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A Robust Market Withdrawal System Can Reduce Your Product Recall Costs

ABSTRACT

Food manufacturers want to avoid required or voluntary market recalls of their products. Recalls are costly and time consuming and can destroy a company's image or force it into liquidation. Despite its initial expense, the installation of a robust market withdrawal system could significantly reduce the overall costs of a recall. A withdrawal system that is routinely tested allows the manufacturer to quickly identify the implicated products' location in the marketing chain and permits immediate quarantine of the suspect product from the market before it reaches retail distribution. Thus, a well-rehearsed market withdrawal system would reduce the major costs of damage to manufacturers' reputations and reimbursements to consumers. In this paper we discuss the basics of a robust withdrawal system, including traceability, detailed written operating procedures, customer compliance and record keeping.

INTRODUCTION

Food safety events can be life threatening and are a major expense for the food processor involved. Product recalls in particular can be a costly part of managing a food safety event. A report by a major reinsurance company, Swiss Re, analyzed publically available food recall information in the U.S. and estimated that in more than half the recalls, the cost was in excess of $10 million per recall event *(33)*. Costs of recalls involving products that are already in national distribution can reach as much as $100 million *(26, 33)*. A report by Tyco Integrated Security *(51)* indicated the overall cost of food recalls can be much larger in the long term, because consumers may continue to avoid a product that has been associated with foodborne illness long after the recall has ended. This leads to a significant drop in future profits for the manufacturer, in addition to the excessive costs associated with the recall itself.

Large-scale recalls tend to be widely publicized in many media outlets and can be highly detrimental to a company's future success. In 2015, Blue Bell Creameries, Brehnam, TX, issued a Class I recall for potential *Listeria monocytogenes*

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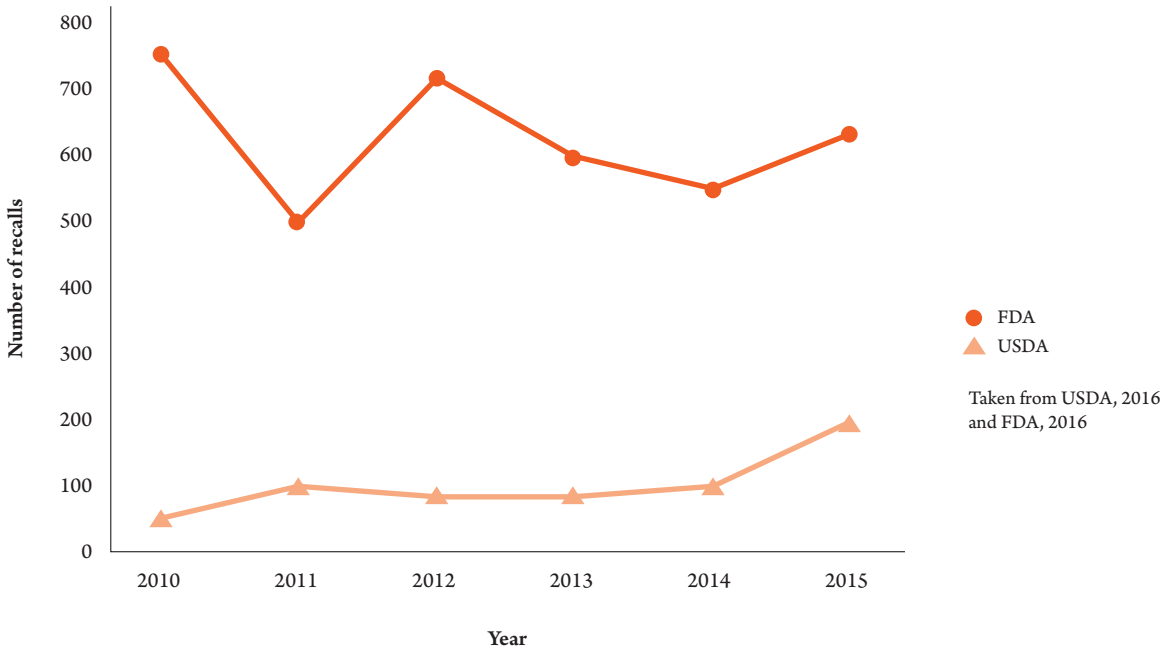

Figure 1. Number of food recalls by USDA and FDA, 2010-2015

contamination in their prepackaged ice cream bars. At the time of the initial recall, there had been ten confirmed cases of listeriosis over a four-year period. Over the next several months, as the FDA investigated, Blue Bell issued several more recalls *(22)*. Because of the loss of revenue after stopping production, Blue Bell laid off approximately 1,450 employees, furloughed 1,400, and reduced the pay for those who were left and were in charge of cleaning the facilities to prepare them to reopen *(35)*.

