Research Reports

Economic Analysis of Food Safety Compliance Costs and Foodborne Illness Outbreaks in the United States

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SUMMARY. This study investigates the potential impact of food safety outbreaks on domestic shipments, imports, and prices of the produce industry. Moreover, the compliance costs associated with new food safety standards were also estimated. Three case studies were analyzed to assess these potential impacts: the muskmelon (*Cucumis melo*) outbreak of Mar.–Apr. 2008, the spinach (*Spinacea oleracea*) outbreak of Sept. 2006, and the tomato (*Solanum lycopersicum*) outbreak of June–July 2008. The results demonstrate that the costs incurred by producers because of food safety outbreaks in produce are far greater than preventing such incidents.

Foodborne illness is a major cause of enteric disease in the United States (Doyle, 2000). Recent incidents of foodborne illness have led to questions regarding the safety of the U.S. food supply. This article delineates the existing food safety standards being used in the produce industry and analyzes the specific costs incurred by the produce industry when these microbiological contamination incidents occur. Moreover, compliance costs for new food safety standards were also

estimated through a survey of producers participating in the California Leafy Green Products Handler Marketing Agreement (LGMA).

The cost borne by producers and handlers of produce is analyzed using the following three incidents as case examples:

- On Sept. 2006, the U.S. Food and Drug Administration (FDA) announced that consumers should not eat bagged spinach (FDA, 2006). Epidemiological evidence pointed to bagged spinach as a possible cause of an ongoing multistate foodborne illness outbreak of the potentially deadly bacterium *Escherichia coli* O157:H7

(Calvin, 2007). The next day the warning was expanded to include all fresh spinach. The FDA worked with California Health Services agencies to investigate and determine the source of the contaminated spinach (California Emergency Response Team, 2007). By the time the outbreak was contained, 227 people had become ill across the United States; 104 had been hospitalized; 31 had developed serious complications from hemolytic-uremic syndrome; and three had died as a result of this outbreak.

- On Mar. 2008, the Centers for Disease Control and Prevention (CDC) alerted the FDA of a multi-state *Salmonella* food poisoning that spanned through 16 states and several Canadian provinces attributed to muskmelon (FDA, 2008a). According to the FDA, muskmelons imported from a company in Honduras, Central America, left 50 people ill with *Salmonella* poisoning. Although no deaths were reported, 14 people required hospitalization. In their warning, the FDA linked the outbreak to a single company in Honduras, Agropecuaria Montelibano (FDA, 2008d).

- On June 2008, the FDA alerted consumers in New Mexico and Texas that a *Salmonella* outbreak appeared to be linked to consumption of certain types of raw, red tomatoes and tomato products (FDA, 2008c). Ultimately, the CDC reported 1200 cases of salmonellosis across New Mexico, Texas, Arizona, Colorado, Idaho, Illinois, Indiana, Kansas, and Utah. However, the source of the outbreak was finally attributed to jalapeno and serrano peppers (*Capsicum annuum*) produced in Mexico and the warning alert was lifted on July 2008 (FDA, 2008b).

These recent outbreaks are not unique. Since the mid-1990s, outbreaks in the produce industry have occurred that were linked to leafy greens, tomatoes, peppers, muskmelon, raspberries (*Rubus* sp.), green onions (*Allium* sp.), and strawberries (*Fragaria × ananassa*), among others. More than 200 known diseases are transmitted through foodborne illnesses because of viruses, bacteria,

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
45.3592	cwt	kg	0.0220
0.4536	lb	kg	2.2046
0.9072	ton(s)	Mg	1.1023

parasites, toxins, and metals (Bryan, 1982). These foodborne illnesses represent a significant burden on the U.S. population and health system as a whole, causing ≈ 76 million illnesses, 325,000 hospitalizations, and 5000 deaths annually (Kennedy and Angulo, 2000). The annual costs associated with these foodborne illnesses or deaths are estimated to be between \$5 billion and \$6 billion (National Institute of Allergy and Infectious Diseases, 2010).

