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# Economic damages of food-safety incidents in complex markets: 2018 *E. coli* outbreak and romaine lettuce

Processors lose the most from leafy greens food-safety incidents because they incur the most financial burden for product that cannot be harvested or sold.

by Ashley Spalding, Rachael E. Goodhue, Kristin Kiesel and Richard J. Sexton

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## Abstract

Food-safety incidents are costly for everyone in the leafy greens industry. However, it is challenging to estimate the size and distribution of these costs in today's complex supply chains. Extensive use of formal contracts in markets such as leafy greens obscures prices and other terms of trade from the public view. Using proprietary data on prices and sales from a major leafy greens processor operating in the retail and food-service sectors, we are able to separately estimate short-run damages associated with the November 2018 romaine *Escherichia coli* advisory for growers, shippers, processors, retailers, and food-service operators. Due to fixed prices in grower-processor contracts, growers were only minimally impacted by the advisory. Processors, meanwhile, lost approximately \$55.3 million from price and quantity impacts. Retailers incurred \$14.1 million in losses after pulling product from distribution channels and shelves. Food-service operators were less impacted because lower prices offset losses from destroying potentially contaminated products. Moving forward, the best way to mitigate losses during food-safety incidents is fast and efficient traceability.

Food-safety incidents are pervasive and have widespread effects on supply chain participants. After identifying an outbreak (two or more epidemiologically related incidents), the U.S. Food and Drug Administration (FDA) and Centers for Disease Control and Prevention (CDC), in coordination with state and local health agencies, investigate foodborne illness outbreaks to determine the source of the outbreak and prevent additional illnesses linked to that outbreak. Public health agencies issue advisories to identify actions to protect consumers, such as avoiding selling or consuming foods linked to the outbreak. In instances where a product from a specific firm is identified, a recall may be initiated, either voluntarily by the firm, or as requested by the FDA. This causes supply chain participants to lose revenue from product that cannot be sold, and also from reduced consumer demand due to food-safety concerns.

Results from an analysis of the 2018 *E. coli* outbreak suggest that in leafy greens supply chains, provisions in grower-processor contracts largely shielded growers from economic losses.  
Photo: iStock.

California produces approximately 75% of the nation's lettuce and leafy greens, the produce category most frequently linked to food-safety outbreaks (CDFA 2021). As a result, California growers are often implicated in and/or affected by outbreaks of foodborne illnesses. From 1996 through 2016, the California Department of Public Health, Food and Drug Branch (CDPH-FDB) identified 46 outbreaks related to California leafy greens (Turner et al. 2019). From 2016 through September 2021, FDA and CDC investigated 36 *Escherichia coli* (*E. coli*) and salmonella outbreaks associated with fruits, vegetables, or nuts. Nine were traced back to California entities, resulting in two advisories and seven recalls of varying size (FDA 2021). Table 1 summarizes these nine outbreaks.

While some recalls have been narrow in scope, other outbreaks have been characterized by uncertainty and lack of information for regulators and market participants as to the extent of implicated products and regions. A study of the economic implications of these outbreaks will aid in understanding how the scope of an advisory impacts the distribution of resulting losses. The November 2018 and November 2019 *E. coli* outbreaks, ultimately traced to romaine lettuce, resulted in broad advisories impacting production that was later determined not to have been implicated in the incident. The result was widespread industry damages.

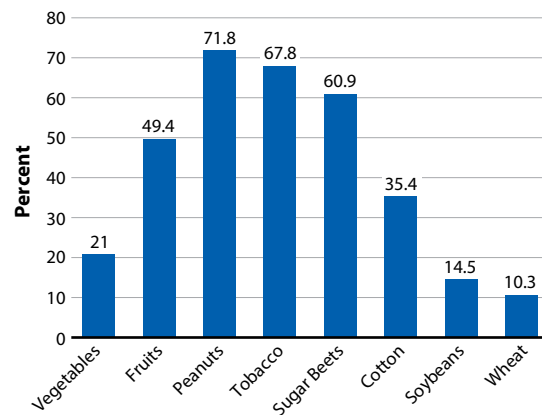
Researchers have sought to quantify the economic damages to industry members from food-safety incidents. The challenge has been in obtaining the information necessary to determine the full scale of damages. For a public company, changes in stock prices may be used (McKenzie and Thomsen 2001; Pozo and Schroeder 2015). However, many companies in the agro-food chain are privately held, limiting the scope of this approach. Spot-market prices are publicly reported by the U.S. Department of Agriculture (USDA), but for many commodities these represent only a small portion of the market.

