Impact of Product Recalls on Stock Price and the Role of Brand Concepts – a Study in the U.S. Automotive Sector

by

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Abstract

Recalling products has been a challenging experience for companies across all industries and is known to have an impact on the firm's value. Based on recall announcements in the U.S. automobile industry, this essay used event study to investigate whether different brand concepts affect the impact of recall announcement on automotive firm's stock performance. The data set consists of 1,165 recall events for 10 automotive companies that are publicly listed in either the United States, Japan, Germany, or Korea during a twenty-year period (2000-2021). The findings imply that automakers with a functional brand concept suffer lower stock returns compared to luxury car brands during severe recall events. Largely consistent to previous literature, this study found the automobile recall announcements generated negative but statistically insignificant cumulative abnormal returns over the [-3,3] event window.

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1. Introduction

Product recall, as an immediate corrective action warranted by firms, has been witnessing an increasing growth in the number of recalls, as well as the number of units affected by each recall (Shah et al., 2017). Various industries, including automobiles, drugs, food, and toys are exhibiting this trend due to the growing globalization of production and rising product complexity (Chen & Nguyen, 2013). In the automobile industry, the annual report of the National Highway Traffic Safety Administration (NHTSA) suggests that the average number of annual automotive recalls in the U.S. from 2001 to 2010 is 547, which increased by 41.68% to 775 recalls in the next ten-year period (2011-2020).

Recalls are announced when a product falls short of industry standards, or it is at the risk of causing a safety hazard to consumers. For example, the notorious “Diesel-gate” of Volkswagen resulted in a massive fallout of 11 million recalls around the world – they were found cheating on the diesel emissions tests (Burrows, 2018). Moreover, in 2010, Toyota recalled 3.8 million vehicles because their floor mats interfered with gas pedals, which could lead to unintended acceleration and serious incidents (Burrows, 2018). Besides the life-threatening hazards, product recalls could result in severe financial damage. For instance, the massive recall of Toyota in 2010 led to a sharp decline of 22% in the following two weeks of the announcement (BBC News 2010). The crises caused by the defective product and the following recall announcement may raise concerns about safety and quality among customers. In addition to the increasingly stringent safety standards, intensive competition among firms and rapid technological development led to the inevitable result of recalls in many industries, especially in advanced products such as automobiles (Shah et al., 2017).

Compared with other industries, the automotive industry has a relatively higher frequency of recalls. The underlying reasons for auto recalls can be varying from a faulty airbag to a deadly ignition switch. The occurrence of auto recalls could be every few weeks or months, which provides a good data sample for researchers to investigate. Additionally, for the U.S. market, the advent of a policy has eliminated the need for manual data collection, therefore facilitating the process of research analysis. In 1966, the U.S. Congress passed the National Traffic Vehicle Safety Act, which empowered the federal government to set national safety standards for motor vehicles. The National Highway Traffic Safety Administration (NHTSA) of the Department of Transportation (DOT), a regulatory agency, was then empowered to mandate manufacturers to recall their model from the market and repair the defects accordingly when safety standards are violated.

The initiation of the National Traffic and Motor Vehicle Safety Act has attracted the interest of many researchers to study various facets associated with U.S. auto recalls. Crafton, Hoffer, and Reilly (1981) focused on the impact on the demand side of consumers. They found severe auto recalls lead to a loss in sales of the recalled models. Lost sales and repairs of defective products are considered the direct cost of recalls (Bromiley & Marcus, 1989). Besides, there are indirect costs associated with product recalls such as deterioration of firms' brand reputation, liability suits, and goodwill (Bromiley & Marcus, 1989; Jarrell & Peltzman, 1985). Although the indirect cost is hard to be measured directly, it can be inferred from the capital market responses measured by the abnormal returns in the stock market (Liu & Varki, 2021; Jarrell & Peltzman, 1985). Some of the previous studies found evidence that product recalls deteriorated the market value of the recalling firm, whereas others did not. For example, the results of Gao et al. (2015)

suggest a significant negative abnormal return just on the announcement day of U.S. auto recalls from 2005 to 2012. Whereas, no significant negative impact on recalling firms was found when a similar study was conducted in India (Singh, 2018).

