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In this paper we analyze the effect of Boeing Dreamliner 787's battery problems on stockholder wealth. Using the event study methodology, we show that the recall in January of 2013 initially caused the company's cumulative abnormal returns to fall by almost 4% in four trading days after the recall. This was followed by an announcement by two major airlines to ground all of the 787 Dreamliner jets. The FAA also ordered all US airlines to ground their 787s and announced an investigation to review all critical systems of 787s. However within four months of the investigation, FAA approved Boeing's revisions to its 787 design. This caused Boeing's abnormal returns to rise by almost 2%. On April 24th Boeing reported it's greater than expected quarterly results which caused its abnormal returns to rise by an additional 3%. The Boeing case provides us an opportunity to study how critical mistakes can change the value of a manufacturer. It also shows how critical it is for the company to redeem itself by quickly addressing a crisis situation.

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I. Introduction

There is documented research that product harm crises and product recalls damage the value of a firm. Jarrell and Peltzman (1985) and Hoffer, Pruitt and Reilly (1987) found evidence of negative effect of recalls by automobile firms on stock returns. Gokhale et al. (2014) find evidence of negative stock market reaction to recalls made by Toyota in 2010 due to its sticky accelerator pedal. In this study we study the stock market reaction to the reports of fire in battery unit of several Boeing 787 Dreamliners, subsequent groundings and investigation by the FAA and its effect on Boeing's financials.

The Boeing 787 has faced several operational problems and aviation incidents since its rollout in 2007. The CEO of Boeing Mr. James McNerney described as those similar with the rollout of new models of passenger airplanes. Among the many problems that it faced, the Boeing 787's main problem has been a problem with its battery. In January of 2013, there were reports of fire in the fuel cell compartment of an empty 787 operated by Japan Airlines (JAL). This was followed by similar reports by All Nippon Airways (ANA), United Airlines (UAL), Ethiopian Airlines. The FAA announced a comprehensive review of all critical process of the 787 Dreamliner. All 787s were grounded and Boeing halted the deliveries of new 787s until a fix to battery problems was found.

While looking at product harm crises, an individual event may not be as interesting or significant for a firm's revenues in the short run. However if the event is life threatening such as the sticky accelerator pedal (Gokhale et al. 2014) or a fire in the battery unit of an aircraft can have a serious effect on the reputation of the firm. In this paper we analyze the financial impact of the Dreamliner groundings made by Boeing due to battery problems. Just like the sticky accelerator pedal problem with Toyota, this problem was due to reasons internal to the company.

Several prior studies investigate the relationship between stock returns of companies and catastrophic events such as airline crashes (Barrett et al. 1987; Davidson et al. 1987) and the September 11 terrorist attacks (Carter and Simkins 2004; Guzhva 2008). However, this investigation differs from these earlier studies because of the nature of firm involvement (external versus internal).

Following the groundings, Boeing worked on a fix to resolve the battery issue. They addressed the fix in three ways (Sinnett 2013). First they made manufacturing improvements by enhancing battery construction process and quality control. Second, they made changes to the engineering design of the battery. Third, they added an enclosure to the battery unit. After working with the FAA, Boeing got a clearance from the FAA on April 19, 2013 that their proposed modifications would make the Dreamliner airworthy. The following week, on April 23rd Boeing reported better than expected financial results even after the groundings negatively affected the company image. Thus the Boeing case provides us with an excellent opportunity to study three distinct events around the 787 Dreamliner groundings. The first event is a series of instances of fires reported by different airlines operating the Dreamliner. The second is the clearance by the FAA, an independent government organization regarding the safety of the Dreamliner. The third is the announcement of financial results by the company following the events.

We use the event study methodology to estimate the effect on Boeing's stock returns due to the battery fire and groundings. We want to see if these events have an impact on the value of the firm given the sensitive nature of the product being involved (an aircraft) and if the clearance by the FAA can reverse the damage to the company reputation if any caused by the problem. Our results indicate that the investors felt that the problem was major and that following the clearance by the FAA, Boeing had indeed settled the problem. The investors were positively surprised by Boeing's financial results that followed which showed that notwithstanding the battery problems, the firm had done a remarkable job of damage control to its reputation. This paper is organized as follows. Section II describes a timeline of the events. Section III describes the event study method. Section IV describes data and empirical results. Section V concludes.