As a reaction to these incidents, efforts have increased to enhance food safety regulation by the government and associated industry groups (Caswell, 1988). Food safety efforts are based on a combination of voluntary measures undertaken by producers and regulatory measures imposed by government (Segerson, 1999). These efforts have focused on increased scrutiny of imported products and the improvement in domestic standards. In some cases, product standards have established tolerance levels for some pathogens; in other cases, process standards have been adopted to recommend good agricultural practice (GAP) standards for the production and handling of products designed to reduce the potential for contamination. However, additional regulatory actions are being considered, such as the consolidation of food safety regulatory activities currently located in Federal government agencies such as FDA and the U.S. Department of Agriculture (USDA) in a new food safety regulatory agency.

Standards setting organizations

The current set of food safety and protection standards include, but are not limited to, those being promoted by governments, producers, food retailers (particularly supermarkets and fast food chains), and international organizations.

U.S. GOVERNMENT STANDARDS. In the U.S. Federal government, the responsibility for food safety is distributed among the FDA, USDA, the CDC, and the Department of Homeland Security (DHS). USDA's food safety responsibilities center on meat and poultry inspection, certification of safe process practices in production and marketing, controlling plant and animal diseases that affect safety, and generating technological progress in

dealing with food safety issues. FDA's responsibilities focus on processed foods and produce. The FDA provides guidance in the form of steps that are designed to minimize microbial food safety hazards in produce. The CDC is responsible for identifying sources of biological and disease contamination of the food supply. The U.S. Environmental Protection Agency (EPA) is responsible for regulating the safety of chemicals used in food production and processing, and dealing with the issues of water quality as they affect food safety. The DHS is responsible for ensuring that imported products meet U.S. standards for food safety.

The 111th Congress enacted the FDA Food Safety Modernization Act (FSMA) and was signed into law by President Obama on Jan. 2011. This is the first comprehensive reform of FDA food safety policy since the Federal Food, Drug, and Cosmetic Act was enacted in 1938, although the food safety programs of Food Safety and Inspection Service and EPA had been modified in the interim.

One of the most important policy changes contained in the FSMA is that it authorizes and mandates that the FDA pursue a science- and risk-based food safety policy (Knutson and Ribera, 2011). The major FSMA strategy for implementing a science- and risk-based approach to food safety policy is the mandate for the use of hazard analysis and critical control points (HACCP) procedures (FDA, 1997). In addition, FSMA requires an up-to-date enforcement registry; all food-handling facilities are required to register with the FDA every 2 years and cannot sell in interstate commerce without being registered. Also, on-farm produce handling, holding, and pack operations are treated as food facilities and must develop and implement their HACCP plan. Finally, FSMA appears to shift the responsibility for enforcement of its science-based food safety measures from FDA to importers, among other provisions.

PRODUCER/INDUSTRY STANDARDS. In 2007, largely in response to the *E. coli* outbreak in spinach, the California leafy green industry came together to establish the LGMA (2008). Nearly 99% of the volume of California leafy greens is grown under practices that fall under the standards

of this voluntary grower, packer, and shipper initiative. Under the terms of the LGMA, members are required to verify compliance with a specific set of food safety practices by submitting to mandatory government audits. The system is currently being used as a model for other states and commodities in dealing with food safety issues.

The process guidelines used by LGMA are for GAP production standards and for good handling practices (GHP) for the harvest/processing of lettuce (*Lactuca sativa*) and leafy greens (LGMA, 2011). These standards include general requirements such as a written best practices plan, by each member, to address issues related to water quality; soil amendments; control of runoff from animal feeding operations; work and field sanitation practices, up-to-date growers' list for handlers; handler compliance with the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (farms are exempt from the act) including the traceability requirements; 24-h contact information for responsible individuals in case of food emergencies; and regular audits to monitor and assure compliance.

Details covering each issue are provided to producers and handlers as well as special guides for in-depth coverage of water surveys, technical baseline information, product testing protocol, and preparation for the process compliance audits.