Food safety and food manufacturing of all fruits and vegetables, dairy, and seafood is regulated by the Food and Drug Administration (FDA) and 80 percent of all other foods, except those containing more than 5 percent of meats, poultry, and certain egg products, which are regulated by the USDA and the FSIS *(25)*. As indicated by *Fig. 1*, the FDA issued approximately six times as many food recalls as the USDA in the time period from 2010 through 2015 *(19, 52)*. The number of food recalls by USDA doubled from 2013 to 2015, which the USDA attributed mainly to a rise in recalls for undeclared allergens present in foods *(52)*.

Recalls are classified into three groups: Class I, Class II, or Class III. A Class I recall is reserved for products with a high probability of causing serious health effects or death; a Class II recall is implemented when temporary or treatable adverse health conditions may occur, and Class III recalls are used for products not likely to cause any health concerns *(20)*. Class I recalls are the most common for all food products, as indicated in *Figs. 2 and 3*. This suggests that the majority of recalls pertaining to food products, may be life threatening to the consumer *(35)*. While Class I recalls comprised the largest number of FDA recalls in 2015, Class II recalls were almost as numerous because of undeclared allergens in food products, as indicated in *Fig. 2 (23)*. All classes of recalls by USDA increased between 2014 and 2015 *(Fig. 3)*, which is a cause for concern for both the manufacturer and consumer.

COMPONENTS OF RECALL COSTS

The foregoing examples provide anecdotal evidence that recalls can be costly. Researchers have also conducted formal studies to better understand all of the components that can be attributed to recall costs. One method of attributing these total costs is the event study. This approach uses evidence from financial markets to infer the effects of recalls on company profitability. Thomsen and McKenzie *(49)* measured stock market reactions to meat and poultry recalls and found that Class I recalls typically result in significant and adverse stock price movements for meat and poultry firms. Salin and Hooker *(46)* examined several specific recalls and found varied stock market responses; one company in their study, Odwalla, experienced a drop in its stock price amounting to about 30 percent of shareholder wealth in the days following an apple juice recall.

Researchers have similarly examined recalls or release of unfavorable product safety information in contexts other than food. Broder and Morrall *(9)* found negative stock market reactions to firms implicated in fatalities. Zhao et al. *(60)* found large negative stock market reactions for Chinese firms implicated in product recall situations. Several researchers have assessed stock market reactions to airplane accidents *(7, 8, 12, 13, 28, 31, 39)*. Other researchers have

