Recurrent Event Survival Analysis of Repeated Food Recalls: Some Insights from the U.S.

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Food safety is an issue of shared responsibility across the food supply chain. Public health officials, policy makers, food firms and consumers, all play an important role in minimizing the risk of a foodborne outbreak. Food firms, in particular, invest in the implementation of food safety technologies and protocols to prevent or reduce the occurrence of these incidents (Henson and Reardon, 2005). Despite such efforts, the number of foodborne outbreaks reported in the United States, particularly those related to meat and poultry products, has been on a constant rise. In 2015, the U.S. Department of Agriculture's (USDA) Food Safety and Inspection Service (FSIS), an agency tasked with monitoring the safety of the U.S. supply of meat, poultry, and egg products, reported 150 recalls, which represents almost threefold increase from the number of recalls issued in 2005. Surprisingly, some firms have experienced more than one food safety incident within a relatively short amount of time. For example, Tyson Foods, one of the largest processors and marketers of chicken, beef, and pork products, has issued 36 different meat and poultry recalls from 1994 through 2015. The case of Tyson Foods is not unique in the food industry, thus raising the question of what factors determine time to next recall for firms producing meat and poultry products, and to what extent these firms learn from previous food safety incidents.

In this study, our main objective is twofold. First, we aim to determine key factors that influence a food firm's risk of recall occurrence at any given time. Towards this end, both firm- and recall-specific factors are evaluated. The firm-specific factors considered include firm size (measured in market capitalization (Fama and French, 1992)), level of diversification, and firm age. For instance, in terms of a firm's level of diversification, we expect the risk of recall to be higher for firms producing solely meat and poultry products than those for more diversified firms. The reason for this is because meat and poultry naturally tend to contain a larger amount of pathogenic bacteria than other products (e.g., vegetables or greens). Since the likelihood of a subsequent recall event may potentially be influenced by the characteristics of a past event, we also control for recall-specific factors, including the size and class of the previous recall issued by a food firm.

Second, we investigate whether food firms that have issued a recall in the past "learn" from that experience in the context of increased time to next recall, and how this learning is influenced by the firm- and recall-specific characteristics. The expectation is that if firms learn from a previous recall incident, they should in theory be able to lengthen the amount of time until the next recall event (by, for instance, implementing more effective food quality monitoring systems), thereby increasing the likelihood of their survivorship (i.e., not experiencing a recall event). Acting otherwise would contradict profit-maximization motives of the firm since food contamination incidents may cause substantial economic losses (Sockett, 1993). As a result, inter-event time can plausibly proxy organizational learning as it reflects the extent of efforts taken by the firm upon a food contamination incident to prevent or reduce the occurrence of future incidents.

We propose to implement a recurrent event survival analysis framework to identify the extent of firm learning from inter-event time. Unlike the methods used in previous literature (e.g., Salin et al., 2003; Teratanavat et al., 2005), which are either inefficient or inappropriate, this approach is opportune for the analysis of repeated recall incidents as it incorporates information provided by subsequent failures times (recalls), while accommodating the order of recurring events as well as accounting for intra-firm correlation arising from these events. As such, differences in recall dynamics between first, second, third, etc. recall events can be directly examined under this methodology, which allows for the analysis of a firm's ability to prevent recalls over time. Recurrent event survival analysis has been commonly used in epidemiology and biostatistics for applications where events occur more than once, such as bladder tumor

recurrence (Amorim and Cai, 2015), repeated occurrence of acute lower respiratory infections (Kelly and Lim, 2000; Amorim and Cai, 2015), and hospital readmission of the elderly (Kennedy et al., 2001), among others. Given that a significant percentage of food firms analyzed in this study has issued more than one recall, a recurrent event survival analysis is clearly more appropriate than those considering only the duration to first failure event. To our knowledge, this is the first application of this methodology to product recalls. As such, our study demonstrates important applications of statistical and related data science methodology and how statistical thinking, design and analyses play a vital role in all walks of life and benefit society in general.

The results from our analysis show that firm-specific factors, including firm size and diversification, play a role in the likelihood of occurrence of recall events. In particular, firms producing only meat and poultry products are at higher risk of issuing a repeat recall compared to more diversified ones, as anticipated. In addition, firms with a more diversified product line incur smaller risk of recall with the expansion of firm size (i.e., increase in market capitalization) relative to their primarily meat producing counterparts. Our analysis also reveals that past recall attributes have a significant effect on future recall occurrences. Specifically, the hazard of recall incident decreases with the amount of product recalled in the past recall event. Furthermore, the risk of a future recall is smaller for firms whose previous recall was of Class I, the most severe class of recalls, compared to those whose past recall was of Class II. This suggests that firms appear to learn from their losses in past recall events, and implement necessary measures to reduce the likelihood of a future foodborne outbreak. While there is no definitive evidence indicating that a firm's ability to prevent recalls grows with the number of recalls it has experienced, we do find some evidence of firm learning between a firm's first and second recall, and third and fourth recall.

In a food safety context, increasing the time between recall events represents a key agenda item for the food industry as well as public health officials. This study contributes to the understanding of firm- and recall-specific factors that make firms more or less prone to food safety incidents, and how prior experience with recalls affects firms' ability to prevent future incidents. As such the paper positions itself to generate productive discussions at the AAEA meetings.

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