PRIVATE SECTOR RETAIL BUYER/SELLER STANDARDS. In an effort to have their suppliers conform to a uniform code of conduct, a consortium of firms, namely the Food Safety Leadership Council (FSLC), published their On-Farm Produce Standards in 2007 (FSLC, 2007). Although the FSLC standards provide details for GAP/GHP covering an almost identical set of activities as LGMA, the specifics of the standards vary in some categories. For example, the FSLC water quality standards are far more restrictive than those of the LGMA. Such conflicting standards set up a confrontational and confusing setting for individual producers who strive to adhere to GAP and GHP standards to satisfy all their customers. Therefore, retail standards are sometimes more restrictive than governments standards because of the

large market power and ability to affect change in the industry and have become the larger hurdle for producers to overcome.

INTERNATIONAL STANDARDS. International food marketers such as Wal-Mart, Costco, and Carrefour must be able to source produce from around the world to provide a daily supply of fresh fruits and vegetables to their customers. When sourcing produce globally, having full confidence in produce safety is essential and is a distinct competitive advantage. Recognition of uniform standards among traders is the motivation behind the development of the GLOBALG.A.P. (2007) system of insuring food safety through third-party audits to guarantee production practices in accordance with detailed guidance criteria.

Economic losses to producers and the food industry sector

The analysis presented in this article provides estimates of the costs borne by producers and handlers as a guide for understanding the direct revenue and cost consequences of a food safety incident. It does not attempt to estimate the cost to the consumers who experience food poisoning. In a related manner, it does not analyze the risk exposure for liability in food safety incident litigation.

Methods

In general terms, following public awareness of a biological contamination incident, consumers would be expected to reduce their consumption of the affected products. Following the official government notification of an incident, there may be a period of time when the affected products are banned for sale in the market until the contamination source is identified, the affected products are withdrawn from the market channel, and the source of contamination is brought under control. Even after the products are allowed back in the market channel following an outbreak, consumption levels may not rebound immediately because of a continued perceived risk by consumers. The reduction in sales depends on the severity of the outbreak, specifically in terms of the number of people affected, number of deaths, regional scope, the type of product, and its origin.

For the three incidents of contamination studied, the contemporaneous effects were analyzed primarily from a U.S. perspective. The variables quantified for the affected product included: industry shipments, including imports; prices; the length of time required for consumption to return to normal levels; and the associated revenue reductions to the United States and the supplying countries' producers. To estimate the impacts of these foodborne illness outbreaks on each produce subsector, we forecasted domestic shipments, imports, and prices that would have existed in the absence of the outbreak. The market news data from production periods before the food outbreaks were used to make these forecasts. These market news data were obtained from the USDA Agriculture Marketing Service (AMS), which are regularly relied upon by the produce industry for market information (USDA, 2009). The specific market news data used were monthly shipments, and average prices for domestic production and imports of spinach, muskmelons, and tomatoes from AMS. The difference between forecasted values and actual values was attributed to information arising from the outbreaks.

Because of the high volatility of prices of agricultural commodities, having accurate price forecasting is critical. Exponential smoothing is sometimes considered as a naive prediction method (Gelper et al., 2010). Yet, it is often used in practice where it shows good performance, as illustrated, for example, in Makridakis et al. (1998) and in Kotsialos et al. (2005). Brandt and Bessler (1983) compared seven forecasting approaches on hog prices over 24 quarters from 1976 to 1981. Their conclusion showed that simple exponential smoothing was one of the forecasting methods with the smallest mean absolute percentage error and better than the naive (random walk) approach over the 24 quarters. The naive approach uses the current period's price as a prediction of price in the next period. The forecasting technique used to estimate domestic shipments, imports, and prices is referred to as triple exponential smoothing, which was first suggested by Winters (1960). This is a commonly used price forecasting method that besides accounting for the overall

smoothing of the data, same as the simple exponential smoothing, it also accounts for both trend and seasonality (Hyndman et al., 2008), which are important in agricultural products.