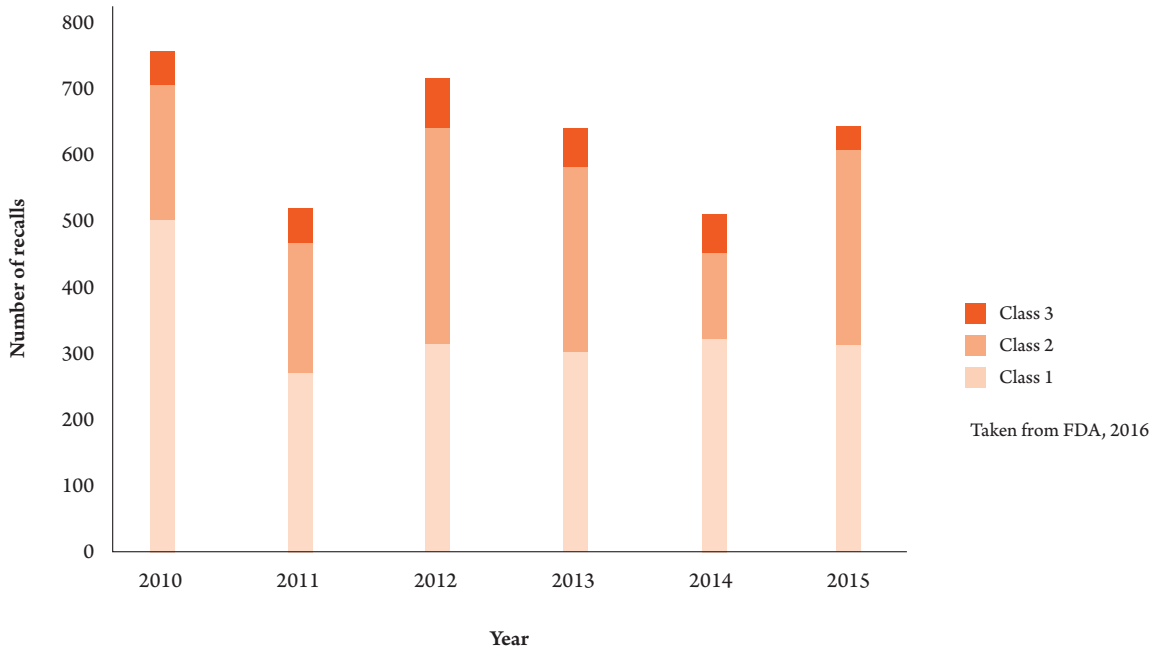

Figure 2. Number of FDA food recalls by class, 2010-2015

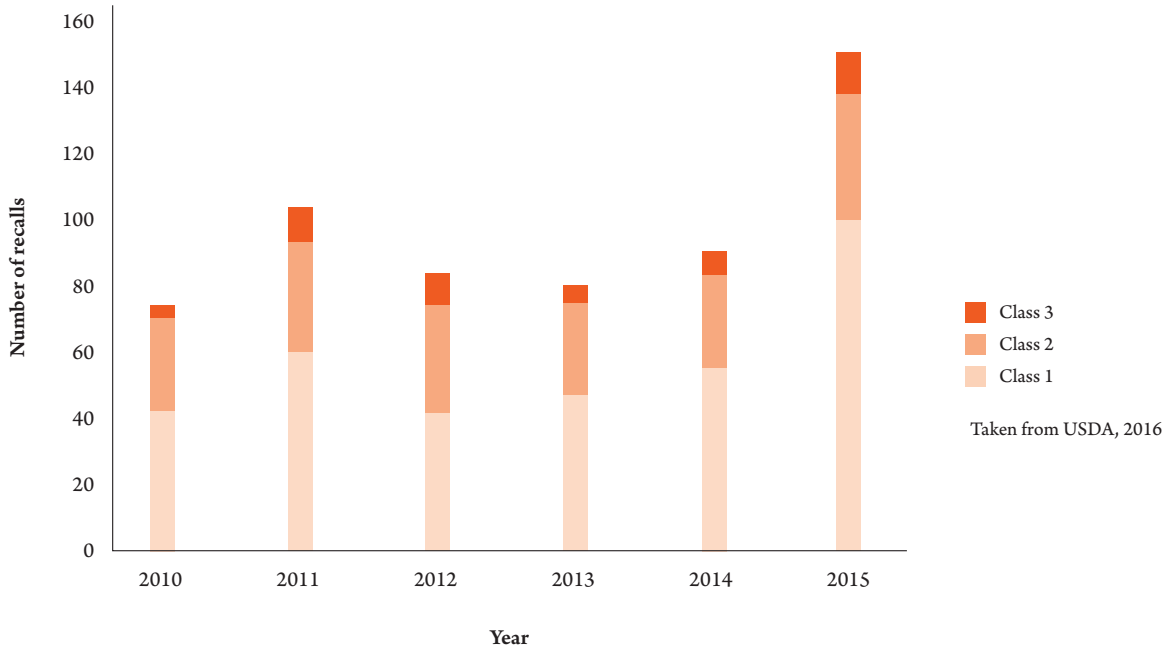

Figure 3. Number of USDA food recalls by class, 2010-2015

evaluated the impacts of automobile recalls *(10, 29, 30, 43, 44, 45)*, recalls of consumer products *(15, 16, 17, 24, 41, 50)*, and recalls of pharmaceuticals or medical devices *(14, 30, 47)*.