II. Boeing and the Dreamliner battery problems in 2013

The Dreamliner has faced several problems both before and since its first delivery in late 2011. Its first customer was All Nippon Airways with an order of 50 aircraft and a scheduled delivery of 2007. However, several testing delays and clearances caused the company to make its first delivery of the aircraft in September 2011. A few glitches and errors related to engines were subsequently corrected through 2012. However on January 7, 2013 a fire broke out in an empty JAL Dreamliner in Boston. The next day there was report of a fuel leak on a JAL Dreamliner. On

January 9, UAL reported problem with wiring near the battery of one of its 787. The National Transportation Security Board (NTSB) announced the launch of an investigation. On January 11 and 13, two JAL Dreamliners were found to have fuel leaks. On January 16, an ANA Dreamliner reported having a battery fire and was diverted in the middle of its flight and grounded. Consequently all Dreamliners in operation at the time were grounded until further investigation. Boeing also announced that deliveries would be halted until battery problem was solved.

III. Event Study Analysis

We use the event study method to investigate the effect of the circumstances related to the battery problems on returns of Boeing stock. The event study method was developed by Ball and Brown (1968) and Fama et al. (1969).[1] The event study technique is a common method used to study effect of manufacturing shortcomings and product recalls. Some examples of application of the event study method in the airline sector include studies by Ceshney et al. (2011), Liu et al. (2013), Jayanti and Jayanti (2009), Mizuno and Hanabusa (2011). The event study approach is based on the assumption that returns from a stock are driven by the returns from the broad market *ceteris paribus*. This is captured in the market model, which is based on the Efficient Markets Hypothesis which assumes the price of a stock reflects all currently available information in the marketplace. More specifically, the return of a stock i at time t (R_{it}), is expressed as a function of market information. This market information is typically measured as the return on a portfolio of stocks (R_{mt}). These include the Dow Jones Industrial Average (DJIA), the Standard and Poor's 500 Index (S&P 500) etc. In the market model, R_{it} is expressed as:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}, \qquad (1)$$

where, $\varepsilon_{it} \sim N(0,\ \sigma^2)$,

ε_{it}, the error term is assumed to follow a random walk. If all available information is captured in the stock returns through market return relationship as captured by the efficient markets hypothesis, expected value of ε_{it} is zero.

[1] For more recent reviews of this method, see Thomson (1985), Armitage (1995), MacKinlay (1997), Bhagat and Romano (2002a, 2002b) and Corrado (2011).

The goal of this study is to test the null hypothesis that an abnormal event such as safety issue with an airplane has no effect on the manufacturing company's expected returns. Thus we define abnormal return as the difference of ex post return and the normal expected return, which is conditioned on the situation that the abnormal safety event never took place. To be precise, the abnormal return (AR) for firm i at event date τ is

$$\mathrm{AR}_{\mathrm{i}\tau} = \mathrm{R}_{\mathrm{i}\tau} - \mathrm{E}(\mathrm{R}_{\mathrm{i}\tau}|\mathrm{R}_{\mathrm{m}\tau}), \quad (2)$$

In case of the market model $AR_{i\tau}$ will be

$$AR_{i\tau} = R_{i\tau} - \hat{\alpha} - \hat{\beta}R_{m\tau}$$

$\mathrm{E}(\mathrm{R}_{\mathrm{i}\tau}|\mathrm{R}_{\mathrm{m}\tau})$ is the expected return and $\mathrm{R}_{\mathrm{m}\tau}$ is the market return (which is the conditioning information). In other words, $\mathrm{R}_{\mathrm{m}\tau}$ is the information that is used to predict expected returns assuming no abnormal event.

