For consistency with adding-up, these coefficients (rho in table 2) were restricted to be the same across equations (Berndt and Savin, 1975).

Despite the magnitude of annual cycles in prices, quantities purchased, and expenditures, prices and expenditures largely explained demand for melons. However, there is evidence of seasonality in demand beyond what prices and expenditures can explain.

The regularity of those cycles suggests that they might be substantially accounted for with a small set of explanatory variables rather than a set of 51 weekly dummy variables (or 52 with no constant term in the regression). To address the remaining seasonality, an annual harmonic (a generalized sine wave) was added to each share equation. In general, such waves take the form $Rcos(\frac{2\pi}{\tau}t - \phi)$, where R is the semi-amplitude, t is a time variable, and τ is the number of observations per cycle (52), so that $2\pi t/\tau$ converts the time variable to radians, and ϕ is the phase angle, which identifies the week in which the seasonal maximum occurs (Arnade et al., 2005). In practice, all the parameters of the annual harmonic can be estimated by invoking the cosine angle difference formula to split the harmonic into two linear terms: one cosine and one sine. The two terms were added to each budget share equation. Here, the time variable is defined as $t = 0, 1, 2, \ldots, 208$.

Most, but not all, of the price and expenditure coefficient estimates are statistically significant at conventional significance levels. But results from share-based models are easiest to discuss in terms of price and expenditure elasticities. The own-price elasticities all indicated that each melon demand was price elastic, with estimates from -1.14 (all other) to -1.89 (honeydew). All but two of the estimated cross-price elasticities are positive, and those two are not statistically significant. The cross-price elasticities generally indicate that melons substitute for each other to some extent.

Estimating Consumers' Responses to *Salmonella* and to *Listeria*

The demand model with the dummy variables for weeks following the two events is designed to provide evidence that would help answer whether consumers' responses were different. If the results of estimation showed consumers responded to both, it might have been difficult to judge whether the responses were similar or not. Judging amounts to comparing the magnitudes of a group of parameter estimates from one time period with the magnitudes of a group from another time period. It might not be immediately obvious which is larger or if there is a difference at all. Here, results are unambiguous—the response to *Listeria* is clearly larger.

For the *Salmonella* event, there is nothing to indicate that consumers' purchase patterns changed. Of the 55 dummy variables[12], coefficient estimates were not significantly different from zero at conven-

[12] Adding-up conditions were used to derive coefficient estimates and standard errors for dummy variables from the dropped equation (all other melons).

Table 2

Results of melon demand estimation: Coefficient and elasticity estimates[1]

	Coefficient	t-Statistic	Elasticity	t-Statistic
Cantaloupe budget share equation				
Constant	0.0758	0.67		
ln cantaloupe price	-0.2421	-17.89**	-1.69	-43.93**
ln honeydew price	0.0269	4.79**	0.07	4.54**
ln mini price	0.0279	4.19**	0.07	3.93**
ln watermelon price	0.1818	15.67**	0.49	15.87**
ln all other melons price	0.0056	0.73	0.01	0.59
ln expenditures/Stone index	0.0140	2.11*	1.04	55.88**
Cos	0.0235	2.03*		
Sin	-0.0015	-0.20		
Honeydew budget share equation				
Constant	0.1106	2.22*		
ln cantaloupe price	0.0269	4.79**	0.40	5.08**
ln honeydew price	-0.0607	-7.41**	-1.89	-15.50**
ln mini price	0.0040	0.78	0.06	0.80
ln watermelon price	0.0246	4.25**	0.37	4.81**
ln all other melons price	0.0052	1.55	0.08	1.57
ln expenditures/Stone index	-0.0016	-0.54	0.98	22.25**
Cos	0.0113	2.56*		
Sin	-0.0060	-2.28*		
Mini/seedless budget share equation				
Constant	0.2372	3.62**		
ln cantaloupe price	0.0279	4.19**	0.35	4.69**
ln honeydew price	0.0040	0.78	0.05	0.88
ln mini price	-0.0651	-8.41**	-1.72	-19.50**
ln watermelon price	0.0369	5.19**	0.45	6.12**
ln all other melons price	-0.0038	-0.86	-0.04	-0.72
ln expenditures/Stone index	-0.0079	-2.05*	0.91	20.92**
Cos	-0.0203	-3.35**		
Sin	0.0086	2.40*		
Watermelon budget share equation				
Constant	-0.1136	-0.56		
ln cantaloupe price	0.1818	15.67**	0.41	13.12**
ln honeydew price	0.0246	4.25**	0.05	3.82**
ln mini price	0.0369	5.19**	0.08	4.71**
ln watermelon price	-0.2491	-17.50**	-1.63	-47.32**
ln all other melons price	0.0059	0.78	0.01	0.47
ln expenditures/Stone index	0.0318	2.56*	1.08	35.92**
Cos	-0.0293	-2.52*		
Sin	0.0017	0.21		
All other melons budget share equation				
Constant	0.6901	3.63**		
ln price cantaloupe	0.0056	0.73	0.26	2.02*
ln price honeydew	0.0052	1.55	0.11	2.20*
ln price mini	-0.0038	-0.86	-0.01	-0.13
ln price watermelon	0.0059	0.78	0.29	2.56*
ln price all other melons	-0.0129	-1.76	-1.14	-11.09**
ln expenditures/Stone index	-0.0363	-3.16**	0.49	3.09**
Cos	0.0149	1.54		
Sin	-0.0028	-0.51		
Rho	0.7899	33.71**		

[1] Statistical significance at 0.01 denoted by **, at 0.05 by *.