Adding to the previous literature regarding automobile recalls on subsequent sales performance, it is reported that brand concept can moderate the negative effect on future sales during severe recalls, which means the market reacts differently to car models with a functional or luxury brand concept (Topaloglu & Gokalp, 2018).Though auto recalls have received significant attention in the current literature, research on the relationship between automobile recalls, stock prices and brand concepts has not been discovered. Besides, the results of previous research on the relationship between recall announcements and shareholder wealth have been inconclusive and were mainly conducted before the 2000s. However, it has been reported that the number of vehicles recalls in the U.S. automobile industry has nearly doubled since the 2000s (NADA, 2014). Besides, consumers now expect the recall events of vehicles as the recall systems in the U.S. had time to mature since the 1980s. Therefore, the debate between researchers in prior studies and the lack of study on the period after 2000s prompt me to re-examine the effect of automobile recall announcements on stock prices in a more recent period.

In this study, I use 1,165 automobile recall announcements over a more recent sample period from 2000 to 2021. To determine the stock market reaction to vehicle recalls in the U.S. market, I employ the event study methodology to calculate abnormal returns with a focus on ten automotive manufacturers from four countries: the United States, Japan, Germany, and Korea. I will classify the automakers as either luxury or functional by following the standard established by Topaloglu and Gokalp (2018). The data source is the National Highway Traffic Safety Administration (NHTSA), Yahoo Finance, and Eikon. My research questions are: In the mature stage of U.S. automobile industry, how do automobile recalls impact the stock prices? As a follow-up question, I will also test if different brand concepts play a role in affecting the level of market responses during severe recalls.

This paper contributes to the existing literature in three ways. Firstly, I extend the literature by highlighting the interaction between automobile recalls and brand concepts regarding their effect on stock prices following undesirable events. Secondly, I revisit this issue of automotive recall influence with data in a more recent period. Lastly, I extended the analysis to manufacturers from countries other than the U.S.

The rest of the paper is structured as follows. In the first section, I discuss the relevant literature related to the research questions, and the hypotheses are presented. In the second section, I describe the data collection and how it was cleaned. In the third section, the methodology has been shown and explained. In the fourth section, I present the results of the research. The conclusion and further possible questions have been given in the last section.

2. Literature Review and Hypotheses

Over the decades, many researchers have been intrigued by the topic of automobile recalls and have attempted to study various aspects of them. Some early studies examined the relationship between vehicle recalls and the subsequent change of consumers' demand. For example, Crafton et al. (1981) analyzed the impact of recalls of a specific model on automobile demand with respect to different levels of severity. Their findings suggest that severe recalls resulted in a loss in sales while such a relation did not exist in less severe recalls. Besides, they have noticed that the sales of automobile firms were adversely influenced by their competitors' recalls rather than benefiting from them (Crafton et al., 1981). Such a negative spillover effect has also been found in the stock market, in which product recalls by a company with higher reputation for providing dependable products would hurt its competitors' market value (Liu & Varki, 2021).

However, for the automotive industry, the stock market reactions to product recall announcements are debatable in the literature. Jarrell and Peltzman (1985) were the first to investigate the financial impact of product recalls on shareholders' wealth focusing on the drugs and automobile industries. For the automotive industry specifically, Jarrell and Peltzman (1985) examined U.S. domestic Big 3, namely GM, Ford, and Chrysler. They used the event study method with a sample of 63 major recalls that occurred from 1967 to 1981 and found that automotive manufacturers bear significant financial losses for every event window they chose. Besides, they noticed that the associated indirect costs (captured by the stock market loss) were greater than the direct cost with the assumption that the direct costs of each recalled unit were reflected in their market value. In addition, they found the negative impact spills over to the shareholders of competitor firms, which leads to a greater aggregate loss. The study of Jarrell and Peltzman (1985) has provided a significant new area of focus for researchers in the field of event studies. Different conclusions were drawn when the work of Jarrell and Peltzman (1985) was re-examined. Hoffer, Pruitt, and Reilly (1988) reproduced the study of Jarrell and Peltzman (1985). With the same sample period, they removed overlaps between each recall, which leads to a reduced sample size. After applying the new criteria, only one of the recalls significantly affected the stock price of the affected company, but none of them impacted the stock price of the competitors.

Additionally, Bromiley and Marcus (1989) reported that the stock market response to negative returns is too small to constitute a sufficient deterrent. Instead of using recalls in a continuous timeframe, they analyzed auto recalls in four separate periods which represent four different stages of NHTSA. The reasoning behind classifying recalls is based on the assumption that the influence of recalls might be viewed differently by a manager or stockholder during each of these periods (Bromiley & Marcus, 1989). With the inclusion of cognitive effects and time-varying effects, they found the influence of market reaction to auto recalls is much less than the deterrent associated with direct costs, which contradicts the conclusion of Jarrell and Peltzman (1985). From the perspective of strategic management, Bromiley and Marcus (1989) suggest that social control cannot be achieved with stock market reactions as there is substantial variation between different regulatory periods and in the situation of the companies in the way the market responds to recalls. Similar research has also been carried out in the context of other countries. By using the methodology of event study, Singh (2018) examined 13 automotive recalls in India from 2010 to 2015. Whereas the study shows that none of the auto recalls has generated a statistically significant adverse impact on the stock prices regardless of the size of the recall volume (Singh, 2018).