Most of the approaches to assessing the impact of recalls in these published studies are consistent with those on food products in that they show statistically significant and negative stock price reactions to safety-related events, but a few exceptions are worth mentioning. Thirumalai and Sinha *(48)* analyzed a sample of medical device recalls and found no significant stock price movements. Bromiley and

Marcus *(10)* concluded that adverse stock price reactions are not large enough to discourage the sale of unsafe automobiles even though these reactions were negative and statistically significant. The literature on automobiles and other consumer products is larger than that focusing on food. It is possible that with larger numbers of studies, similar null findings of a meaningful relationship between food recalls and stock market valuation will emerge from food-industry studies as well. Finally, Freedman, et al. *(24)* found that the statistical significance of the average stock market response to the toy recalls in their study depended on one influential event. This is worth mentioning in that it shows that one event can make the average effect of a recall appear worse than that of the typical recall. The influential event in question was a follow-up recall of the Thomas the Tank Engine line of toys that came on the heels of a larger, June 2007 recall for high levels lead in the paint used on the toys *(24)*. As will be explained later, recall preparation efforts are one way to prevent a typical recall event from turning into something that is financially devastating. While the evidence is overwhelming that adverse product safety information meaningfully affects market valuation and future profitability, these few exceptions in the literature suggest that recalls are not always catastrophic and that there may be preparatory actions companies can take to mitigate the adverse financial effects of recalls when they occur.

Other researchers have estimated the duration for which markets are affected by recalls. The evidence from food markets is summarized as follows: Bakhtavoryan et al. *(4)* examined demand for peanut butter following a salmonellosis outbreak that led to a recall of the Peter Pan and Great Value brands and to the temporary removal of the Peter Pan brand from the market. Their estimates of demand relationships among brands before and after the recall suggest that Peter Pan had largely recovered from the food safety crisis after a six-month recall period. In another study, frankfurter brands recalled for *Listeria monocytogenes* contamination took four to five months, on average, to recover to pre-recall levels after experiencing an average 22 percent initial drop in sales volume *(47)*.

Similar patterns of a drop in demand or prices followed by a recovery with time are also apparent in commodity-level studies. Brown *(11)* estimates that per-capita cranberry purchases dropped 26 percent in the wake of a 1959 pesticide contamination scare, but that purchases in the 1960 to 1962 period had recovered to pre-scare levels. O'Rourke *(40)* estimated that red delicious apple prices were lower by 21 percent (from a predicted price of $14.71/box that dropped to $11.62/box) during the 1988–1989 marketing year as a result of two "60 Minutes" television segments on pesticide use in apple production. More recently, Arnade et al. *(2)* found that retail purchasing declined by as much as 63 percent and 32 percent for bagged and bulk spinach, respectively, after a 2006 *Escherichia coli* outbreak linked to spinach and an advisory that consumers avoid consumption of bagged spinach. These authors found that bulk spinach expenditures recovered within six months. Bagged spinach expenditures also recovered, but took longer and had not completely reached pre-event levels by the time the study period ended, over a year later. Attavanich et al. *(3)* found that media coverage of the H1N1 (swine flu) outbreak in 2009 caused a significant drop in lean hog futures prices, which persisted for approximately four months.

These studies provide evidence that market disruptions due to adverse food safety information last for at least several months and can generally be expected to exceed the volume removed from the market directly by a recall. One explanation for slow recovery in the wake of a food scare is that adverse product safety information has an asymmetric impact on consumer preferences. Several studies demonstrate that the impact of negative media stories on food safety is much larger than the impact of positive stories *(42, 47, 57)*.

DEVELOPING A ROBUST WITHDRAWAL SYSTEM

A survey of food manufacturers showed that product disposal, business interruption, and customer reimbursement were the top three costs associated with food recalls *(27)*. However, a proactive company with a robust market withdrawal system in place that has been routinely tested may be able to remove a suspect product from the market quickly so as to minimize the risk to consumers and their brand image. A robust recall system may reduce all of the cost associated with product withdrawal. The purpose of this portion of this report is to examine the foundations of a robust withdrawal system.

It stands to reason that if the time that consumers are exposed to a contaminated or mislabeled product is reduced, the potential harm and associated cost will be diminished. A robust market withdrawal system allows the manufacturer to track the product the moment it leaves the production facility. A report by the Grocery Manufacturers Association *(27)* found that 88 percent of companies surveyed had Hazard Analysis Critical Control Point (HACCP) plans in place; integrating HACCP plans electronically allows for more checkpoints and faster identification of potential sources of contamination, mislabeling, or manufacturing errors. This reduces the likelihood that a contaminated product will make its way into the hands of a consumer. In addition, if the food product can be withdrawn before entering the market, the cost incurred by creating hotlines for consumers, damages to those that purchased the products, recall consultants, and product avoidance would be negligible.

