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Heechang Shin
Iona College

Robert Richardson
Iona College

Oredola Soluade
Iona College

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Heechang Shin
Iona College, USA
hshin@iona.edu

Robert Richardson
Iona College, USA
rrichardson@iona.edu

Oredola Soluade
Iona College, USA
osoluade@iona.edu

ABSTRACT

A major recall is defined as the recall in which the affected number of cars is more than certain threshold level per recall. It has a negative impact on sales, since there are fewer customers inclined to purchase an automobile from a manufacturer that is producing a defective product. This paper introduces the application of event study, used extensively in the area of financial research, to the automobile industry in order to evaluate the sales loss from a major recall. A case study of Toyota Motor Corporation is presented to demonstrate the use of the model. The model suggests that the sales may decline for the subsequent five months from the time a major recall is announced. In future, the assumption of statistical independence between recalls will be removed, and further research will be conducted to determine if this will affect the outcome of the analysis.

Keywords: Recall, event study, sales, Toyota

INTRODUCTION

An automobile safety recall is based on defects identified in a motor vehicle. Such recalls are either conducted by the manufacturer or ordered by the National Highway Traffic Safety Administration (NHTSA). The manufacturer estimates the direct cost of recall as a business expense. The costs include (1) notification cost (including the development of a complete list of current owners from corporate files or state DMV records, the composing and mailing of the letters to each owner), (2) the cost of training technicians to make repairs, (3) labor cost and other expenses associated with the time required to resolve the issue, (4) cost of the parts—including manufacturing cost and shipping cost, (5) the management cost associated with scheduling and supervising staff, and (6) sales loss—the decline in sales as a result of the problem (Shin, Richardson, & Soluade, 2012). However, the indirect cost such as opportunity cost is often ignored, and they cannot be derived from financial statements. For example, an automobile safety recall has a negative impact on sales, since there are fewer customers inclined to purchase an automobile from a manufacturer that is producing a product that is perceived by the customer as defective. As a result, it incurs opportunity cost (i.e., the lost sales, measured by assessing the company's market share or number of cars sold).

Since market responses to a recall may be different depending on the number of affected vehicles in the recall, the recalls were classified into *major recalls* with more than certain number of cars per recall (i.e., 500,000 cars), and *minor recalls* with less than the threshold level per recall. This categorization also follows the NHTSA protocol that categorizes auto recalls as major or minor based on the number of cars affected for a particular defect (Etayankara & Bapuji, 2009). Recently, Shin et al. (2012) determined that minor recalls may produce no damage to the sales over the period of study. This effect can be explained by the fact that such recalls are perceived by consumers as a signal of an automaker's diligence in attending to quality control issues. The speed with which minor problems are found and fixed, help a company to maintain public confidence in their product as (Rhee & Haunschild, 2006) stated. On the contrary, major recalls show strong evidence of negative impact on the market share as expected (Shin et al., 2012).

The purpose of this paper is to present a procedure for estimating the critical opportunity cost associated with the loss in sales encountered as the result of a major recall. In section 2, a model is presented to evaluate the sales loss derived from the major recalls. Section 3 presents a case study to demonstrate the use of the model. A related work is presented in section 4. Finally, a discussion of the application of the model and its limitations, and future work is presented in section 5.

MODEL DEVELOPMENT

Figure 1 illustrates the sales loss around a major recall. When a major recall occurs at *T*, the sales will decline during the *recall period* although sales may initially continue to increase from the momentum developed by the last sales. When the effect of the recall diminishes (i.e., Point *S* is reached in Figure 1), sales increase until they return to the original sales level at Point *P*. This period is called as *post-recall period*. The *pre-recall period* refers to the time period prior to the announcement of the major recall event. Therefore, the shaded area indicates the total loss in sales from at Point *T* to at Point *P*.