In this paper, we address how the expansion of contract production in industries such as leafy greens over the past half century complicates the measurement of

damages and their diffusion across supply-chain participants. Using a combination of proprietary price and sales data from an industry partner, retail scanner sales data from Nielsen, and publicly available spot prices, we estimate damages to grower-shippers and processors, retailers, and food-service operators resulting from the November 2018 romaine *E. coli* advisory and its aftermath. We then discuss how government regulation and industry collective action can limit damages from food-safety incidents.

## Contracts assign risks

The structure of produce supply chains has changed dramatically in past decades in ways that may affect how damages from food-safety incidents are transmitted to industry participants, how participants respond, and their incentives to avoid such incidents going forward. Increasingly, exchange in the produce industry is governed by formal contracts. Nearly one-third of the value of agricultural production was governed by contracts in 2019 compared to just 11% in 1969 (MacDonald 2015; USDA ERS 2020). The share under contract varies significantly across commodities and commodity groups (fig. 1).



**FIG. 1.** Percent of U.S. agricultural production under contract by commodity or commodity group in 2019. Source: USDA ERS 2020.

**TABLE 1.** Public health advisories from investigations of *E. coli* and salmonella foodborne illness outbreaks traced to California produce, 2016–2021

Date	Product	Pathogen	Total illnesses	Recall	Advisory
Apr 2021	Cashew brie	Salmonella	20	Yes	No
Dec 2020	Leafy greens	<i>E. coli</i>	40	No	No
Fall 2020	Leafy greens	<i>E. coli</i>	18	Yes	No
Aug 2020	Peaches	Salmonella	101	Yes	No
July 2020	Onions	Salmonella	1,127	Yes	No
Dec 2019	Salad mix	<i>E. coli</i>	10	No	No
Nov 2019	Romaine	<i>E. coli</i>	27	Yes	Yes
Nov 2018	Romaine	<i>E. coli</i>	62	Yes	Yes
Mar 2016	Pistachio	Salmonella	11	Yes	No

Source: FDA, CDC.



Uncontracted produce not produced under vertical integration or sold directly to consumers is sold through shipping point (spot) markets. Shipping points are the first stage in the post-farm supply chain for spot sales; the concept refers to the district from which produce is originally shipped to processors, retailers, or distributors. The USDA's Agricultural Marketing Service (AMS) reports crop prices at shipping point and terminal markets across the United States and in parts of Mexico, making spot prices readily available.

In a supply chain that relies exclusively on spot sales, the incidence of damages is relatively easy to assign. Growers bear the costs of plowing under crops that cannot be sold and of harvested product for which the processor has not taken delivery. The processor bears the cost of product that cannot be marketed from the time it takes delivery to the time the retail or food-service buyer receives the product. The retail or food-service buyer bears the cost of unmarketable product in its possession. The loss due to reduced consumer demand due to avoidance of the impacted product is distributed across supply chain members according to the relative price responsiveness of the buyers' demand functions and sellers' supply functions.

Contracted product is more easily traceable than spot-sale product in the event of a food-safety incident; however, the private nature of contracts makes it difficult to compute the full scope of damages or determine who incurs them. From the point of view of researchers and public agencies, contracts obscure prices paid and received and may stipulate cost-sharing practices and product liabilities that are not obvious to outside observers. In many instances, contracting processors assume partial or full responsibility for the variable costs of growing and harvesting the product. Contracts may also specify who is liable for product that cannot be delivered due to recalls and/or safety advisories. These

terms vary across commodities and contract partners. For many commodities, the structure of specific contract terms may be similar across contracts accounting for a significant share of production. Figure 2 summarizes common contract terms for the leafy greens industry.

Nearly all leafy greens are procured from growers or grower-shippers through contracts with processors; industry sources estimate that spot markets account for only about 10% of sales. Most often, contracts are for a season/year. Contract terms vary, but it is common in the leafy-greens industry for grower-processor contracts to have fixed prices, as shown in figure 2. Grower-processor contracts for romaine often stipulate that growers will be paid a fixed price per acre planted rather than by weight or other product characteristics. Once the crop is planted, the processor has the right to determine whether it is harvested or plowed under. This arrangement enables the processor to adjust harvest schedules as needed based on projected demand and respond to unanticipated changes in demand post-planting.

Another type of contract less commonly used involves both the grower and the processor bearing some of the risks associated with a recall. Contracts also define which party is responsible for harvest costs. Typically, the buyer pays rather than the grower. A single processor may use different contracts with different growers, and the processor's ability to set contract terms rather than negotiate can vary, depending on such factors as the acreage/volume the grower can supply and the harvest season for the grower's output.