Ketchen et al. *(32)* classify recalls into four types, namely (1) precise recalls, (2) overkill recalls, (3) cascading recalls, and (4) incomplete recalls. As the name implies, a precise recall refers to a situation in which the firm knows the nature of the problem, can identify the exact lots and locations of

the products affected, and can recover them rapidly and efficiently. In Ketchen et al.'s *(32)* framework, precise recalls require that the firm have sufficient resources that are both adequate and properly orchestrated. The term "resources" is used broadly in this framework. Presumably, product recall resources would include information technology, human resources, and less tangible resources that facilitate immediate traceability and recovery, such as knowledge of and relationships with suppliers and customers. The second category, overkill recalls, are larger and broader than they need otherwise be. Incomplete recalls are those that are ineffective in recovering all of the potentially harmful products. In both of these cases, the problem was rooted in the firm's inability to specifically identify and track unsafe products in the scope of its distribution because of inadequate and/or improperly orchestrated firm-level resources. The inability to identify contaminated lots of peanut butter ultimately led to a leading brand being completely pulled from retail distribution for a significant period of time *(4)*. Poorly orchestrated resources may also increase the likelihood of a cascading recall, a situation in which the scope of the recalls expands over time in terms of size or into related products. The earlier example of the Thomas the Tank Engine toy recall would typify a cascading recall. It is interesting that in this case it was the second, follow-up recall that was identified as the influential event that drove the magnitude of the average stock market response *(24)*.

Given this framework, recall preparation activities can be viewed as an effort to increase the likelihood of a precise recall if there is a food-safety problem. Company recall plans are a way to take stock of what resources the firm has at its disposal. A sound recall plan should help the firm identify what resources it can bring to bear in a recall situation and rectify any shortcomings in its resource base. Many resources are available for recall planning and plan templates are available from regulatory bodies *(53)*, land-grant universities *(1)*, or trade associations. Once a recall plan is in place, simulated or mock recall scenarios help ensure that the firm is capable of orchestrating its resources to bring about a precise recall. Elements of a robust withdrawal system include traceability, detailed operating procedures, ability to assess compliance from customers, detailed record keeping and, finally, plans for recovery of value on recalled products if possible.

Traceability

FDA has projected that improved product tracing could reduce the impact of contaminated food on public health by 55 per cent and decrease the economic impact of recalls by as much as $14 million per foodborne outbreak *(37)*. The Food Safety Modernization Act (FSMA) in the U.S. has instituted new requirements that food and beverage processors track and trace products across the entire lifecycle, from source to finished product *(21, 54)*. The FSMA requires a "one up and one down" traceability capability. In other words, each entity in the food and beverage chain keeps track of the immediate upstream source of materials and the immediate downstream customer. For instance, a manufacturer that uses sugar as an ingredient needs to keep track of the supplier that provided the sugar as well as the fate of the production batch that used that sugar. Extending this to all partners up and down the food and beverage chain achieves complete traceability.

The recall plan

A recall plan is an important part of an efficient recall management system and should be developed in advance, with each step being well documented. The recall plan should be tested periodically by using "mock recall" events to guarantee that in the event of a recall, all of the necessary steps are executed thoroughly and correctly the first time. The recall plan should contain detailed information on every step of the recall process starting with submission of information to the responsible governing agencies. The recall plan serves as an action plan directing the company through each step of the recall process. For example, the organization will need to describe the notification method and how it will be sent (overnight or facsimile, for example). The company must submit a report stating exactly what information has been communicated to customers who already have the product. If the product must be returned, the organization must also state exactly how it will conduct this process.

An up-to-date recall plan coupled with periodic simulations to test the plans are the cornerstones of a robust market withdrawal system. If done properly, these preparation activities will go a long way toward increasing the likelihood of being able to conduct a precise recall. Nevertheless, planning exercises can go only so far. Firms also need to integrate their ability to trace and recover products into their operations and supply chain management practices *(34, 36)*. Recent operations research models have been developed that incorporate traceability into optimal production and inventory control plans *(38, 55, 56, 57)*. A key feature of these models is that they balance batch dispersion, a determinant of traceability and recall size, with efficiencies in production and inventory management.