The main objective in this paper is to develop a model that estimates the shaded area for a major recall. An event study (Bowman, 1983; de Jong, 2007) was used as a basis for development of the model. Event study is a statistical method that has been used extensively in financial research to find the stock market reaction to important financial events such as mergers and acquisitions, earnings announcements, corporate reorganizations, investment decisions and corporate social responsibility (MacKinlay, 1997; McWilliams & Siegel, 1997). In this paper, the event study is used to measure the impact of the major recall on the sales performance of a firm instead of applying it to the financial performance. The model involves the following steps:

(1) Identify the major-recall events;
(2) Establish the basis (or *normal return* in an event study);

(3) For each month of the recall and post-recall periods, calculate the sales loss (or *abnormal returns* in an event study). An aggregation of sales loss in each month of the recall and post-recall periods is used to estimate the total sales loss;
(4) Perform the statistical test to measure the significance of the recall.

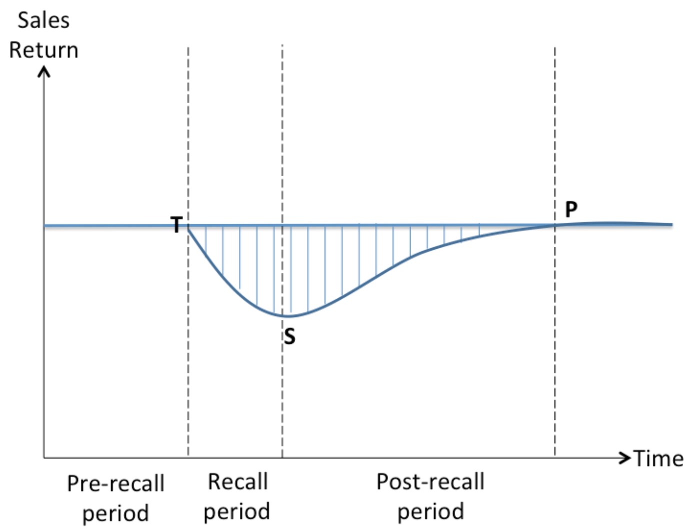

Figure 1: Sales Loss Based on Major Recall.

Identify the Major Recall Events

The first step is to define the data upon which the market would receive the news of a major-recall event. In this paper, the event date is defined as the date when a major recall is announced to the public. Since the news spreads gradually to the public, the *event window*, defined as [t_1, t_2] in Figure 2, is set to find the impact to sales loss during the recall and post-recall periods.

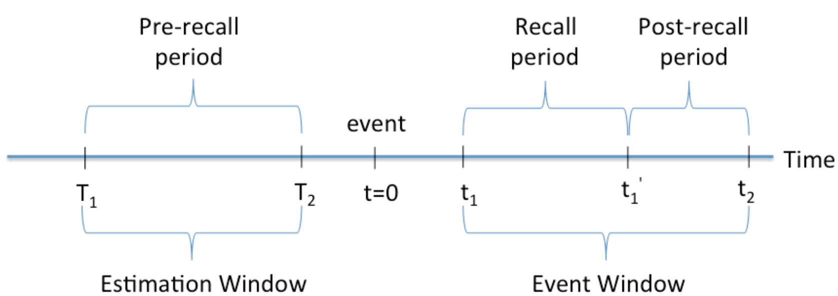

Figure 2: Event Window and Estimation Window.

Establish the Normal Return (or Basis)

A normal return is defined as the stock return of an individual company where there has been no special event occurring from the finance literature (Bowman, 1983; de Jong, 2007). In this paper, the term *basis* is used to refer to the normal return in finance literature. The *Basis* is used as a benchmark to compare against sales loss instead of stock return. Four models were investigated for determining the *basis*: (1) mean-adjusted return; (2) market-adjusted return; (3) proxy portfolio return; (4) risk-adjusted return (de Jong, 2007). After careful consideration, it was decided to focus on the mean-adjusted return model because of its clarity and ease of computation. The main limitation of the mean-adjusted return model is that it does not respond well when the market is trending up or down. In future work, these other models will be tested.

To estimate a basis using the mean-adjusted return, it is necessary to define an estimation window period [T_1, T_2] that precedes the event period [t_1, t_2]. The mean-adjusted return assumes that the mean of the company's sales performance over the event window is expected to be the same as the mean over the estimation period (de Jong, 2007). The basis is defined as:

$$B_i = \frac{1}{T}\sum_{t=T_1}^{T_2} R_{it} \quad (1)$$

where i is the company index and $T=T_2-T_1+1$, which equals the number of months during the estimation period. In Equation (1), R_{it}, monthly return of sales performance, is defined as:

$$R_{it} = \frac{M_{it}-M_{it-1}}{M_{it-1}} \quad (2)$$

where i is the company index, t refers to time (month), and M_{it} is the market share— i at time t.