In the event study method, the relation between R_{it} and R_{mt} is measured in the estimation window. This allows us to estimate the sample value of $\hat{\alpha}_i$ and $\hat{\beta}_i$. Let W_{pre} be the length of the estimation window and T_{pre} be the number of observations in the estimation window. The value of T_{pre} needs to be sufficiently long and yet should not include any abnormal events, which may cause the estimates $\hat{\alpha}_i$ and $\hat{\beta}_i$ to be unstable. Let W_{event} be the length of the event window, which starts at τ=0. This is before the official start of the event if there are fears of information leakage. The length of W_{event} is > 1 if there are inefficiencies in transmission of information to investors, or if the event studied is a complex series of smaller events. In such a case, τ extends through several trading days.

Using the estimated values of $\widehat{\alpha}_i$ and $\widehat{\beta}_i$ from W_{pre}, we can estimate abnormal returns and cumulative abnormal returns (CARs). CARs aggregate abnormal returns over the event window. If an event does not have an impact on returns, then ARs (and hence CARs) would not be statistically significant. A negative (positive) event would produce negative (positive) ARs and CARs.

If W_{event} ranges from τ_1 to τ_2, then

$$\mathrm{CAR}_{\mathrm{i}\tau} = \sum_{t=\tau_1}^{\tau_2} \mathrm{AR}_{\mathrm{i}\tau}. \quad (5)$$

In addition to the market model, we also estimate ARs using the Fama French 3-Factor model and the 4-Factor model. In the three factor model, there are two additional regressors. SMB (the variable 'Small minus Big') – which represents the anomalies that occur due to the size difference of firms and HML (the variable High minus Low) which occurs due to some stock being more growth oriented vis-à-vis value oriented stocks (in today's world stocks such as Tesla can be perceived as growth stocks while Apple, IBM etc. can be perceived as value stocks).

$$R_{it} = \alpha_i + \beta_i R_{mt} + \beta_i^{SMB} SMB_{mt} + \beta_i^{HML} HML_{mt} + \varepsilon_{it} \qquad (6)$$

In yet another specification, we augment the 3-factor model by a momentum factor (MOMmt) on winners and losers for the market in addition to SMBmt, HMLmt and Rmt. This is based on the theory that stocks which have price momentum in their favor (for example due to consistent earnings beat) tend to outperform stocks which do not have momentum.

$$R_{it} = \alpha_i + \beta_i R_{mt} + \beta_i^{SMB} SMB_{mt} + \beta_i^{HML} HML_{mt} + \beta_i^{MOM} MOM_{mt} + \varepsilon_{it} \qquad (7)$$

To account for risk, we also employ the Capital Asset Pricing Model, which uses the correlation of riskiness of a stock to the riskiness of the market to predict AR and CAR. This model uses risk free rate (the interest rate on the 1-month treasury bill) in the equation below,

$$R_{it} = R_{ft} + \beta_i (R_{mt} - R_{ft}) + \varepsilon_{it} \qquad (8)$$

IV. Data and Estimation Techniques

The data consists of returns from Boeing Stock and that from the S&P 500 Index obtained from the Center for Research in Security Prices available from the Wharton Research Data Services from the University of Pennsylvania. We use estimation period window of 250 days preceding the first event (battery fire in 787 at Boston's Logan International Airport). We study the following events:

Event 1: January 7, 2013 Fire breaks out in empty 787 JAL Dreamliner in Boston

Event 2: January 8, 2013 A 787 JAL Dreamliner suffers a fuel leak and flight out of Boston

Event 3: January 11, 2013 FAA announces a comprehensive review of all critical systems of Boeing 787

Event 4: January 16, 2013 battery fire detected in an airborne ANA flight from Ube to Tokyo. All Boeing 787s were grounded and delivery of new 787s was halted until a resolution of the issue was found.

