Firm Learning and Food Product Recalls: An Application of Recurrent Event Survival Analysis to Food Recalls

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Introduction

- In 2015 the U.S. Department of Agriculture's Food Safety and Inspection Service (USDA FSIS), which monitors meat and poultry recalls, reported 150 recalls. This is a 53 percent increase over 2010 (FSIS Recall Case Archive, 2016).
- Food recalls are of major concern not only because of the public-health burden associated with illnesses and deaths, but also because they represent an expensive challenge for food firms.
- Recalls of meat and poultry products are of particular concern as they can be contaminated with deadly pathogens such as E. Coli, Salmonella, and Listeria.
- High profile incidents may cost firms millions of dollars in recall handling, regulatory fines, liability costs, and decrease product sales.
- For example, the 1998 Listeria recall issued by Sara Lee directly cost the company $76 million, not including the $4.4 million in settlements, and additional $200 million in sale losses.
- Previous literature examined:
  - The costs of meat and poultry recalls (Thomsen and Mckenzie, 2001; Pozo and Schroeder, 2016)
  - Negative effect on stock return for a repeated recall (Pozo and Schroeder, 2016; Salin and Hooker, 2001)
  - Duration time from recall issuance to the close of the recall (Teratanavat et. al, 2005).
- Main limitation of these studies is the use of a standard Cox Proportional Hazard model, which only takes into account duration to first failure event.
- This paper applies **recurrent event survival analysis** framework to study repeated recall data.

Research Objectives

- Using a recurrent event survival analysis framework, analyze repeated recall data of meat products in the US for the period 1994-2015.
  1. What are the key factors that affect time to next recall for a food firm?
  2. Is there any evidence of firm "learning" in the context of increased time to next recall for firms that have experienced a recall in the past?
  3. How does this learning differ between different types of firms?

Empirical Methodology

- Repeated event survival analysis methods are commonly used in epidemiology for applications where events occur more than once:
  - Bladder tumor recurrence (Amorim and Cai, 2015)
  - Hospital readmission of the elderly (Kennedy, 2001)
- The advantage of a repeated event survival analysis framework is that it does not leave out possibly valuable information that may be provided by subsequent failures times.
- **Andersen-Gill Counting Process Model** (Andersen and Gill, 1982)
  - Assumes that recurrent events within subject are independent and identical.
  - If subjects display multiple failure times they stay in the risk set until their last failure time or until they are censored.
  - The Cox PH model is $h(t, \boldsymbol{X}) = h_0(t)\exp(\boldsymbol{X\beta})$, where $\boldsymbol{X}$ is a vector of covariates (firm size, diversification, and age).
  - The one-subject-per-failure time partial likelihood function is

$$L = L_1 \times L_2 \times \cdots \times L_{72}$$

$$L_j = \text{Prob}\big(\text{recall at time } t(j) | \text{survival up to } t(j)\big) = \frac{\exp(\boldsymbol{X}_j\boldsymbol{\beta})}{\sum_{s \in R(t_j)} \exp(\boldsymbol{X}_s\boldsymbol{\beta})}$$

  where there are 72 unique failure times for all firms.
  - Fitting this model allows us to answer the first question of interest.
- **Stratified Cox PH Model** (Prentice, Williams, and Peterson, 1981)
  - Also known as *conditional 2* or *the PWP Gap Time Model* (PWP-GT).
  - Does not assume that each recall event is identical.
  - The Cox PH model is $h_g(t, \boldsymbol{X}) = h_{0g}(t)\exp(\boldsymbol{X\beta})$, where $g = 1,2,3,4$ is the strata: $g = 1$ (timing till the first event), $g = 2$ (duration between first and second), etc.
  - The Cox PH model can be specified with interactions between strata and $\boldsymbol{X}$'s.
  - Fitting this model allows us to answer the second question of interest.

Data

- USDA FSIS meat and poultry recall data for publicly traded companies for Jan 1994-April 2016.
- 96 specific recall events total from 31 unique companies.
- Firm specific factors used in this analysis are:
  - Firm size (market capitalization, in billions of $)
  - Firm diversification (1 if meat is the firm's main product, 0 otherwise)
  - Firm age (1 if publicly traded for less than 7 years, 0 otherwise)

	1 recall only	2 recalls only	3 recalls only	4 recalls only or truncated
Number of Firms	12	3	5	11
Frequency	38.70%	9.69%	16.13%	35.48%

Results

Estimated Coefficients for Andersen-Gill Model

	Coefficient	exp(Coefficient)	Standard Error	P-value
Size	0.004	1.003	0.002	0.114
Diversification (meat is main product)	1.153	3.167	0.263	0.001
Age (young)	-0.783	0.457	0.308	0.011

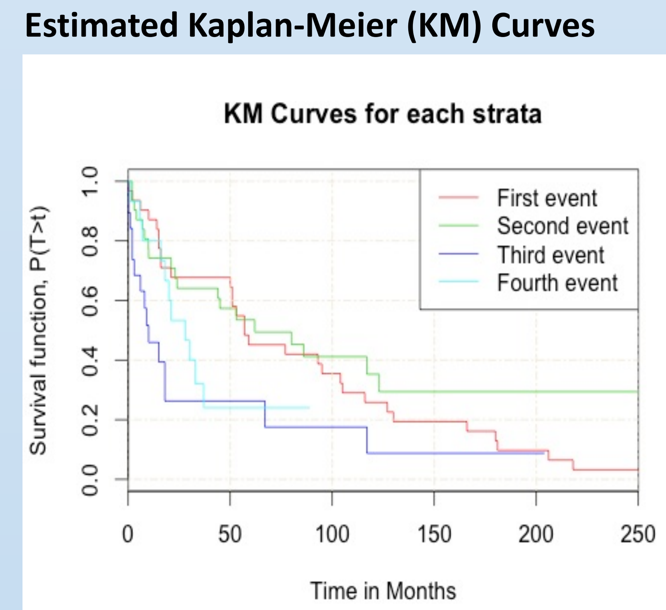
Note: The Breslow approximation method is used to handle tied survival times. Robust standard errors are reported.