The choice of the estimation period is not fixed in the literature. Brown and Warner (1980) used 35 months as the estimation period, but Renneboog (2006) used 240 days. This estimation window period should be established by analyzing prior recall periods to identify when a stable, consistent sales return is produced. In this paper the estimation window is one year, (or 12 months) prior to the major recall as the estimation period after analysis by classical decomposition and adjustment for seasonal fluctuations.

Calculation of the Abnormal Returns to Estimate Sales Loss

The third step is to calculate the sales loss measured by *abnormal returns* during the recall and post-recall periods. Abnormal return is defined as the difference between the return and the *basis* since the event occurred (Bowman, 1983; de Jong, 2007). This is illustrated by the formula:

$$AR_{it} = R_{it} - B_i \quad (3)$$

where AR_{it} is the abnormal return of the sales performance of the company i at time t; R_{it} is the return of the sales performance for the company i at time t; B_i is the basis (or normal return) of the company i at time t. Then, the abnormal returns matrix can be constructed as:

$$\begin{pmatrix} AR_{1t_1} & \cdots & AR_{Nt_1} \\ \vdots & \ddots & \vdots \\ AR_{1t_2} & \cdots & AR_{Nt_2} \end{pmatrix} \quad (4)$$

where N is the total number of companies used for the event study. If there is more than one major recall happening at a company, we treat them as if they were separate companies.

Since the focus is on the overall sales loss after a major recall, the cumulative abnormal returns (CAR_i) can be defined as the summation of abnormal returns over the period [t_1, t_2]:

$$CAR_i = \sum_{t=t_1}^{t_2} AR_{it} \quad (5)$$

The cumulative average abnormal returns of all the companies' sales performance is defined as

$$CAAR = \frac{1}{N}\sum_{i=1}^{N} CAR_i \quad (6)$$

and *CAAR* is used to test the abnormal performance discussed in Section 2.4.

<u>Performing Statistical Tests to Measure the Significance of the Model</u>

The objective is to test if the major recall has an influence on the sales performance of a company. The null hypothesis that the abnormal return during the recall and post-recall periods is zero (or no effect on the sales performance) and the alternative hypothesis where abnormal returns before and after the recall are different, are specified as:

$$H_0: E(CAR_{it}) = 0 \quad (7)$$
$$\mathrm{H}_\alpha: \mathrm{E}(\mathrm{CAR}_{\mathrm{it}}) \neq 0 \quad (8)$$

Determining which hypothesis is appropriate depends on the way in which the abnormal returns are constructed and on the statistical properties of the returns. The most commonly used test for such a scenario is t-test (de Jong, 2007). The following simplifying assumptions are made: (1) $E(AR_{it}\, AR_{jt}) = 0\ for\ \forall i \neq j$; (2) AR_{it} and CAR_i are independent and identically distributed − which will be relaxed in a future work.

For an arbitrary event interval [t_1, t_2], the standard deviation is estimated as:

$$s = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(CAR_i - CAAR)^2} \quad (9)$$

and the test statistic is:

$$t = \sqrt{N}\frac{CAAR}{s} \sim t_{N-1} \quad (10)$$

APPLICATION OF MODEL

A case study of Toyota Motor Corporation is presented to demonstrate the use of the model. Recently, Toyota recalled 5.77 million vehicles for floor mat issues and 4.45 million vehicles for the "sticky-pedal" fix during year 2009 and 2010 (Rechtin, 2011) after reports that several vehicles experienced unintended acceleration. These recalls resulted from a car accident on August 28, 2009 that killed four people including the driver—an officer with the San Diego California Highway Patrol (10News, 2009). Before the accident, his wife called 911 stating that she and three others were in a car with an accelerator pedal that was stuck and traveling at more than 100 miles per hour. This accident led to intense media coverage. As a California Highway Patrol Officer, he was an experienced driver with special training. This casts doubt on whether or not driver error was the main cause of the recalls in Toyota's previous sudden acceleration cases.