Source: Author's calculations using IRI InfoScan data, 2009-12.

tional levels of significance (0.05) for 54 variables. Random chance alone might have yielded more variables meeting a test of statistical significance.

There is an indication that consumers responded to the *Listeria* warning, eventually cutting back purchases of cantaloupe and substituting honeydew and watermelon. Figure 4 plots the coefficients on the *Listeria* dummy variables (dark lines) over the 11-week period starting September 4, 2011, when the news first broke. Each of the coefficient estimates is surrounded by 95-percent confidence intervals (2 standard errors each side). The confidence intervals offer a systematic way of identifying weeks in which dummy variables are decidedly positive or negative. That is, confidence intervals in which upper and lower limits are above zero strongly suggest that budget shares were abnormally high—too high to be explained as the result of market prices and consumers' income. Confidence intervals in which upper and lower limits are below zero point to abnormally low budget shares.

Confidence intervals on the budget share dummy variable coefficients (for cantaloupe) are entirely below zero for 4 weeks beginning October 9, 2011. In contrast, honeydew budget share dummy variables are higher than normal for 3 weeks beginning October 2, 2011.[13] And watermelon budget shares are abnormally high over the same period that cantaloupe shares are low.

The budget share dummy variables indicate changes in budget shares and can be used to solve for changes in quantities demanded. As weekly budget shares for a melon variety are defined as $S_i = \frac{P_i Q_i}{E}$, under the assumption that prices and melon expenditures are exogenous, the changes in budget shares are reflected in quantity changes: $\Delta S_i = \frac{P_i \Delta Q_i}{E}$. This equation can be solved for changes in quantity demanded, given exogenous weekly prices and expenditures along with changes in budget shares. The total for the 4-week period left U.S. cantaloupe purchases 6.2 million pounds below normal. Honeydew sales were up for 3 weeks, for a total of 1.0 million pounds. And watermelon purchases were up 3.7 million pounds over a 4-week period.

Expenditures on melon varieties, $P_i Q_i$, were also reallocated ($P_i \Delta Q_i$) after the listeriosis outbreak. Cantaloupe purchases fell $3.9 million, and honeydew and watermelon increased $0.9 million and $3.2 million, respectively, over the 4-week period. The average (2009-10) weekly expenditures on cantaloupe during October were $14.4 million. The $3.9-million dropoff represents a 6.7-percent reduction over the 4-week period.

The pattern of dummy variable magnitudes suggests that consumers understood the message from Federal health and safety officials and reduced purchases of cantaloupe. At the same time, consumers apparently parsed the warning closely and recognized that other melons were safe to consume. The reaction was relatively modest and temporary, in keeping with Sandman's characterization of adjustment to new risks.[14]