Estimated Coefficients for Stratified Cox PH Model (PWP-GT)

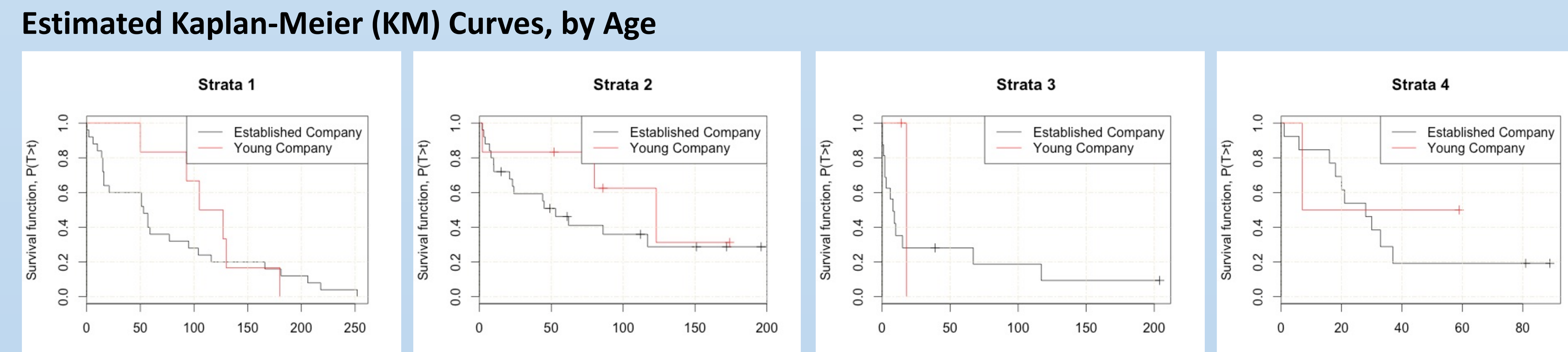
	Coefficient	exp(Coefficient)	Standard Error	P-value
Size	0.005	1.005	0.002	0.004
Diversification (meat is main product)	1.128	3.584	0.291	0.001
Age (young)	-0.780	0.458	0.296	0.008

Note: The Breslow approximation method is used to handle tied survival times. Robust standard errors are reported.

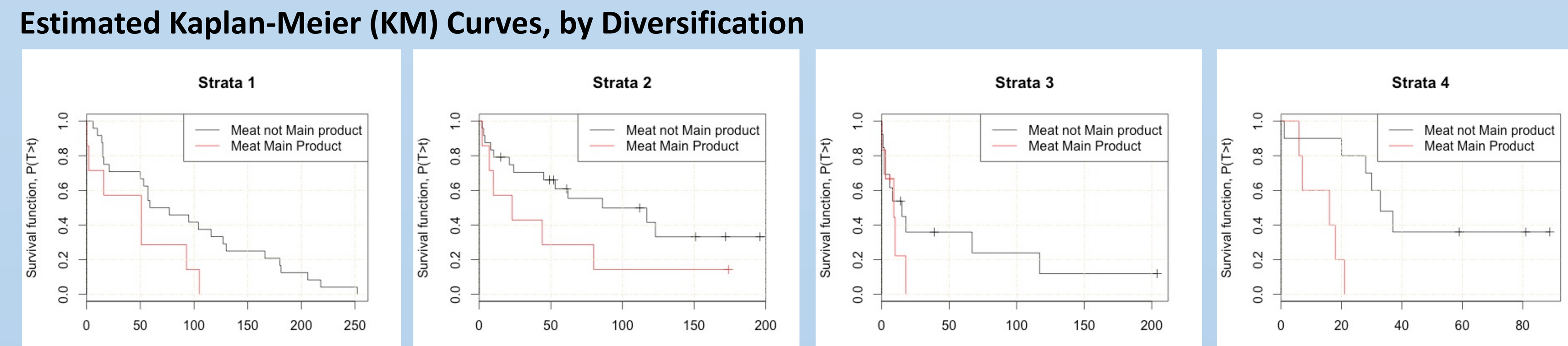
Estimated Kaplan-Meier (KM) Curves



Estimated Kaplan-Meier (KM) Curves, by Age



Estimated Kaplan-Meier (KM) Curves, by Diversification



Conclusion

- Firm specific factors, specifically firm size, diversification, and age, play a role in a firm's time to next recall.
- Larger and less diversified firms are more at risk than smaller and more diversified firms.
- Surprisingly, we find that younger firms exhibit longer duration times to next recall than longer established firms. This may be because of the greater potential risk to young firms.
- 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, however, find strong evidence of firm "learning" between a firm's first and second recall, and third and fourth recall.

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