TMC has three divisions in North America: Toyota, Scion, and Lexus. The sample data from Automotive News Data Center (Automotive News, 2011) includes TMC's monthly sales in the United States between January 2005 and February 2011. Consistent with prior studies of auto recalls (Borenstein & Zimmerman, 1988; Crafton, Hoffer, & Reilly, 1981; Rhee & Haunschild, 2006), *month* was used as the unit of analysis. Also, when calculating R_{it} (the monthly return of sales performance) in Equation (2), market share is used for M_{it} instead of sales unit because market shares, unlike sales units, are not affected by temporal fluctuations in seasonal demand, which is consistent with other literature in the auto industry (Rhee & Haunschild, 2006).

Recall information was obtained from the National Highway Traffic Safety Administration (NHTSA) database (2012). Following the result of (Shin et. al., 2012), *major recalls* are defined as the recall in which the affected number of cars are more than 500,000 autos per recall. In TMC, the division of Toyota (or Lexus) experienced total of eleven (or three major) recalls over the period of study (between January 2005 and February 2011). There is no record of major recalls from the Scion division.

Each major recall should have its own estimation window and event window. If more than one major recall occurred during relatively short period of time, the event window might overlap the estimation window of the subsequent recall. In other words, if an estimation window of a major recall includes another one, the basis cannot be a benchmark of a stable, consistent sales return. In order to address this issue, the earliest major recall is used to calculate the basis and ignore the subsequent ones whose estimation windows overlap with the first one. As a result, the major recalls that occurred in January 2007, April 2008, and October 2009 were used, and their effect tested on the sales performance for all three divisions of TMC.

As discussed in Section 2.2, twelve months prior to the major recall were used as the estimation period. Table 1 presents the result of estimated basis for each division of TMC per major recall considered in this paper.

Recall Date	TOYOTA	LEXUS	SCION
January 2007	0.01752	0.01663	-0.00473
April 2008	0.00309	0.00358	0.02134
October 2009	0.01606	0.04079	-0.01589

Table 1: *Basis* per Major Recall.

Event Window t_1	t_2	CAAR	s	G	p-value
1	2	-0.05575	0.09280	-1.80236	0.13136
1	3	-0.08002	0.14191	-1.69155	0.15152
1	4	-0.08432	0.19745	-1.28116	0.25634
1	5	-0.09782	0.14058	-2.08738	0.09120
1	6	-0.05974	0.17469	-1.02592	0.35198
1	7	-0.07019	0.23168	-0.90885	0.40511
6	7	0.02763	0.18569	0.44637	0.33700

Table 2: Estimation of *Basis* per Major Recall.

Various event window sizes were tested for measuring the effect of a major recall. More specifically, *setting* t_1 to one and t_2 to between two and seven in the event window [t_1, t_2], the impact on the sales performance was tested from one-month after the announcement of the major recall through two-, three-, …, and seven-month. Two periods are identified: Recall period (when sales are continuously declining, and Post-Recall period (when the effect of the recall becomes diminishing, and sales increase until the territory returns to its original sales level) as illustrated in Figure 1. Table 2 presents the values of *CAAR* in Equation (6), *s* in Equation (9), *t* in Equation (10), and *p-value* of the test statistic (double-sided test with the degree of the freedom as $N – 1 = 8$) for the corresponding event window. In Table 2, for $t_1 = 1$ and $t_2 = 1, 2, …, 7$, the value of *CAAR* is continuously declining as t_2 increases until t_2 becomes 5, suggesting that sales are continuously declining for the subsequent five months since the month when a major recall had been announced. This suggests that the recall period of TMC may be [t_1, t_2] = [1, 5]. At a significance level 0.1, the null hypothesis in Equation (7) is rejected, and therefore, it can be concluded that the sales may be impacted (negatively) for the subsequent five months since the month when a major recall had been announced.