Although there are some studies on automobile recalls and the recalling firms' financial performance, they were mainly conducted before the 2000s. As the recall system in the U.S. is getting mature over the last two decades, the recurring nature of vehicle recalls makes the consumers and investors now expect the occurrence of the recall events. Besides, the opposing view in the prior studies and the lack of study on the more recent period makes it imperative to re-analyze the stock prices of the manufacturers. As a baseline, I propose:

Hypothesis 1: *In the past two decades, the automobile recall system is getting mature and regulated. Therefore, recalling automobiles is not a surprise to the consumers, and it will not result in a significant loss in the financial market.*

Other aspects of product recalls that have attracted researchers' interest include the severity of the recall. Van Heerde et al. (2007) argue that both baseline sales and advertising effectiveness face negative consequences following a severe recall. Additionally, Gao et al. (2015) found that the extent to which a firm's stock market value is affected, depending on the severity of the hazard and product type, can be determined by the extent to which they adjust their adverting expenditures prior to announcing a product recall. In the automobile sector, severe recalls have been perceived not only as a sign of a quality issue, but also as a signal of safety concerns. Trivial automotive recalls have been defined as issues with the audio system, locks, and seats. Major issues such as brake, steering, and acceleration could result in severe outcomes such as occupant's injuries, car crash, or fire (Gao et al., 2015). Product recalls caused by minor issues have not been found to hurt a company's performance, and in some cases, they have been seen as evidence of the manufacturer's diligence in fixing even trivial issues with their products (Rhee & Haunschild, 2006). Serious recalls, on the other hand, are more likely to cause consumer backlash because the issues pose a significant personal risk and the vehicles cannot be used until corrective actions are taken (Topaloglu & Gokalp, 2018). In addition, severe auto recalls are associated with lower reputation because of receiving higher attention from social media with less positive media coverage, which impacts not only the existing users, but also future potential clients (Zavyalova et al., 2012). Hence, compared to nonsevere recall, the adverse impact of severe recalls has been emphasized greatly and long-lasting because of media's propagation. I propose:

Hypothesis 2: *When an automobile company experiences a severe product recall (i.e., the recall is caused by severe quality defects which may cause occupant injury and car crash), its stock prices tend to be adversely impacted to a larger extent.*

Besides, the role of customers' perception of recall announcements has also intrigued researchers to study. It is proposed that how consumers would react to the recall crisis is significantly influenced by their level of product knowledge (Wei et al., 2016). From their study of customers' early responses to the Volkswagen product recall crisis in China, Wei et al. (2016) argue that when customers are more knowledgeable about a firm's product, their perception of risk about a crisis of that product is lower. One possible explanation is that customers who are knowledgeable about recalling cars tend to evaluate the risk objectively and rationally, which makes them behave more favorable towards the involved companies (Wei et al., 2016). Among various factors that can influence customer decision-making, branding is one of the most powerful strategies for creating and sustaining a strong competitive advantage realized in consumers' cognition (Aggarwal, 2004). It has been proposed that consumer attitudes have separate hedonic and utilitarian components, and that the proportion of these two components make up consumers' overall attitudes varies across product categories (Batra & Ahtola, 1991).

The automotive industry is a good example of using a branding strategy because of its heterogeneous demand. For instance, Germann et al. (2014) propose that a high level of brand commitment augments negative consumer responses in the event of high-severity product recalls. When it comes to recalling products with different brand concepts in the automobile sector, consumers derive hedonic and psychological benefits by purchasing luxury car brands because of their luxurious design and symbol of prestige (Bian & Forsythe, 2012). On the other hand, a car brand with a functional brand concept is associated with utilitarian benefits such as safety or durability. Take the impact of recalling cars on future sales for an example, recalling vehicles with a functional brand concept is expected to have a more negative impact on future sales (Topaloglu and Gokalp, 2018). The reason is that product recall is a result of a failure to meet expectations of functional product attributes. Using sample data from the U.S. auto industry from 2003 to 2014, Topaloglu and Gokalp (2018) found that despite the adverse impact on sales brought by severe recalls of auto units, different brand concepts could mitigate the negative impact by affecting consumers' perception. More specifically, they argue that recalled units with a functional brand concept were more adversely impacted than products with a luxury brand concept because an "expectancy violation" occurs (Rhee & Haunschild, 2006). While the research of Topaloglu and Gokalp (2018) has examined the impact of product recalls on sales from the perspective of branding strategy, whether such a relationship exists in the reaction of the stock market remains to be studied. Therefore, I propose:

Hypothesis 3: *Brand concept plays a role in the relationship between severe recalls and stock prices. Severe recalls are more likely to result in a drop in stock prices for brands with a functional concept.*

3. Data Collection and Sample Construction

3.1 Sample Construction

3.1.2 Sample Automakers

My study focused on ten automotive firms from four countries (USA, Japan, Germany, and Korea). Previous studies mainly focused on the U.S. (i.e. GM, Ford, and Chrysler) and Japan's Big Three automakers (i.e. Toyota, Honda, and Nissan) because these firms make up about 90% of U.S. motor vehicle sales (Gao et al., 2015; Liu & Varki, 2021). My study extended the previous studies by adding three representative German and two Korean automakers (Volkswagen, BMW, and Benz for German; Hyundai and Kia for Korea). However, I excluded recalls by Chrysler as it changed ownership several times during the evaluation period, therefore assessing the impact of recalls on the parent companies would not be accurate. My sample companies ended up with GM, Ford, Nissan, Toyota, Honda, BMW, Audi, Volkswagen, Kia, and Hyundai.

3.1.2 Classification of Brand Concepts

As my third hypothesis is at the level of brand, I classified their brand concepts based on the standards developed by Topaloglu & Gokalp (2018). An automaker is considered to have a luxury brand concept if they were classified in a category with luxury connotations such as "luxury, ultra-luxury, or premium"; on the other hand, brands' concepts were coded as functional if they were labeled with functional connotations such as "economy, standard, or lower mid-range" (Topaloglu & Gokalp, 2018). The detail of my sample automakers' brand concept classification can be found in **Table 1.** However, some companies have subsidiary brands that have different brand concepts from their parent companies. For example, Lincoln is a luxury brand owned by a functional brand Ford. As my recall data is at the level of companies, I separated recalls of automakers (i.e., Lincoln) whose brand concepts are inconsistent with their parent companies (i.e., Ford). For example, a Ford's recall announcement was coded as "functional" if it did not include Lincoln in the recall description. On the other hand, a recall announcement of Ford is coded "luxury" if it was mainly recalling Lincoln cars in the recall description.

3.2 Data source

3.2.1 Data of U.S. Automotive Recalls

The dataset of automotive recalls by manufacturers is obtained from the National Highway Traffic Safety Administration (NHTSA). As a regulatory agency under the Department of Transportation (DOT) of U.S. government, NHTSA records and maintains a comprehensive database which includes information related to automotive recalls with the earliest recall dated back to 1966. Each recall includes the specification of which component of cars failed the standard, which group of cars are to be recalled, the number of vehicles to be recalled, what's the potential outcome, and what further actions to remedy the issues. The distribution of the number of vehicles affected per recall is highly skewed — some recalls only affected a few hundred vehicles or less, while others impacted millions. Therefore, sample selection is necessary to drop insignificant cases (too trivial to affect the market), while maintaining sufficient variety that allows me to examine the impact of recall magnitude. Liu & Varki (2021) propose that the determination of major product recalls should be based on the value size of the company. Based on previous literature, a recall is considered major if the number of affected vehicles exceeds

50,000 for Toyota, 40,000 for GM and Ford, 30,000 for Honda, and 20,000 for Nissan (Gao et al., 2015; Jarrell & Peltzman, 1985; Liu & Varki, 2021). For the rest of companies in Germany and Korea, I chose 20,000 units as the threshold for the number of recalled cars to be a major recall. I collected major automotive recalls from 2000 to 2021, and I ended up with 1,165 recalls in my dataset with 438, 363, 153, 211 for U.S., Japan, Korea, and Germany companies respectively. Detail of the recalls by company are listed on **Table 2**.

Fig. 1 shows the number of affected cars of all sample manufacturers in the United States from 2000 to 2021. It presents an increasing trend over the past two decades with a peak in year 2014. **Fig. 2** and **Fig. 3** show the trend of affected recalled cars of manufacturers from four countries. It is clear to see that in general the number of cars recalled is gradually increasing in U.S., Japanese, Korean, and German car brands especially experienced a sharp increase after 2014.