Contracts between processors and retailers are generally negotiated between the two parties and signed for one or two years. Most often, prices are fixed, while the retailer has some flexibility to determine its purchase quantity. In contrast, contracts negotiated between processors and food-service buyers include a minimum quantity purchased and a two-part pricing mechanism: a base price and a "trigger" price linked to the spot price. If the trigger price is reached or exceeded, then the price for contract deliveries increases above the base price.

The impact of food-safety incidents on participants in the leafy greens supply chain is very strongly influenced by the nature of contracting at every level of the supply chain, i.e., between grower-shippers and processors and between processors and their downstream buyers in retail and food service. At the farmgate level, only spot-market sellers are fully exposed to the forces of supply and demand in effect during a food-safety incident. Processors bear losses for contracted product that cannot be harvested or is not profitable to harvest due to a food-safety incident. They also incur losses based on the volume of harvested product in their possession at the time of the incident that cannot be sold, due either to a recall or to reduced consumer demand in response to the incident. Losses to retailers and



**FIG. 2.** Common contract terms in the leafy greens industry.

food-service buyers depend on the amount of unsalable product in their possession at the time of the incident.

## November 2018 outbreak

On November 1, 2018, U.S. and Canadian health and regulatory agencies, including the CDC, the FDA, and various state partners, launched an investigation into an outbreak of *E. coli* O157:H7 infections spanning multiple states and provinces, reported from October 8 through October 31. On November 20, 2018, health agencies in both countries issued a food-safety advisory, calling on consumers not to eat and restaurants and retailers not to serve or sell any romaine lettuce or salads containing it. At the time of the advisory, 50 people from 11 states and two provinces had reported illnesses, only one of whom had been hospitalized.

Figure 3 illustrates how the geographic scope of the advisory for romaine production in California evolved over time. The advisory initially covered all romaine production in California and elsewhere. CDC updates issued on November 26 and December 6 reduced the geographic scope of the advisory until, on December 13, only romaine from Santa Barbara, San Benito, and Monterey counties remained subject to the advisory.

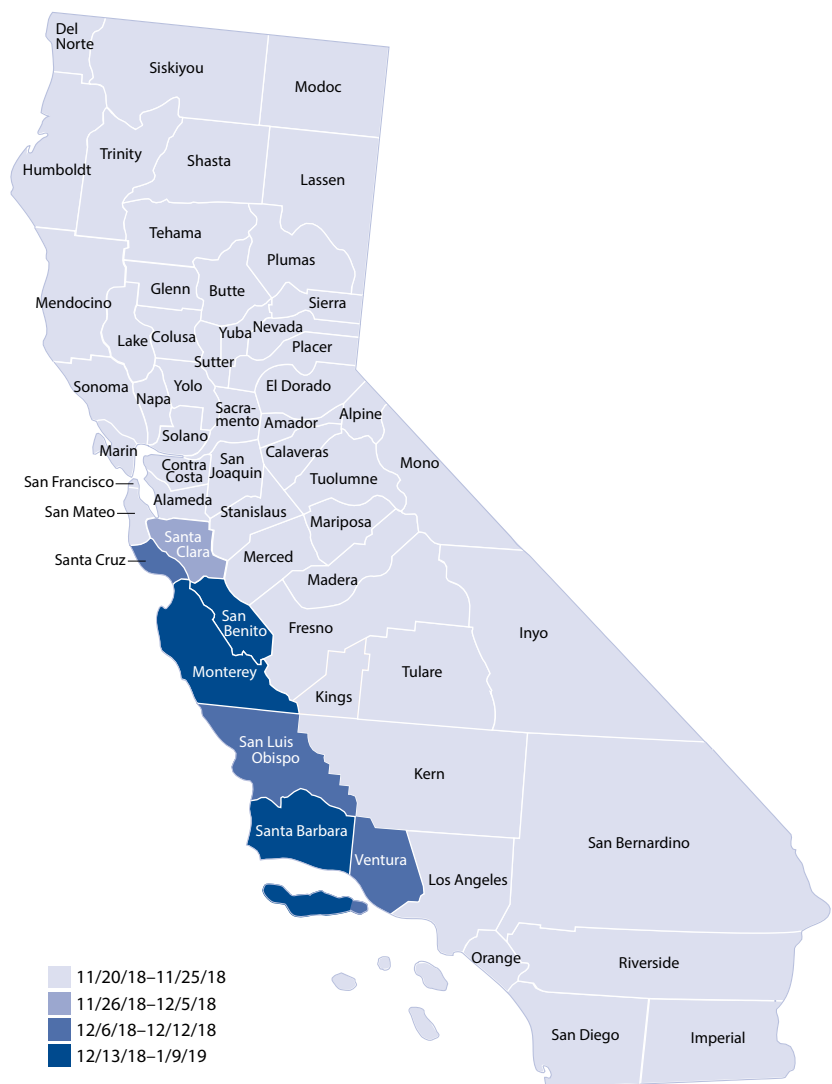
That day, investigators located the outbreak strain in a reservoir on a farm owned by Adam Bros. Farming, Inc. (a grower-shipper of leafy greens in Santa Barbara County), but did not rule out other sources of contamination (FDA 2019). The company had not shipped romaine since November 20 but voluntarily recalled all red leaf lettuce, green leaf lettuce, and cauliflower harvested between November 27 through November 30 out of an abundance of caution (FDA 2018). While the investigation continued for several weeks, no additional sources were identified.