Event 5: April 19, 2013 FAA approves the battery design fix proposed by Boeing

Event 6: April 24, 2013, Boeing announces better than expected quarterly financial results

We test for robustness of the results using a 90-day and a 180-day window and find that results are consistent across the three estimation windows. We use a 50-day estimation window for events during April of 2013. However, the 50-day estimation window for events 5 and 6 does not guarantee loss of contamination from the previous events. So we use the 250 day estimation window used in Events 1 through 4 for these events as well. We use a single day event window because some these events are spaced very closely. All events except the clearance by the FAA are unanticipated. Table 1 presents a summary of different estimation and event windows used. Table 2 presents summary statistics of data used for regression. Table 3 presents results of regression and OLS parameter estimates. There is a positive and significant association between Boeing returns and market returns. These parameter estimates are then used to generate expected returns and abnormal returns from each event. To analyze if abnormal return associated with each event is significantly different from zero, we carried out parametric test. The abnormal returns and significance calculated using the market model are listed in table 4. We find that the first event of the fire, produced abnormal returns of -1.7% significant at 5% level. The event next day of another fire in JAL Dreamliner caused abnormal returns of -2.3% significant at 1% level. Abnormal returns for the third event of announcement of review of critical systems of 787 by the FAA were -2.47% significant at 1%. This shows that the markets were getting prepared for the worst case scenario on the Dreamliner. For the battery fire in airborne ANA flight incident (Event 4), abnormal returns were -3.37% significant at 1%. For the event in which the FAA approved battery design fix (Event 5), abnormal returns were 1.3% (significant at 10%). For the event in which Boeing surprised investors with positive earnings surprise (Event 6), abnormal returns were 3.03% significant at 1% level. These results are further corroborated by the 3-factor model (table 5), the 4-factor model (table 6) and the CAPM model (table 7).[2] The abnormal returns and cumulative abnormal returns for events 1-4 are shown in figure 1 and for events 5 and 6 are as in figure 2.

The empirical results are significant given the fact that events associated with accidents or reports related to fire produced negative abnormal returns while events related to the fix and positive earnings surprise produced positive abnormal returns. These are consistent with investor expectations.

V. Concluding Remarks

We estimate the extent to which a chain of negative events related to the battery problems of Boeing Dreamliner affected the returns of Boeing stock. These involve four major reports associated with battery fire or fuel leak in different Dreamliner aircrafts on different days. This was followed by grounding of all Dreamliner aircrafts delivered until then by Boeing and suspension of delivery of new Dreamliners. All these events produced negative abnormal returns. The FAA announced an investigation of the issue. Boeing created a fix for the problem and the FAA declared that the fix was good. This was followed by a positive earnings surprise by Boeing. Both these events produced positive abnormal returns.

This evidence supports two main conclusions. The reports of accidents made the investors nervous about the financial impact on Boeing's financial value. Clearance of the fix by the FAA exonerated the company of its previous design flaw and reassured the investors that the problem had been solved. The announcement of financial results by the company further reassured the investors that the company had tackled the issue successfully despite the groundings and non-delivery of new aircraft. This case provides an excellent opportunity to study how a company can successfully navigate product harm crisis.

[2] We also considered a smaller estimation window of 55 days (after events 1 – 4) for events 5 and 6 and found that the ARs for events 5 and 6 were still robust but significance levels dropped.

Table 1 Description of Estimation and Event Windows

Estimation/ Event Window	Dates	Brief Description
Estimation Window	01/03/2012 to 01/02/2013	251 trading days in the previous year
Event 1	01/07/2013	Fire breaks out in empty 787 JAL Dreamliner in Boston
Event 2	01/08/2013	A 787 JAL Dreamliner suffers a fuel leak
Event 3	01/13/2013	Fuel leak in another JAL 787 Dreamliner
Event 4	01/16/2013	Battery fire detected in an airborne ANA flight from Ube to Tokyo. All Boeing 787s grounded and delivery of new 787s halted until resolution of the issue.
Event 5	04/19/2013	FAA approval for the battery design fix proposed by Boeing
Event 6	04/24/2013	Better than expected quarterly results announced by Boeing