A successful recall plan must also be integrated into the fabric of the organization. First, the structure of the organization of the firm should accommodate and not hinder execution of the recall plan. Structure refers to the division of the company into a hierarchy of specialized units or departments and the means of coordinating and controlling recall activities across departments *(6)*. A prominent feature of any recall plan is a list of names and contact information for individuals that need to be involved in recall activities. In all but the smallest of organizations, these individuals will invariably come from different departmental units. Thus, it is important to take steps to

ensure that structural barriers within the company do not limit coordination and information flows during a recall situation. Second, the company's culture should reinforce the importance of product safety and recall preparation efforts. Wowack and Boone *(59)* argue that a culture of food safety needs to be considered in understanding responses to recalls and provide examples where culture has facilitated (Johnson & Johnson) or hindered (General Motors) the management of product recalls.

CONCLUSIONS

Each food manufacturer needs to make their own decision concerning the allocation of current and future resources to their product recall plans. With this article we have pointed out the downside of being inadequately prepared to carry out a precise food recall. Many food manufacturers have been in existence for decades and have never had a recall due to a foodborne illness outbreak. However, with the increased use of whole-genome sequencing by federal regulators and the advent of PulseNet International, widely dispersed foodborne illnesses can now be more rapidly and precisely attributed to a food source *(58)*. For all of these right reasons, food processors today must carefully consider implementing a robust recall system and continually testing their plans to insure they are adequate.