The basic equations for the triple exponential smoothing are given by: $S_t = \alpha \frac{y_t}{I_{t-L}} + (1 - \alpha)(S_{t-1} + b_{t-1})$ for overall smoothing, $B_t = \gamma(S_t - S_{t-1}) + (1 - \gamma)b_{t-1}$ for trend smoothing, $I_t = \beta \frac{y_t}{I_{t-L}} + (1 - \beta)I_{t-L}$ for seasonal smoothing, and $F_{t+m} = (S_t + mb_t)I_{t-L+m}$ for forecast, where y is the observation, S is the smoothed observation, B is the trend factor, I is the seasonal index, F is the forecast at m periods ahead, t is an index denoting a time period, and α , γ , β are constants between 0 and 1 used to minimize the mean square error of the model.

Although the emphasis was on estimating changes in producer revenue flows, the analysis was extended to the retail level by using an estimate of the marketing margin. Marketing margin is the difference between the retail price and the farm-level price, which includes expenses associated with packing, wholesaling, distributing, and retailing. In the 1990s and early 2000s, marketing margins for fresh leafy greens have averaged 81%, whereas those for fresh tomatoes have averaged 72% (Lucier et al., 2006; USDA, 1998). Since no information on the marketing margins for muskmelon were available, we used the tomato marketing margin as both are sold on a per-pound basis, not bagged or per bunches as spinach. The inclusion of the retail margin was performed because in certain products such as leafy greens, the industry is becoming sufficiently producer-handler integrated that the levels of the marketing chain are difficult to distinguish. Not studied were the effects of other related products (substitutes or complements) on prices, shipments, or imports. Also not studied were the human costs associated with illness, deaths, or the effects on farm labor, management, and asset values.

The incidents analyzed were those described at the beginning of this article, namely the spinach incident acknowledged on Sept. 2006, the muskmelon incident acknowledged on Mar. 2008, and the tomato incident officially acknowledged on June 2008 (Palma et al., 2010).

Spinach

Movement of spinach, both domestic and imports, immediately began to fall below expected levels in August following the CDC identification of *E. coli* O157:H7 attributable to spinach. Sales of U.S. spinach declined by 4175 Mg while imports declined by 2170 Mg in September (Fig. 1). In October, as attention shifted to California production as the source of the problem, U.S. spinach shipments dropped by 2912 Mg while imports declined by 1361 Mg as consumers were still concerned about the safety of both domestic and imported spinach. Despite an early October indication that the source of the problem was under control, it was November before spinach sales rebounded for both U.S. and imported sources.

Spinach prices followed the same pattern as shipments; farm-level prices

were down by an average of \$4.07 per bunch or 58% in September and October (Fig. 1). Prices stayed low through November by an average of \$3.37 per bunch and went back to normal levels by December. In value terms, the farm-level loss in U.S. spinach sales was ≈\$12 million, and the retail loss was over \$63 million. The marketing margin for spinach is higher than for tomato because spinach is mainly sold bagged and ready to serve. Of the \$12 million, \$4 million was a loss to foreign producers of imported spinach.

Muskmelon

Although the CDC identified the onset of the outbreak of *Salmonella* food poisoning attributed to muskmelon as early as Jan. 2008, the shipping data in this case does not reflect a decline in sales until April when imported muskmelons were implicated

as being the potential source. At this point, U.S. shipments dropped by 9843 Mg while imports declined by 40,537 Mg (Fig. 2). By May, muskmelon sales had rebounded from both U.S. and imported sources.

During March, farm-level prices of muskmelons were down by \$9.62 per cwt or 47%. Prices rebounded earlier than shipments as by April prices were back to expected levels (Fig. 2). In value terms, total import losses reached \$23.7 million at farm-level prices with almost all losses sustained by Honduran imports. Ultimately, as a result of the outbreak, there was a loss of revenue in U.S. muskmelon sales of \$5.8 million at farm level and \$20.7 million at retail level.