Table 2 Descriptive Statistics

Variable	Description	N	Mean ($\times10^2$)	Std. Dev. ($\times10^2$)	Min ($\times10^2$)	Max ($\times10^2$)
R_{it}	Returns from Boeing stock	251	0.0362	1.1788	-3.6213	5.2862
R_{mt}	Returns from S&P 500 Index	251	0.0635	0.8178	-2.4643	2.5403

Table 3 Regression Results from Estimation Period

	Coefficient	Std. Error	t-statistic	P> |t|
Intercept	-0.0003	0.00054	-00.51	0.609
R_{mt}	+1.0031	0.06560	+15.29	0.000

Table 4 Abnormal return (AR), standard error of abnormal returns (SAR) and p-value of abnormal returns (PSAR) for 6 events related to Boeing Battery Problems using the market model

Date	Event Number	AR ($\times 10^2$)	SAR	PSAR
1/7/2013	Event 1	-1.6673**	-1.9606	0.026
1/8/2013	Event 2	-2.2744***	-2.6746	0.004
1/11/2013	Event 3	-2.4713***	-2.9073	0.002
1/16/2013	Event 4	-3.3716***	-3.9665	0.000
4/19/2013	Event 5	+1.2765*	+1.4987	0.068
4/24/2013	Event 6	+3.0321***	+3.5671	0.000

*p<0.1, **p<0.05, ***p<0.01

Table 5 Abnormal return (AR), standard error of abnormal returns (SAR) and p-value of abnormal returns (PSAR) for 6 events related to Boeing Battery Problems using the 3-factor model

Date	Event Number	AR ($\times 10^2$)	SAR	PSAR
1/7/2013	Event 1	-1.8515**	-2.2063	0.014
1/8/2013	Event 2	-2.2715***	-2.7067	0.004
1/11/2013	Event 3	-2.6427***	-3.1503	0.001
1/16/2013	Event 4	-3.3183***	-3.9665	0.000
4/19/2013	Event 5	+1.3342*	+1.5873	0.057
4/24/2013	Event 6	+3.4926***	+4.1635	0.000

*p<0.1, **p<0.05, ***p<0.01

Table 6 Abnormal return (AR), standard error of abnormal returns (SAR) and p-value of abnormal returns (PSAR) for 6 events related to Boeing Battery Problems using the 4-factor model

Date	Event Number	AR ($\times 10^2$)	SAR	PSAR
1/7/2013	Event 1	-1.8636**	-2.2176	0.014
1/8/2013	Event 2	-2.2293***	-2.6526	0.004
1/11/2013	Event 3	-2.6646***	-3.1721	0.001
1/16/2013	Event 4	-3.3077***	-3.9376	0.000
4/19/2013	Event 5	+1.4274**	+1.6958	0.046
4/24/2013	Event 6	+3.4766***	+4.1387	0.000

*p<0.1, **p<0.05, ***p<0.01

Table 7 Abnormal return (AR), standard error of abnormal returns (SAR) and p-value of abnormal returns (PSAR) for 6 events related to Boeing Battery Problems using the CAPM model

Date	Event Number	AR ($\times 10^2$)	SAR	PSAR
1/7/2013	Event 1	-1.6673**	-1.9606	0.026
1/8/2013	Event 2	-2.2744***	-2.6746	0.004
1/11/2013	Event 3	-2.4713***	-2.9073	0.002
1/16/2013	Event 4	-3.3716***	-3.9665	0.000
4/19/2013	Event 5	+1.2765*	+1.4987	0.068
4/24/2013	Event 6	+3.0321***	+3.5671	0.000

*p<0.1, **p<0.05, ***p<0.01

Figure 1 Abnormal Returns (AR) and Cumulative Abnormal Returns (CAR) for Boeing for events 1 to 4