## Estimating economic damages

We estimated economic damages associated with the advisory and its aftermath using the methodology described in Spalding et al. (2022). Note that the aftermath is the short-run period following lifting of the advisory. In the longer run, growers may need to rotate land out of lettuce due to reduced demand, and buyers in both channels may move away from using romaine, either of which could result in additional economic damages. Specific firms could also incur reputational damage.

We separately estimated losses to growers, processors, retailers, and food-service operators, as well as losses to consumers and providers of inputs to the industry. The broad scope of this analysis is facilitated by access to proprietary data on prices and sales within the leafy greens supply chain from a cooperating processor who serves both food service and retail.

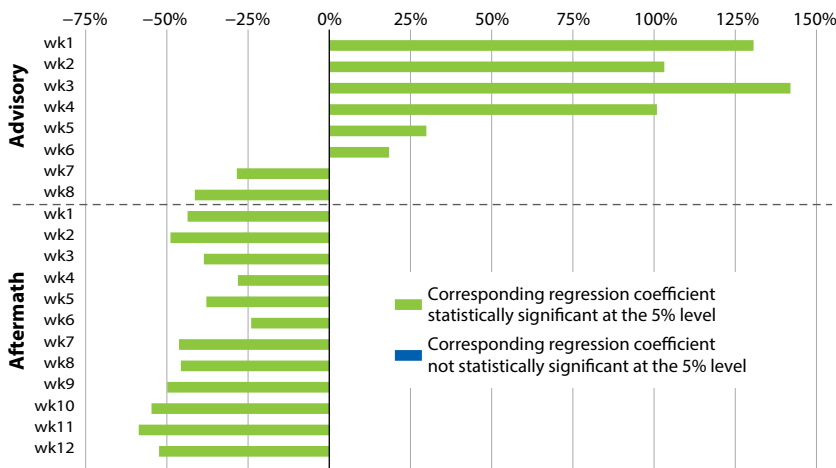
Similar to Spalding et al. (2022), the proprietary data used to study the food service includes the processor's cost of acquiring romaine from growers, pounds



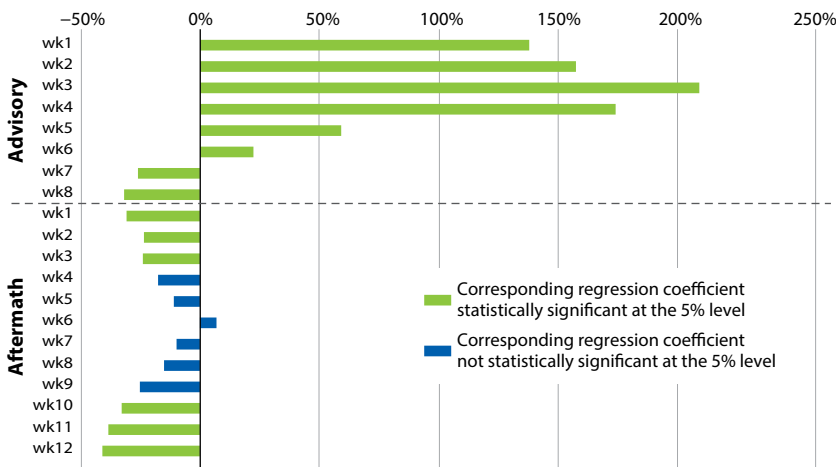
**FIG. 3.** Geographic scope of advisory associated with the November 2018 outbreak over time. The 11/20/18–11/25/18 advisory also included all growing regions outside of California.

shipped, wholesale price obtained, and the processor's cost of labor per pound. Data regarding the retail channel included weekly pounds sold and revenues obtained from romaine and iceberg products identified by stock-keeping unit (SKU), as well as monthly procurement costs for romaine and iceberg lettuce.