However, identifying the post-recall period is not as straightforward as the recall period. In Table 2, for $t_1 = 1$ and $t_2 = 1, 2, …, 7$, the value of *CAAR* becomes smaller after $t_2 = 5$ is reached, suggesting that the impact of the major recall is diminishing. In Table 7, the value of CAAR for [t_1, t_2] = [6, 7] is positive, 0.33700, which suggests strong recovery of sales for the post-recall period. However, the test statistic for the post-recall period of [t_1, t_2] = [6, 7] is not statistically significant even at a significance level of 0.1. Various values of t_2 up to twelve (when t_1 is fixed as 6) were tested, but none of them is statistically significant. In future work, more hypotheses will be tested by relaxing the basic assumptions (specified in Section 2.4).

Based on the findings of the analysis it is recommended that sales promotion including media and non-media marketing communication should be focused on the first two months after the announcement of a major recall. The main reason for this recommendation is that the marginal rate of decline in CAAR is much higher in the first two months of the recall-period. Therefore, in order to compensate for the expected sales decline, it is recommended to incorporate such a marketing campaign for that period. However, this guideline is not generalizable, but only illustrates how one company used the information. Applying this technique to a different company or industry may yield significantly different results and lead to totally different conclusions and guidelines.

RELATED WORK

Event studies have been widely used especially in economics and finance disciplines. For example, MacKinlay (1997) applied event studies in finance research. Recently, researchers such as Dehning, Richardson, and Stratpoplis (2003), Roztochi and Weistroffer (2008), and Konchitchki and O'Leary (2011) began to use event studies in information systems area. They examine the stock price reaction to IT investment announcements. However, their use of the event study is limited to the valuation of the firm, and no work uses event study to evaluate the sales performance of a firm and its application.

A recent literature review (Etayankara & Bapuji, 2009) identified several studies on product recalls and sales. Early studies (Crafton et al., 1981; Wynne & Hoffer, 1974) found that only the most severe recalls influenced customer demand for a new car. Severe problems are defined as those that involve fires or loss of control of the vehicle. Reilly and Hoffer (1983) showed that the competition's sales increased after a competitor had a recall. Recently, Shin et al. (2012) analyzed Toyota recalls and its economic impact on the sales performance. An analytic framework using time-series analysis for estimating the critical opportunity cost encountered as the result of a recall was presented. The model suggested that the major recalls had negative impact on the market share, while minor recalls showed positive impact on the market share. However, Shin et al. (2012) did not specifically identify the total decline in sales (i.e., shaded area in Figure 1). Our study accounts for the total decline in sales from the time the recall is announced until the company regains the sales momentum established by the previous sales trends. $CAAR$ in Equation (6) naturally captures the total decline in sales, and therefore, seems more appropriate for analyzing the impact of the event (i.e. a recall) and its implications.

CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

A major recall is defined as the recall in which the affected numbers of cars are more than certain threshold level per recall. It has a negative impact on sales, since there are fewer customers inclined to purchase an automobile from a manufacturer that is producing a defective product. Although calculation of direct costs of a recall is straightforward, the indirect cost such as the loss in sales, considered as an opportunity cost, is often ignored, and they cannot be derived from financial statements. In this paper we presented a framework for estimating the critical opportunity cost associated with the loss in sales encountered as the result of a major recall using an event study. Event study (Bowman, 1983; de Jong 2007) is a statistical method that assesses the impact of an event on the value of a firm, and it has been used extensively in financial research to find the stock market reaction to important financial events. However, this methodology is now applied to the automobile industry to estimate the impact of a major recall. A case study of Toyota Motor Corporation is presented to demonstrate the use of the model. The model suggests that the sales may decline for the subsequent five months from the time a major recall is announced.

The main limitation of this model is that it does not address the interaction of recalls (i.e., another recall has been occurred during the recall and post-recall period of an initial recall). Between October 2009 and February 2011, there have been 7 major recalls with average interval in month between the subsequent recalls = 2.67. Event study is not suitable to measure the sales loss in such cases unless the interaction of subsequent recalls is properly addressed. In future work, these basic assumptions (specified in Section 2.4) will be relaxed and the sales performance will be analyzed. Also, more advanced models such as market-adjusted return, proxy portfolio return, or risk-adjusted return will be applied to estimate the *basis*.

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