Tomato

Tomato sales declined immediately as news began to spread that tomatoes produced in both the United States and Mexico were implicated as being the potential contamination source of *Salmonella* food poisoning. In Apr. 2008, shipments of U.S. tomatoes declined by 20,700 Mg while imports, mainly from Canada, increased by 37,000 Mg (Fig. 3). In May, imports increased even further, by 40,900 Mg, as speculation shifted to Mexico as the potential source of the problem, while U.S. tomato sales rebounded. Below expected sales of both Mexican and U.S. tomatoes continued through July as the source of contamination, jalapeno peppers was not identified until July 2008.

During the outbreak, tomato prices decreased by an average of \$3 per cwt or 7% at farm level as demand decreased and prices returned to normal levels by August (Fig. 3). In value terms, the farm-level loss in U.S. tomato sales was \$25 million and the retail loss was \$89 million. Although U.S. and Mexican producers lost revenue, producers from Canada and other tomato-exporting countries profited as U.S. tomato imports increased by 96,900 Mg (\$97 million) at farm-level prices.

Compliance costs

Outbreaks of foodborne disease have an important influence on the development of public health policy (Palmer et al., 2000). Moreover, outbreaks of foodborne illnesses have

Fig. 1. Time series plots of shipments, imports, prices of spinach based on monthly data from June to Nov. 2006. Vertical lines are placed at dates of interest: Sept. 2006 (beginning date of food scare) and Oct. 2006 (ending date of food scare); 1 Mg = 1.1023 t, \$1 per 24-lb (10.9 kg) bunch = \$0.0919/kg.

Fig. 2. Time series plots of shipments, imports, prices of muskmelon based on monthly data from Dec. 2007 to July 2008. Vertical lines are placed at dates of interest: Mar. 2008 (beginning date of food scare) and Apr. 2008 (ending date of food scare); 1 Mg = 1.1023 t, \$1/cwt = \$0.0220/kg.

increased fears about the effectiveness of protective measures designed for food safety assurance (Antle, 1995). From a grower perspective, making decisions on actions that need to be taken on issues of food safety are highly complex. It is simplistic to assert that it is a matter of weighing the costs and the benefits, although that is a starting point. The benefits to growers accrue not only from taking leadership to prevent occurrence of incidents that disrupt revenue flows but also from adjusting the organization of their operations to be in compliance with process standards. These benefits may be in the form of higher product prices, maintaining and growing sales in existing markets, expanding to new markets, reducing the adverse revenue effects of an incident, reducing legal liability and insurance costs, and improving operational efficiency. Although the benefits

accrue over time and are uncertain, the costs of compliance are upfront and in many cases are required to participate in a preferred market. Clearly, taking actions to be in compliance with process standards represents an added cost of doing business.

Information on costs is difficult to find and document, thus suggesting an avenue for future research. Many examples are more anecdotal than reflective of the result of careful economic analysis. In a survey of participants in the California LGMA, the annual cost of compliance for industry members was reported to be \$604,000, up from \$210,000 before the 2006 outbreak. Estimates of the comparative farm and market losses for U.S. producers were \$12 million at the farm level and \$63 million at the retail level. Clearly, in this incident the potential losses from the

foodborne illness were several times greater than the costs of complying with escalating standards designed to minimize the potential for such an outbreak.

The following major areas where costs increased as a result of compliance with the LGMA included third-party audits: one of the substantial additional costs is that of obtaining third-party compliance audits and of performing required self-audits. The costs of third-party audits are typically reported on a per farm or ranch basis and appeared to be ≈\$400 to \$500 in 2008; staffing: those members who responded to the survey reported having one trained staff person overseeing food safety issues before the leafy green incident, they now have two; and water testing: the mandatory requirements that all sources of water used in production of leafy greens be tested resulted in the approximate number of monthly water tests increasing from 10 to 52 at projected total costs of \$3657.