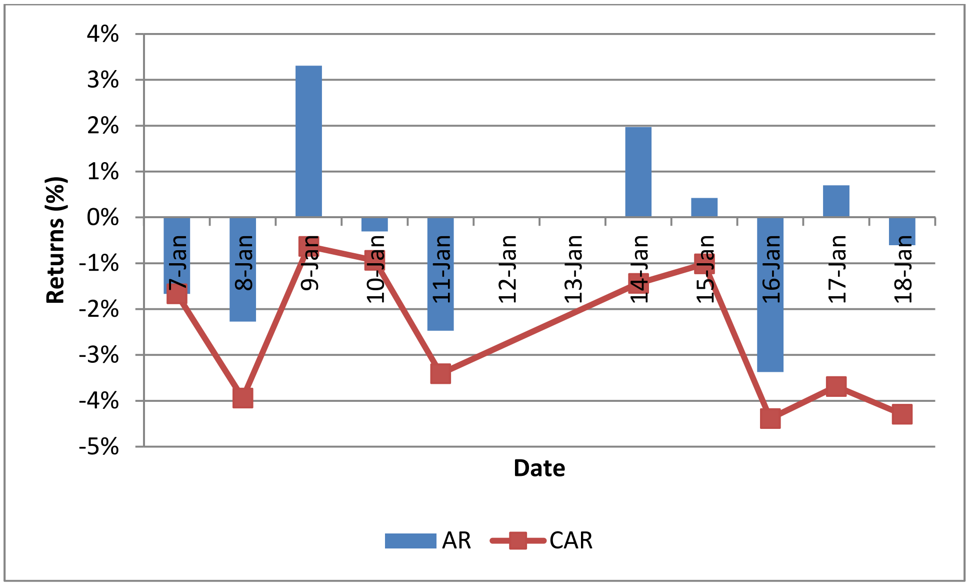
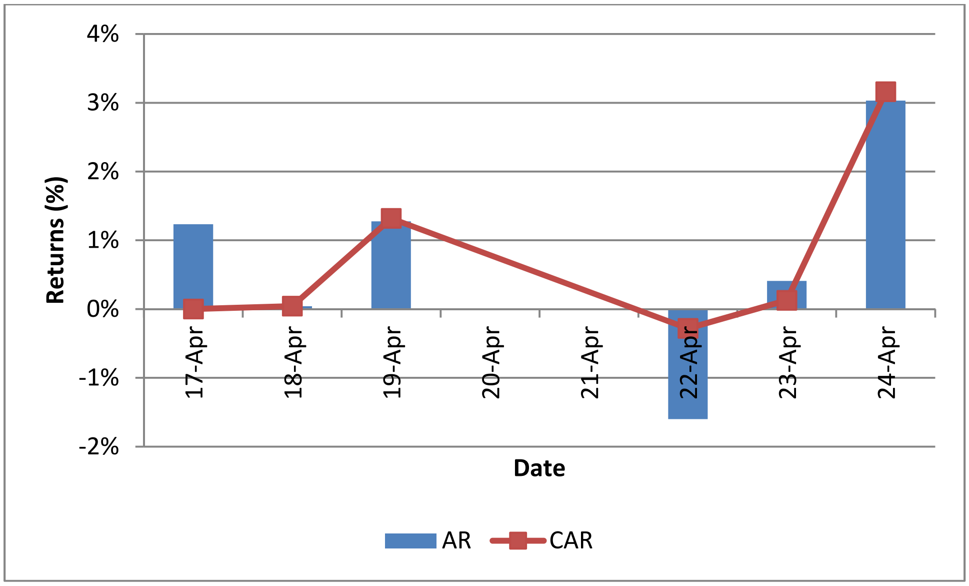


Figure 2 Abnormal Returns (AR) and Cumulative Abnormal Returns (CAR) for Boeing for events 5 and 6



References

Armitage, Seth, “Event Study Methods and Evidence on their Performance,” *Journal of Economic Surveys*, 8 (4), March 1995, 25-52.

Ball, Ray and Philip Brown, “An Empirical Evaluation of Accounting Income Numbers,” *Journal of Accounting Research*, 6(2), Autumn 1968, 159 – 178.