REFERENCES

1. Archer, D. L., K. L Schneider, R. H. Schmidt, W. S. Otwell, R. M. Goodrich, and C. Thomas. 2004. The food recall manual. Retrieved September 2, 2016, from http://edis.ifas.ufl.edu/fs108.
2. Arnade, C., L. Calvin, and F. Kuchler. 2009. Consumer response to a food safety shock: The 2006 foodborne illness outbreak of *E. coli* O157: H7 linked to spinach. *Rev. Agric. Econ.* 31:734–750.
3. Attavanich, W., B. A. McCarl, and D. Bessler. 2011. The effect of H1N1 (swine flu) media coverage on agricultural commodity markets. *Appl. Econ. Perspect. Policy* 33: 241–259.
4. Bakhtavoryan, R., O. Capps Jr., and V. Salin. 2012. Impact of food contamination on brands: A demand systems estimation of peanut butter. *Agric. Resource Econ. Rev.* 41: 327–339.
5. Barney, J. G., D.G. Ketchen, Jr., and M. Wright. 2011. The future of resource-based theory: Revitalization or decline? *J. Mgmt.* 37:1299–1315
6. Besanko, D., D. Dranove, M. Shanley, and S. Schaefer. 2010. The Economics of Strategy, John Wiley & Sons, Hoboken, N.J.
7. Borenstein, S., and M. B. Zimmerman. 1988. Market incentives for safe commercial airline operation. *Am. Econ. Rev.* 78:913–935.
8. Bosch, J.-C., E. W. Eckard, and V. Singal. 1998. The competitive impact of air crashes: Stock market evidence. *J. Law Econ.* 41:503–519.
9. Broder, I. E., and J. F. Morrall III. 1991. Incentives for firms to provide safety — regulatory authority and capital-market reactions. *J. Regul. Econ.* 3:309–322.
10. Bromiley, P., and A. Marcus. 1989. The deterrent to dubious corporate behavior: Profitability, probability and safety recalls. *Strategic Mgmt. J.* 10:233–250.
11. Brown, J. D. 1969. Effect of a health hazard 'Scare" on consumer demand. *Am. J. Agric. Econ.* 51:676–679.
12. Chalk, A. J. 1987. Market forces and commercial aircraft safety. *J. Indus. Econ.* 36:61–81.
13. Chance, D. M., and S. P. Ferris. 1987. The effect of aviation disasters on the air transport industry: A financial market perspective. *J. Transport Econ. Policy* 21:151–165.
14. Cheah, E., W. Chan, and C. Chieng. 2007. The corporate social responsibility of pharmaceutical product recalls: An empirical examination of U.S. and U.K. markets. *J. Bus. Ethics.* 76:427–449.
15. Chen, Y., S. Ganesan, and Y. Liu. 2009. Does a firm's product-recall strategy affect its financial value? An examination of strategic alternatives during product-harm crises. *J. Marketing.* 73:214–226.
16. Chu, T.-H., C.-C. Lin, and L. J., Prather. 2005. An extension of security price reactions around product recall announcements. *Quart. J. Business Econ.* 44:33–48.
17. Davidson III, W. N., and D. L. Worrell. 1992. The effect of product recall announcements on shareholder wealth. *Strategic Mgmt. J.* 13:467–473.
18. Dupuy, C., V. Botta-Genoulaz, and A. Guinet. 2005. Batch dispersion model to optimize traceability in food industry. *J. Food Eng.* 70:333–339.
19. FDA. 2003. Product recalls, including removals and corrections. Retrieved 10 November 2016 from: http://www.fda.gov/Safety/Recalls/IndustryGuidance/ucm129259.htm.
20. FDA. 2009. Background and definitions. Retrieved March 05, 2016, from http://www.fda.gov/Safety/Recalls/ucm165546.htm.
21. FDA. 2011. FDA food safety modernization act. Retrieved 10 November 2016from: http://www.fda.gov/Food/GuidanceRegulation/FSMA/.
22. FDA. 2015. FDA investigates *Listeria monocytogenes* in ice cream products from Blue Bell Creameries. Retrieved February 19, 2016, from http://www.fda.gov/Food/RecallsOutbreaksEmergencies/Outbreaks/ucm438104.htm.
23. FDA. 2016. Enforcement activity. Retrieved June 01, 2016, from http://www.fda.gov/ICECI/EnforcementActions/ucm247813.htm.
24. Freedman, S., M. Kearney, and M. Lederman. 2012. Product recalls, imperfect information, and spillover effects: Lessons from the consumer response to the 2007 toy recalls. *Rev. Econ. Stat.* 94:499–516.
25. Goetz, G. 2010. Who inspects what? A food safety scramble. Retrieved March 12, 2016, from http://www.foodsafetynews.com/2010/12/who-inspects-what-a-food-safety-scramble/#.VuXhZJwrLIU.
26. Grocery Manufacturers Association. 2010. Recall execution effectiveness: Collaborative approaches to improving consumer safety and confidence. Retrieved June 24, 2016, from http://www.gmaonline.org/downloads/research-and reports/WP_RecallExecution.pdf.
27. Grocery Manufacturers Association. 2011. Capturing recall costs. Retrieved March 5, 2016, from http://www.gmaonline.org/file-manager/images/gmapublications/Capturing_Recall_Costs_GMA_Whitepaper_FINAL.pdf.
28. Ho, J. C., M Qiu, and X. Tang. 2013. Do airlines always suffer from crashes? *Econ. Letts.* 118:113–117.
29. Hoffer, G. E., S. W. Pruitt, and R. J. Reilly. 1987. Automotive recalls and informational efficiency. *Fin. Rev.* 22:433–442.
30. Jarrell, G., and S. Peltzman. 1985. The impact of product recalls on the wealth of sellers. *J. Polit. Econ.* 93:512–536.
31. Kaplanski, G., and H. Levy. 2010. Sentiment and stock prices: The case of aviation disasters. *J. Fin. Econ.* 95:174–201.
32. Ketchen, D. J., K. D. Wowak, and C. W. Craighead. 2014. Resource gaps and resource orchestration shortfalls in supply chain management: The case of product recalls. *J. Supply Chain Mgmt.* 50:6–15.
33. Knusli, D., R. Friedli, and J. Bursenhart. 2015. Food safety in a globalized world Retrieved 20 July 2016 from http://media.swissre.com/documents/ Food_safety_in_a_globalised_world_final.pdf.

34. Manning, L., and J. M. Soon. 2016. Building strategic resilience in the food supply chain. *Br. Food J.* 118:1477–1493.

35. Marler, B. 2015. Mr. Kruse: An agonizing decision – but it was preventable. Retrieved April 9, 2016, from http://www.marlerblog.com/case-news/mr-kruse-an-agonizing-decision-but-it-was-preventable/#.Vwq6NKQrLIU.

36. Marucheck, A., N. Greis, C. Mena, and L. Cai. 2011. Product safety and security in the global supply chain: Issues, challenges and research opportunities *J. Oper. Mgmt.* 29:707–720.

37. McEntire, J., and T. Bhatt. 2012. Pilot projects for improving product tracing along the food supply chain. Retrieved 10 November 2016 from: http://www.fda.gov/ downloads/Food/GuidanceRegulation/UCM341810.pdf.

38. Memon, M., Y. Lee, and S. Mari. 2015. Analysis of traceability optimization and shareholder's profit for efficient supply chain operation under product recall crisis. Mathematical Problems in Engineering. DOI: http://dx.doi.org/10.1155/2015/896239.