Conclusions

The short-term farm-level impacts of the tomato, spinach, and muskmelon food outbreaks to their industry were estimated by forecasting domestic shipments, imports, and prices using only information known before the food outbreaks. The difference between forecasted variables and actual values is attributed to information arising from the outbreaks. It was estimated that the short-term farm-level losses for U.S. tomato were \$25 million, while imports to the United States increased by \$97 million. U.S. spinach farm losses were estimated at \$12 million. Domestic shipments of spinach dropped by 7087 Mg. Finally, short-term farm-level muskmelon losses were estimated at \$5.8 million for the domestic market and \$29.5 million for imports as the contamination source was found to be foreign. Moreover, produce shipments usually recover more slowly than prices probably due to the “stickiness” of retail prices, where prices rise quickly but come down very slowly even when supply increases.

The results of this study demonstrate that the costs incurred by producers because of produce food outbreaks appear to be far greater than those involved in preventing such incidents. More research is

Fig. 3. Time series plots of shipments, imports, prices of tomato based on monthly data from Jan. to Aug. 2008. Vertical lines are placed at dates of interest: Apr. 2008 (beginning date of food scare) and July 2008 (ending date of food scare); 1 Mg = 1.1023 t, \$1/cwt = \$0.0220/kg.

needed to verify the costs involved in prevention of incidents of food outbreaks.

Literature cited

Antle, J.M. 1995. Choice and efficiency in food safety policy. 1st ed. AEI Press, Washington, DC.

Brandt, J.A. and D.A. Bessler. 1983. Price forecasting and evaluation: An application in agriculture. *J. Forecast.* 2:237–248.

Bryan, F.L. 1982. Disease transmitted by foods. A classification and summary. 3rd ed. Centers for Disease Control and Prevention, Atlanta, GA.

California Emergency Response Team. 2007. Investigation of an *E. coli* O157:H7 outbreak associated with Dole pre-packaged spinach. Final Report, 21 Mar. 2007. California Dept. Health Services, U.S. Food Drug Admin., Sacramento, CA.

California Leafy Green Products Handler Marketing Agreement. 2008. California Leafy Green Marketing Agreement

Releases First Report on Program Audits and Actions. 2 Apr. 2011. <<http://www.caleafygreens.ca.gov/trade/LGMAReleasesFirstReportonAuditsandActions.asp>>.

California Leafy Green Products Handler Marketing Agreement. 2011. Commodity Specific Food Safety Guidelines for the Production and Harvest of Lettuce and Leafy Greens. 10 Aug. 2011. <<http://www.caleafygreens.ca.gov/sites/default/files/LGMA%20Accepted%20Food%20Safety%20Practices%207.22.11.pdf>>.

Calvin, L. 2007. Outbreak Linked to Spinach Forces Reassessment of Food Safety Practices. *Amber Waves* 5(3)24–31. 29 Mar. 2011. <<http://www.ers.usda.gov/AmberWaves/June07/Features/Spinach.htm>>.

Caswell, J.A. 1988. Federal and state regulations of food product safety and quality: A selected partially annotated bibliography. Bibliographies Literature Agr. No. 70. U.S. Dept. Agr., Econ. Res. Serv., Commodity Econ. Div., Washington, DC.

Doyle, M.P. 2000. Food safety issues arising at food production in a global market. *J. Agribusiness* 18(1):129–133.

Food Safety Leadership Council. 2007. On-farm produce standards. FSLC Version 1.0, 10 Sept. 2007. Food Safety Leadership Council, Burbank, CA.

Gelper, S., R. Fried, and C. Croux. 2010. Robust forecasting with exponential and Holt-Winters smoothing. *J. Forecast.* 29:285–300.

GLOBALG.A.P. 2007. GLOBALG.A.P. Standards. 15 Mar. 2011. <http://www.globalgap.org/cms/front_content.php?idcat=3>.

Hyndman, R.J., A.B. Koehler, J.K. Ord, and R.D. Snyder. 2008. Forecasting with exponential smoothing: The state space approach. 1st ed. Springer-Verlag, Berlin and Heidelberg, Germany.

Kennedy, M. and F.J. Angulo. 2000. Incidence of foodborne illness: 1999 Data from FoodNet. *Ir. J. Agr. Food Res.* 39:295–300.