Barrett, W. Brian, Andrea J. Heuson, Robert W. Kolb and Gabriele H. Schropp,” The Adjustment of stock prices to completely unanticipated events,”*Financial Review*, 22(4), November 1987, 345-354

Bhagat, Sanjai and Roberta Romano, “Event Studies and the Law: Part I: Technique and Corporate Litigation,” *American Law and Economics Review*, 4 (1), 2002a, 141-168.

Bhagat, Sanjai and Roberta Romano, “Event Studies and the Law: Part II: Empirical Studies of Corporate Law,” *American Law and Economics Review*, 4 (2), 2002b, 380-423.

Carter, David A., Daniel A. Rogers and Betty J. Simkins, “Does Hedging Affect Firm Value? Evidence from the US Airline Industry,” *Financial Management*, Spring 2006 • pages 53 - 86.

Chesney, Marc, Ganna Reshetar, and Mustafa Karaman, "The impact of terrorism on financial markets: An empirical study." *Journal of Banking & Finance* 35(2), 2011, 253-267.

Corrado, Charles J., “Event Studies: A Methodology Review,” *Journal of Accounting and Finance*, 51, 2011, 207 – 234.

Davidson, Wallace N. III, P. R. Chandy and Mark Cross, “Large Losses, Risk Management and Stock Returns in the Airline Industry,” *Journal of Risk and Insurance*, 54 (1), March 1987, 162 - 172

Davidson, Wallace, N. III, and Dan Worrell, “The Effect of Product Recall Announcements on Shareholder Wealth,” *Strategic Management Journal*, 13 (6), September 1992, 467–73.

Fama, Eugene F., Lawrence Fisher, Michael C. Jensen and Richard Roll, “The Adjustment of Stock Prices to New Information,” *International Economic Review*, 10 (1), February 1969, 1 – 21.

Gokhale, Jayendra, Raymond M. Brooks and Victor J. Tremblay, “The Effect on Stockholder Wealth of Product Recalls and Government Action: The Case of Toyota’s Accelerator Pedal Recall,” *Forthcoming*, 2014

Govindraj, Suresh, Bikki Jaggi and Beixin Lin, “Market Overreaction to Product Recall Revisited – The Case of Firestone Tires and Ford Explorer,” *Review of Quantitative Finance and Accounting*, 23, 2004, 31 – 54.

Guzhva, Vitaly S., “Applying Intervention Analysis to Financial Performance Data: The Case of US Airlines and September 11th," *Journal of Economics and Finance*, 32 (3), 243 - 259

Hoffer, George, Stephen Pruitt and Robert Reilly, “The Impact of Product Recalls on the Wealth of Sellers: A Reexamination,” *Journal of Political Economy*, 96 (3), June 1988, 663–670.

Jarrell, Gregg and Sam Peltzman, “The Impact of Product Recalls on the Wealth of Sellers,” *Journal of Political Economy*, 93 (3), June 1985, 512–536.

Jayanti, Rama K., S. V. Jayanti, "Effects of airline bankruptcies: an event study," *Journal of Services Marketing*, 25(6), 2011, 399-409.

Liu, Kun, Jonathan D. Arthurs, Daeil Nam, and Fariss-Terry Mousa. "Information diffusion and value redistribution among transaction partners of the IPO firm." *Strategic Management Journal*, 2013.

MacKinlay, A. Craig, "Event Studies in Economics and Finance*", Journal of Economic Literature*, 35, March 1997, 13 – 39.

Mitchell, Mark L., "The Impact of External Parties on Brand-Name Capital: The 1982 Tylenol Poisonings and Subsequent Cases," *Economic Inquiry*, 27 (4), October 1989, 601-618.

Mizuno, Tomomichi, Kunihiro Hanabusa, "Market Definition of Long Distance Transportation Market in Japan: An Event Study Approach," *Asian Journal of Law and Economics,* 2(2), 2011, Article 3.

Sinnett M., "Certification of 787 Battery Solution," www.boeing.com accessed February 28, 2014, April 2013,

Thompson, Rex, "Conditioning the Return-Generating Process on Firm-Specific Events: A Discussion of Event Study Methods," *Journal of Financial and Quantitative Analysis*, 20, June 1985, 151-168