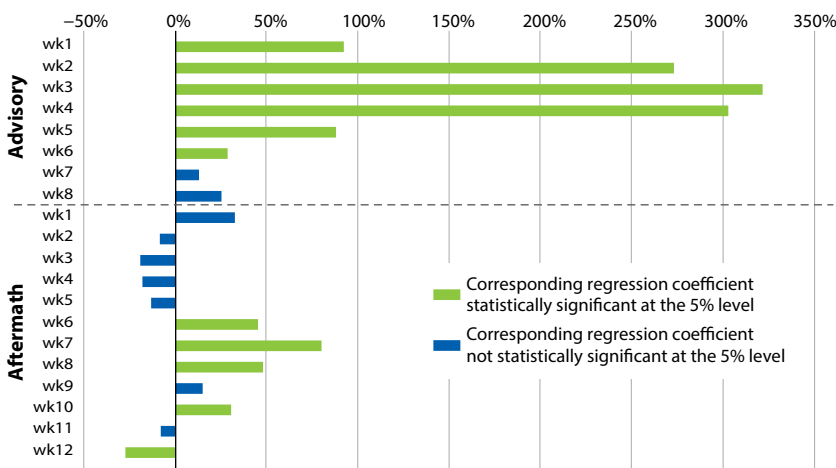
Processing costs are likely quite similar across major firms because contracting practices are quite uniform across the industry for each marketing channel, and the technology of the processing plants producing bagged-salad products is rather basic and common among them. In addition, the processing facilities are all located in relatively close proximity within the localized producing regions. Accordingly, using these proprietary firm-specific data should allow a reasonable estimation of industry-level damages. We combined these data with public data on spot-market prices provided by the USDA-AMS and scanner data on national-level retail prices and sales for prepackaged salads by universal product code (UPC) from Nielsen.



**FIG. 4.** Percentage change in average North American farmgate spot-market price for romaine hearts associated with each week of the advisory and aftermath relative to the counterfactual.



**FIG. 5.** Percentage change in average North American farmgate spot-market price for romaine heads/leaf associated with each week of the advisory and aftermath relative to the counterfactual.



**FIG. 6.** Percentage change in average North American farmgate spot-market price for iceberg lettuce associated with each week of the advisory and aftermath relative to the counterfactual.

## Losses in each stage

Damages to supply-chain actors from the incident and its aftermath include both price and quantity effects. The price effects result from disruptions to supply and demand. The quantity effects are caused not only by removal of the romaine product under advisory from the supply chain, but also from reduced demand for romaine product not covered under the advisory. Quantity-based damages from removing product from the supply chain depend on the product's stage in the supply chain at the onset of the advisory. Each unit of harvested romaine removed from the supply chain already had incurred most or all production and handling costs, creating losses for processors, retailers, and food-service operators who were responsible for the product under their control but could not recoup costs through product sales. Losses per pound were lower for romaine that was planted but removed from the supply chain prior to harvest due to reduced demand, because harvest and post-harvest costs were not incurred.

We used multivariate regression analysis to predict what prices and sales would have been absent the *E. coli* advisory. This analysis detected the incident's impacts on the market for up to 12 weeks after the advisory was lifted. Comparisons of these counterfactual prices and quantities to the actual prices and quantities during the advisory period and the 12 weeks immediately following it, henceforth known as the aftermath period, yield estimates of impacts from price changes and lost sales.

## Safe product earned premium

Results indicate that farmgate spot-market prices for romaine hearts and romaine heads and leaf increased for the first several weeks of the advisory period, relative to their counterfactual values. Grower-shippers and processors who had safe romaine to sell earned a premium in these early weeks due to the significant reduction in supply, but eventually faced reduced demand due to the incident, which caused prices to fall. Prices decreased beginning in week 7 of the 8-week advisory and remained lower for as long as an additional 12 weeks in the aftermath of the advisory. Conversely, spot prices for iceberg lettuce increased throughout the advisory relative to counterfactual values, consistent with statements by multiple industry stakeholders that buyers sought to replace romaine with iceberg.

Figures 4 through 6 illustrate the estimated spot-market price changes for each week of the outbreak and its aftermath. Green bars indicate that the point estimates underlying the estimated percentage price changes were statistically significant at the 5% level. Conversely, blue bars represent weeks in which the estimated price effect was not statistically significant at the 5% level. For a given variable, we concluded that the effect of the advisory had dissipated if the estimated effects of the weekly indicator variables were not statistically significant for three consecutive weeks. In such



Overall, the romaine lettuce industry incurred damages of roughly \$70 million due to the advisory and its aftermath. Photo: Elena Zhukova.

instances, we set the estimated effects for those weeks and all later weeks to zero. We included all estimated effects prior to the three-week period, or throughout the entire aftermath period if no three-week period existed, regardless of their significance level.