Knutson, R.D. and L.A. Ribera. 2011. Provisions and Implications of FDA's Food Safety Modernization Law. *Agr. Food Policy Ctr., Texas A&M University, AFPC Issue Paper 11-1*. 10 Sept. 2011. <<http://www.afpc.tamu.edu/pubs/1/554/IP%2011-01.pdf>>.

Kotsialos, A., M. Papageorgiou, and A. Poulimenos. 2005. Long-term sales forecasting using Holt-Winters and neural network methods. *J. Forecast.* 24:353–368.

Lucier, G., S. Pollack, M. Ali, and A. Perez. 2006. Fruit and vegetable backgrounder. *Electronic Outlook Rpt., U.S. Dept. Agr., Econ. Res. Serv. VGS-313-01*.

Makridakis, S., S. Wheelwright, and R. Hyndman. 1998. Forecasting, methods and applications. 3rd ed. Wiley, Hoboken, NJ.

National Institute of Allergy and Infectious Diseases. 2010. Foodborne Diseases. 20 Mar. 2011. <<http://www.niaid.nih.gov/topics/foodborne/Pages/default.aspx>>.

Palma, M.A., L.A. Ribera, D. Bessler, M. Paggi, and R. Knutson. 2010. Potential impacts of foodborne illness incidences on market movements and prices of fresh produce in the United States. *J. Agr. Appl. Econ.* 42:731–741.

Palmer, S., S. Parry, D. Perry, R. Smith, M. Evans, L. Nehaul, R. Roberts, M. Walapu, and D. Wright. 2000. The role of outbreaks in developing food safety policy: Population based surveillance of *Salmonella* outbreaks in Wales 1986–1998. *Epidemiol. Infect.* 125:467–472.

Segerson, K. 1999. Mandatory versus voluntary approaches to food safety. *Agribusiness* 15(1):53–70.

U.S. Department of Agriculture. 1998. Leafy greens: Foundation of the vegetable industry. *Agr. Outlook* 1998. U.S. Dept. Agr., Econ. Res. Serv., Washington, DC.

U.S. Department of Agriculture. 2009. Fruit and vegetable news portal. Price and shipment information, 2000–2008. U.S. Dept. Agr., Agr. Mktg. Serv., Washington, DC.

U.S. Food and Drug Administration. 1997. Hazard Analysis and Critical Control Point Principles and Application Guidelines. 25 Mar. 2011. <<http://www.fda.gov/Food/FoodSafety/HazardAnalysisCriticalControlPointsHACCP/HACCP>

[PrinciplesApplicationGuidelines/default.htm](http://www.fda.gov/Food/FoodSafety/HazardAnalysisCriticalControlPointsHACCP/HACCP)>.

U.S. Food and Drug Administration. 2006. FDA Warning on Serious Food-borne *E. coli* O157:H7 Outbreak. 21 Mar. 2011. <<http://www.fda.gov/bbs/topics/NEWS/2006/NEW01450.html>>.

U.S. Food and Drug Administration. 2008a. Archived Updates on the FDA Investigation in Honduras. 15 Mar. 2011. <<http://www.fda.gov/oc/opacom/hottopics/cantaloupearchive.html>>.

U.S. Food and Drug Administration. 2008b. FDA Lifts Warning about Eating Certain Types of Tomatoes. 16 Mar. 2011. <<http://www.fda.gov/bbs/>

[topics/NEWS/2008/NEW01862.html](http://www.fda.gov/bbs/topics/NEWS/2008/NEW01862.html)>.

U.S. Food and Drug Administration. 2008c. FDA Warns Consumers in New Mexico and Texas Not to Eat Certain Types of Raw Red Tomatoes. 16 Mar. 2011. <<http://www.fda.gov/bbs/topics/NEWS/2008/NEW01843.html>>.

U.S. Food and Drug Administration. 2008d. FDA Warns of Salmonella Risk with Cantaloupes from Agropecuaria Montelibano. 16 Mar. 2011. <<http://www.fda.gov/bbs/topics/NEWS/2008/NEW01808.html>>.

Winters, P.R. 1960. Forecasting sales by exponentially weighted moving averages. *Manage. Sci.* 6:324–342.