39. Mitchell, M. L., and M. T. Maloney. 1989. Crisis in the cockpit? The role of market forces in promoting air travel safety. *J. Law Econ.* 32:329–355.

40. O'Rourke, A. D. 1990. Anatomy of a disaster. *Agribusiness.* 6:417–424.

41. Pruitt, S. W., and D. R. Peterson. 1986. Security price reactions around product recall announcements. *J. Fin. Res.* 9:113–122.

42. Richards, T. J., and P. M. Patterson. 1999. The economic value of public relations expenditures: food safety and the strawberry case. *J. Agr. Resour. Econ.* 24:440–462.

43. Robinson-Jacobs, K. 2015. Bass bailout may force Blue Bell's hand to go public. Retrieved June 6, 2016, from http://www.dallasnews.com/business/headlines/20150717-bass-bailout-may-force-blue-bells-hand-to-go-public.ece.

44. Rupp, N. G. 2001. Are government initiated recalls more damaging for shareholders? Evidence from automotive recalls, 1973–1998. *Econ. Letts.* 71:265–270.

45. Rupp, N. G. 2004. The attributes of a costly recall: Evidence from the automotive industry. *Rev. Ind. Organ.* 25:21–44.

46. Salin, V., and N. H. Hooker. 2001. Stock market reaction to food recalls. *Rev. Agric. Econ.* 23:33–46.

47. Smith, M. E., E. O. van Ravenswaay, and S. R. Thompson. 1988. Sales loss determination in food contamination incidents: An application to milk bans in Hawaii. *Am. J. Agr. Econ.* 70:513–520.

48. Thirumalai, S., and K. K. Sinha. 2011. Product recalls in the medical device industry: An empirical exploration of the sources and financial consequences. *Mgmt. Sci.* 57:376–392.

49. Thomsen, M. R., and A. M. McKenzie. 2001. Market incentives for safe foods: An examination of shareholder losses from meat and poultry recalls. *Am. J. Agr. Econ.* 83:526–538.

50. Thomsen, M. R., R. Shiptsova, and S. J. Hamm. 2006. Sales responses to recalls for *Listeria monocytogenes*: Evidence from branded ready-to-eat meats. *Rev. Agr. Econ.* 28:482–493.

51. Tyco Integrated Security. 2012. Recall: The food industry's biggest threat to profitability. Retrieved February 17, 2016, from https://www.tycois.com/wps/ wcm/connect/ab4fd1f4-4aa2-45a3-a4f1-b91b36539e0f/LT1000-02FoodDefenseWP_Part2_hireresDigital.pdf? MOD=AJPERES.

52. USDA. 2016. Summary of recall cases in calendar year 2015. Retrieved June 01, 2016, from http://www.fsis.usda.gov/wps/portal/fsis/topics/recalls-and-public-health-alerts/recall-summaries/recall-summaries-2015.

53. USDA Food Safety and Inspection Service. 2015. How to Develop a Meat and Poultry Product Recall Plan, Revised Edition, United States Department of Agriculture, Food Safety and Inspection Service.

54. U.S. Government Publishing Office. 2011. FDA food safety modernization act. Retrieved March 27, 2016, from https://www.gpo.gov/fdsys/pkg/PLAW-111publ353/ pdf/PLAW-111publ353.pdf.

55. Verbeke, W., and R. W. Ward. 2001. A fresh meat almost ideal demand system incorporating negative TV press and advertising impact. *Agric. Econ.* 25:359–374.

56. Wang, X., D. Li, and C. O'Brien. 2009. Optimization of traceability and operations planning: an integrated model for perishable food production. *Int. J. Prod. Res.* 47:2865–2886.

57. Wang, X., D. Li, Y. Li, and C. O'Brien. 2010. A production planning model to reduce risk and improve operations management. *Int. J. Prod. Econ.* 124:463–474.

58. Wiedmann, M. 2015. Use of whole-genome sequencing in food safety. *Food Safety Mag.* June/July:12–17.

59. Wowak, K. D., and C. A. Boone. 2015. So many recalls, so little research: A review of the literature and road map for future research. *J. Supply Chain Mgmt.* 51:54–72.

60. Zhao, X., Y. Li, and B.B. Flynn. 2013. The financial impact of product recall announcements in China. *Int. J. Prod. Econ.* 142:115–123.