The effect of the advisory on the processor's acquisition costs varied by supply channel and week. We estimate that the processor that provided our data incurred higher weekly acquisition costs that ranged from 21% to 29% in the retail channel throughout the study period. In the food-service channel, the processor's weekly acquisition costs increased by between 83% and 124% across weeks 2–4 of the advisory before returning to around the same levels as in the counterfactual. Because prices received by contract growers are typically fixed in the retail channel, increases in acquisition costs reflect loss of harvested product due to the advisory and costs associated with plowing under unsalable product or harvesting product at suboptimal times due to the advisory. Contracts in the food-service channel may have built-in price triggers, so cost increases in this channel reflect a combination of these costs as well as price increases.

### Price paid to processors

Compared to the no-outbreak counterfactual, the price paid to processors by food-service operators increased in the early weeks of the outbreak before modestly decreasing in the remaining weeks of the advisory and aftermath, likely because of reduced demand. In the retail channel, prices received by processors for bagged products containing romaine (e.g., kits and blends) decreased by 25% to 37% in the first full week of the advisory (week 2) followed by modest decreases (< 8%) for blends through week 6, 11% increases for premium classics through week 6, and small increases (< 10%) for kits throughout the study period, reflecting the fixed-price aspect of most retail contracts. Similarly, prices charged at retail for bagged products containing romaine were consistent across the study period.

Consequently, retailers' margins on bagged products remained relatively stable.

### Romaine sales fell

We estimated changes in sales volume associated with the advisory using an econometric model and Nielsen retail sales data and data on sales to food-service operators from our cooperating processor from January 2017 through December 2019. Processor sales of romaine leaf to food-service operators decreased 73% in the initial week of the advisory and sustained more modest decreases through week 10 of the aftermath. Retail sales for all romaine products decreased dramatically in the initial weeks of the outbreak due to product being removed from shelves. The largest decreases, 97%, occurred in week 2, the first full sales week after the advisory. Sales for romaine hearts remained lower through the remaining weeks of the advisory and 11 weeks of aftermath (fig. 7). Sales for other romaine products followed a similar pattern, indicating consumers avoided romaine even after it was deemed safe to consume. Across the entire study period, according to our estimate, retail sales decreased by about 25% for romaine hearts and 26% for premium classic salads. We estimated a somewhat smaller sales decrease in the range of 16% to 18% for salad blends and kits containing romaine.

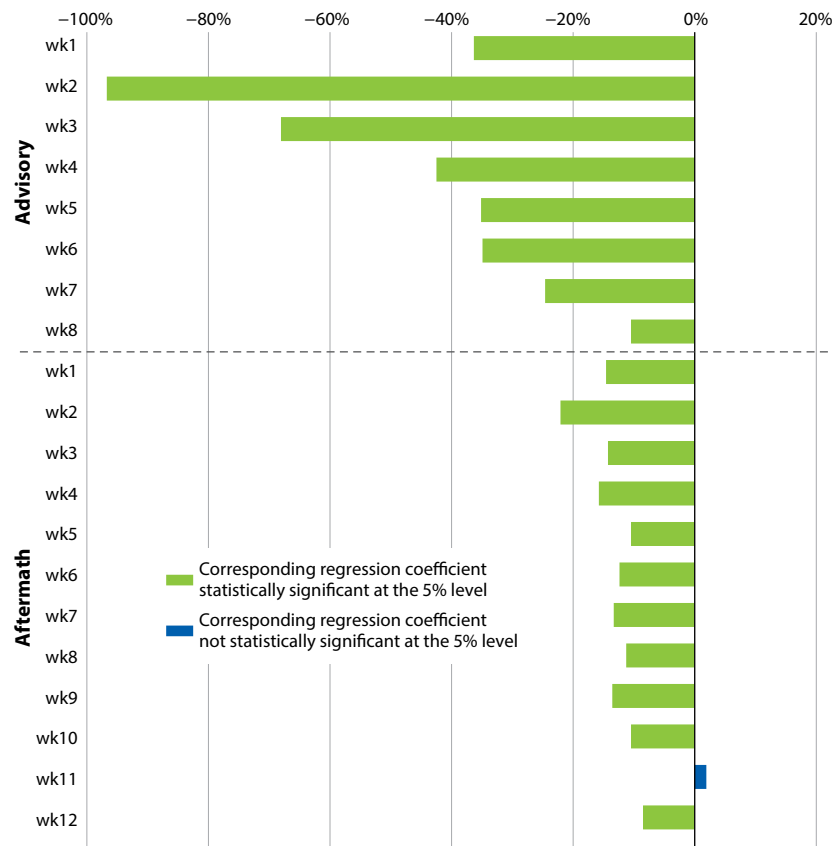


FIG. 7. Percentage change in average North American retail sales for romaine hearts associated with each week of the advisory and aftermath relative to the counterfactual.