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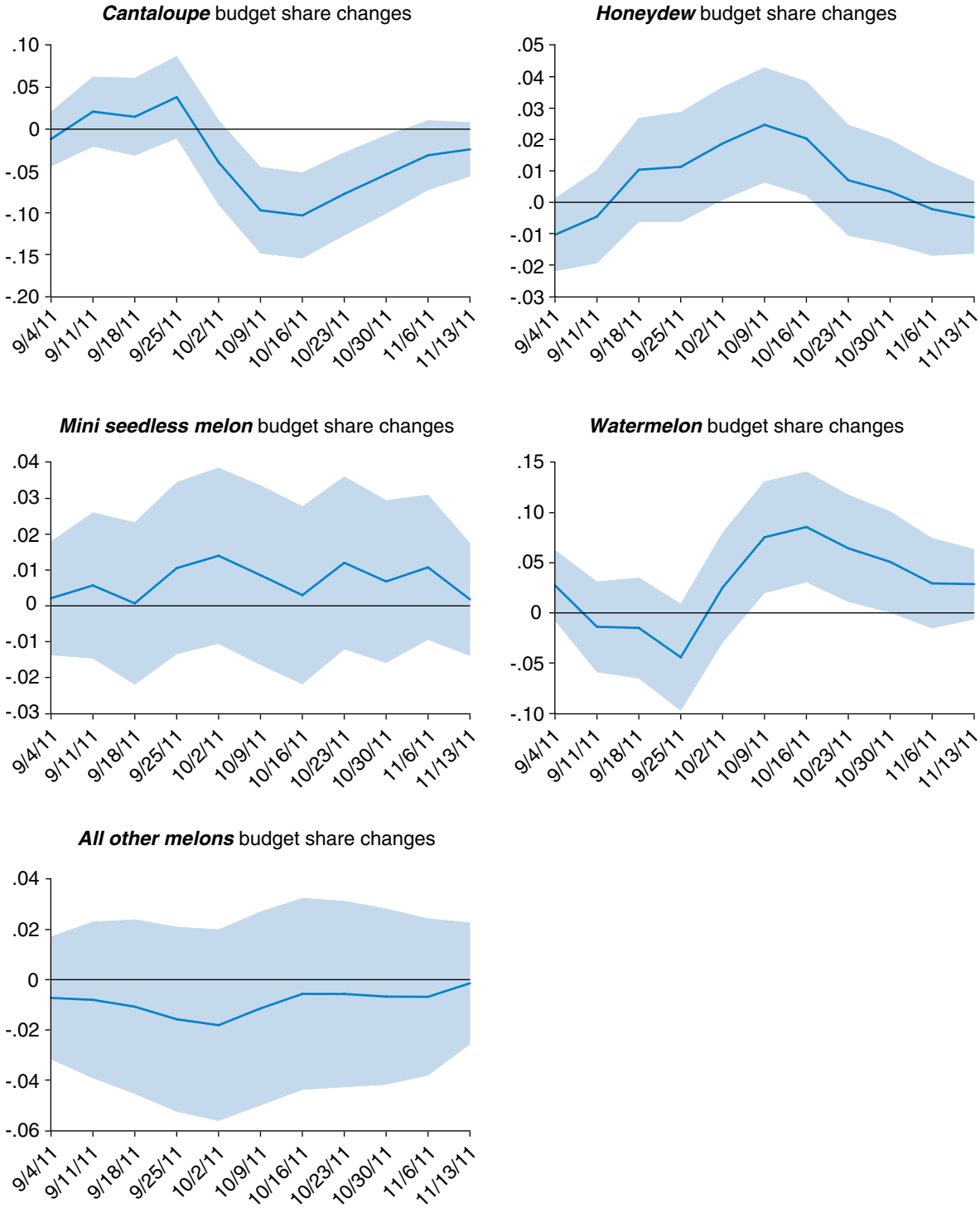
[13] The first major spike in the newspaper report series occurred a few days before the melon demand model shows the cantaloupe budget share dummy variable becoming statistically significant.

[14] Entirely different conclusions might be drawn if there was evidence that consumers fled from melons. Here, consumers are assumed to make two-stage budgeting decisions, first choosing to allocate expenditures among groups of foods, one of which is melons. Then, expenditures on melons are allocated among the varieties. If consumers reduced expenditures on the melons group, the impact of the warnings would not be confined to allocating expenditures among melon varieties. Unfortunately, there is not enough data to judge whether melon expenditures during 11 weeks in the fall of 2011 were unusually low. As the data display annual cycles and the first data available come from 2009, there are effectively two observations that might be used to establish a baseline for comparison with expenditures in 2011. More data cycles would have to be observed before 2011 to credibly establish a baseline for comparison with 2011 expenditures.

Figure 4

Weekly changes in budget shares (dark lines) associated with the 2011 listeriosis outbreak

Estimates surrounded by two-standard-error bands



Source: Authors' calculations using IRI InfoScan data, 2009-12.

Conclusions

Empirical evidence points to consumers reacting when Federal health and safety officials recalled cantaloupe in 2011 because of contamination with *Listeria monyocytogenes.* Consumers temporarily reduced purchases of cantaloupes, even after accounting for the influence of prices and income. And they seemed to receive the message that other melons were safe: purchases of watermelon and honeydew increased. A year later, Federal health and safety officials again recalled some cantaloupe, this time for *Salmonella* contamination. There is no evidence that consumers responded to the second recall. News media appear to be associated with the differing consumer responses: there was television and newspaper coverage of both outbreaks, but the *Listeria* outbreak received substantially more coverage than the *Salmonella*.

Some attributes of the listeriosis outbreak were unique. A pathogen had found a new way into the food supply, after being linked only to meat before. The pathogen had a high fatality rate and was especially hazardous for the elderly and pregnant women. This event received media attention, and consumers took advantage of the new information to protect themselves. Further, by the time the salmonellosis outbreak occurred, several earlier salmonellosis outbreaks had alerted consumers and reduced their demand for the implicated foods, with few fatalities. Under those conditions, alarm or a dramatic swing in purchases by consumers seems unlikely.

If retail food demand does shift in response to the magnitude of foodborne disease risks, those shifts might result in greater food safety. When consumers are alerted to a food safety problem and they decide to avoid the risk and spend their money on other goods, they exhibit more control over food safety than do food safety regulators. Unlike regulatory actions that might be slowed by legal challenges, withholding purchases can quickly put firms out of business; all the resources put into building a brand can be wiped out. If information given to consumers precisely identifies products that are unsafe, consumers' individual choices might rapidly punish firms that were not vigilant about food safety. Consumers' choices would create strong incentives for suppliers to make food safe.

Here, however, the demand shifts were slightly mistimed to accomplish that task perfectly. Melon demands shifted a month after the recall. By that time, supplies were sourced outside Colorado and the costs imposed by consumers' choices accrued to suppliers who had nothing to do with compromised food safety. That is, there are still welfare gains possible from better communication between health/safety officials and consumers.

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