## Processors hit hardest

Overall, the romaine lettuce industry incurred damages of roughly \$70 million due to the advisory and its aftermath. About 85% of losses occurred in the retail channel; however, the distribution of damages within the two channels differed at times, as shown in figures 8 and 9. Growers were minimally impacted by the advisory due to contract terms that largely insulate them from loss in a food-safety event, including in many instances payment by the acre rather than by the volume of lettuce delivered, with processors bearing the cost of product that is plowed under. This finding of minimal grower losses is particularly notable because the food-safety incident originated at this level. Only grower-shippers selling on the spot market were exposed to the full impact of the incident. Significantly, spot sellers gained in the early weeks of the advisory due to rising

spot prices. Some of those gains were transferred to processors operating in the food-service channel due to contract trigger prices tied to spot prices.

Processors were hit hardest by the incident, losing approximately \$55.3 million, with profits down 28.1% and 13% in the food-service and retail channels, respectively, compared to the same period a year prior. This amount was due entirely to lost sales on harvested product during the initial weeks of the outbreak, and to planted romaine under processors' control that was not harvested or sold due to reduced demand later in the advisory period and its aftermath. Processors also gained a few million dollars on net from price movements caused by the incident.

Retailers also incurred a significant share of the total losses, \$14.1 million, mostly due to pulling product in the early weeks of the advisory. However, this amount is small compared to the estimated \$1 billion in romaine retail sales in the 20 weeks prior to the advisory. Food-service operators were impacted to a lesser degree because the loss associated with destroying implicated product at the outset of the advisory was offset by lower net costs to acquire romaine during the advisory and aftermath periods.

Including losses to consumers and providers of inputs such as labor in the supply chain, we estimate that societal losses from the November 2018 incident were in the range of \$275 to \$343 million, depending on how responsive the quantity of romaine demanded is to changes in price. The more responsive the quantity demanded is to price, the smaller are societal losses. As with industry damages, the bulk of societal losses occurred in the initial weeks of the advisory.

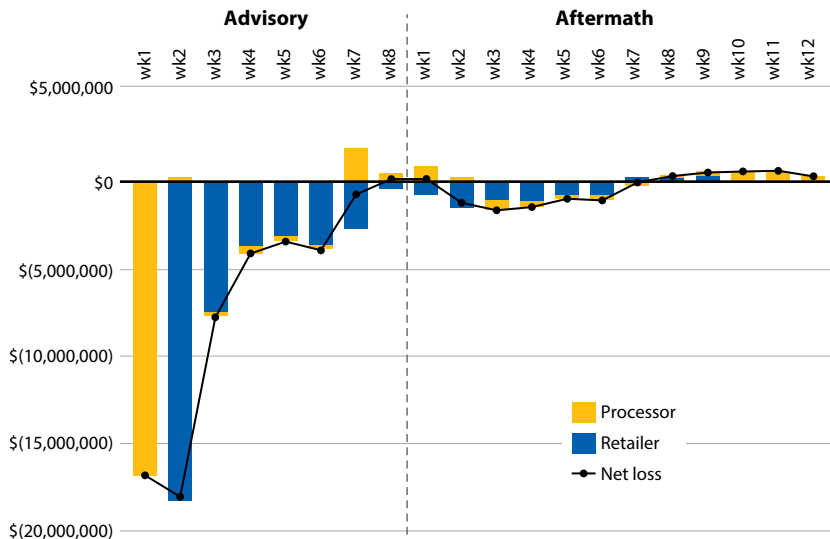


FIG. 8. Weekly damages by supply-chain participant and net losses in the retail channel.

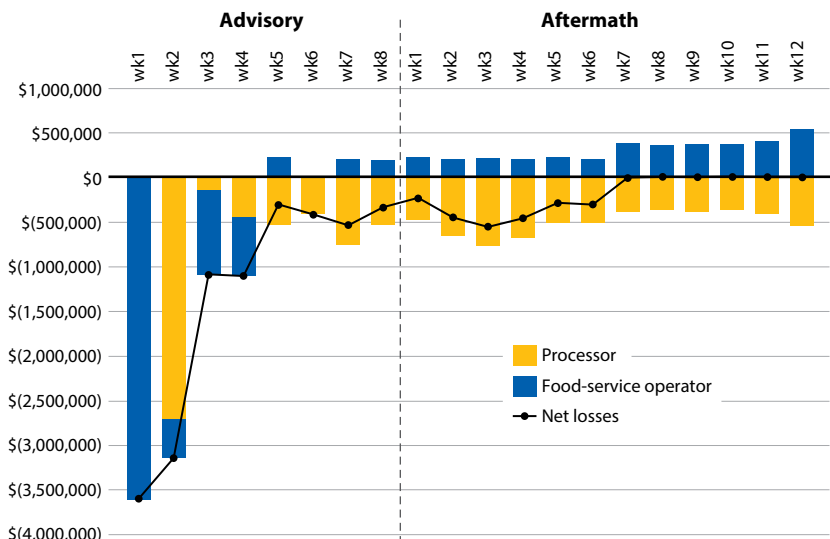


FIG. 9. Weekly damages by supply-chain participant and net losses in the food-service channel.

## Mitigating economic damages

The first and most obvious way to reduce damages associated with food-safety outbreaks is to reduce their occurrence. Since the turn of the century, industry members and government agencies have implemented policies to reduce the likelihood of microbial contamination. The California leafy greens industry established the first commodity-specific food safety program in 2007, the Leafy Greens Marketing Agreement (LGMA), in response to the 2006 *E. coli* outbreak linked to fresh spinach produced in San Benito County, which resulted in three deaths. Arizona produce operators followed suit, creating their own LGMA. These voluntary programs establish minimum safety standards for on-farm practices that are verified by third-party auditors. Members of the agreements produce roughly 90% of the leafy greens grown in the U.S (Latack and Ozeran 2021).

The 2006 outbreak also prompted the federal government to pass the Food Safety Modernization Act (FSMA) in 2011. The FSMA authorizes the FDA to order recalls of contaminated food products and set minimum safety standards for growing, harvesting, packing, and holding fruits and vegetables; the



standards are based on scientific research and good agricultural practices (GAPs). The standards, as established by the Produce Safety Rule (PSR) in 2016, were phased in from 2017 through January 2020. A 2017 change in LGMA rules aligned the California and Arizona standards with the PSR's on-farm standards, such that LGMA certification is equivalent to PSR compliance.

After a series of *E. coli* outbreaks in the preceding years, including three originating in California between November 2018 and December 2019, and in tandem with its FSMA implementation efforts, the FDA released the 2020 Leafy Greens STEC Action Plan, where STEC stands for Shiga-toxin producing *E. coli*. The FDA rolled this plan into the broader New Era of Smarter Food Safety Plan, the blueprint for which was released in July 2020.

Informed by the FDA's implementation of FSMA, the New ERA plan establishes an overarching goal to create a safer food system with improved traceability. Relying on smarter technologies and new management approaches, the FDA, in partnership with industry, has announced its intention to standardize tracking data and develop a system to trace contaminated food to the source in minutes (FDA 2020). While such a goal is ambitious, and its success remains to be seen, our analysis indicates that improvements in traceability have the potential to drastically reduce industry and societal damages associated with future outbreaks by narrowing the initial scope of public health advisories and helping restore consumer confidence in the safety of the impacted products.

## Improved traceability is key

Our analysis of the November 2018 *E. coli* outbreak associated with romaine lettuce highlights the importance of considering contracted output and specific contract terms when estimating damages resulting from food-safety incidents and apportioning those damages to supply-chain participants. To do this, it is necessary to understand the implications of contract terms for risk

distribution. Our findings show that, in leafy greens supply chains, provisions in grower-processor contracts largely shielded growers from economic losses during and after the advisory. Additionally, leafy greens processors instead incurred the largest share of damage for products that could not be harvested or sold during and after the incident.

Further, the distribution of damages over time indicates the potential for curtailing losses by more quickly identifying the source of outbreaks and limiting the geographic scope of associated advisories. Most economic damages associated with the 2018 romaine advisory were concentrated in the initial weeks of the advisory, when romaine from all growing regions was pulled from retail shelves and menus. This is likely the case in other incidents in which there is prolonged uncertainty surrounding the outbreak's source, resulting in broad advisories. Santa Barbara County, the source of the 2018 outbreak, is home to less than 8% of California's lettuce acreage. Limiting the initial advisory to romaine grown in Santa Barbara County, instead of to the entire country, would have kept a substantial portion of romaine on retail shelves and in restaurants, thereby reducing damages to processors, retailers, and food-service operators, as well as consumers and suppliers of inputs to the industry. Even if quick pinpointing was not initially feasible, any narrowing of the advisory would have reduced losses to some extent. This means that the FDA's recent efforts to require firms to improve traceability may yield substantial benefits in reducing both illnesses and economic damages associated with future outbreaks. [CA](#)

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