3.2.2 Data source of sample companies' stock prices and the market indexes

I obtained the historical stock price data from Yahoo Finance. In addition, I obtained the daily market return for countries in which the companies are based. According to the study of Barber and Darrough (1996), using only the local market index as the benchmark for the corresponding firms is appropriate. Four market indexes are employed to measure abnormal returns. For the U.S. automakers, I use Dow Jones Industrial Average Index, which include 30 prominent companies listed in the U.S.; for Japanese auto manufacturers, I use Nikkei 225 Stock Average Index, which consists of 225 stocks in the Tokyo Stock Exchange; for Korean firms, I use Korean Composite Stock Price Index, which includes all common stocks traded on the Korea Stock Exchange; for German companies, I use Deutsche Aktien Xchange Performance Index, which consists of the 40 major German companies on the Frankfurt Stock Exchange (Barber & Darrough, 1996; Jarrell & Peltzman, 1985; Ji et al., 2022). Given the daily price of each stock and market index, I calculated the logarithmic return by using this equation:

$$R_{it} = ln(P_{t'}) - ln(P_t) \quad (1)$$

Where R_{it} is the return of individual stock i; $P_{t'}$ is the closing price of day t and P_t is the opening price of day t (i.e., the closing price of the prior day).

3.2.3 Data of firms' financial characteristics

The third dataset includes the financial characteristics of each firm by year. It tells the information about total asset, return on assets, market-to-book ratio, and debt-to-equity ratio of sample firms from year 1999 to 2021, which is obtained from Thomson Reuters Eikon. Eikon is a financial markets database powered by Datastream that provides access to comprehensive company and market data. With the access to historical annual data provided by Eikon, the regression on financial ratios is feasible.

4. Model Specification

4.1 Event Study Methodology

I use event study methodology to estimate the short-term impact of recall announcements on the stock prices of the recalling firms. The event study method is considered a highly effective tool for researchers to evaluate the financial consequences of alterations in a company's policies and it is developed based on the efficient market theory (MacKinlay, 1997). The semi-strong form of the efficient market hypothesis states that all publicly available information should be already reflected on the securities prices. More specifically, when an unanticipated announcement or new information goes public (e.g., a recall of a product), stakeholders will quickly assess the impact of the information, and act differently based on their perception. As a result, stock prices will either go up or down depending on if the information is perceived either positive or negative by the stakeholders. The event study methodology is commonly used as an effective approach to capture the potential profit or loss of the recalling firm due to the announcement, based on three essential assumptions below:

1. The stock market is efficient, which can accurately reflect the economic impact of a particular event by the stock returns in the event window.
2. There has not yet been a price adjustment for the unexpected event.
3. The stock price change is not due to any other events taking place during the event window.

The investigation process of automotive recalls includes screening, analysis, investigation, and management. After reviewing consumer complaints in the screening process, and examining petition in the step of analysis, a safety recall will be announced once a problematic issue is identified by technical professionals. In this study, an automotive recall announcement is defined as an event that provides new information to the stock market. Following the event study of Zhao et al. (2013), I employed the following steps:

Step 1: Estimation of Daily Residual

To estimate the abnormal returns associated with automotive recall announcements on stock prices, I use the market model, which is derived from the Capital Asset Pricing Model (CAPM). Comparing with other approaches such as mean-adjusted and market-adjusted measures, using market model is more prevalent in prior study for the advantage of adjusting overall market fluctuations, controlling systematic risk, and isolating the impact of market-related factors (Govindaraj et al., 2004; Rhee & Haunschild, 2006). The market model expresses a linear relation between a firm's stock return and the market return as the following equation:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \tag{2}$$

Where R_{it} is the actual return of individual stock i on each day t of the estimation period. α_i is the intercept term of stock i. β_i is the systematic risk of stock i. R_{mt} is the rate of return on a market portfolio of stocks. ε_{it} is the error term with $E(\varepsilon_{it}) = 0$. I estimated α_i , β_i using ordinary least squares (OLS) in an estimation window $[T_0 - 123, T_0 - 3]$, where T_0 represents the event day when a recall was announced. More specifically, the estimation period includes 120 trading days, and it ends three trading days before the recall announcement. Event window is defined as the period in which I examine the market's reaction to the recall announcement. This study primarily focuses on the event window $[T_0 - 3, T_0 + 10]$.

The abnormal return (AR) for individual stock i on day t can be estimated using the following formula:

$$AR_{it} = (R_{it}) - (\widehat{\alpha_i} + \widehat{\beta_i}\, R_{mt}) \tag{3}$$

Where AR_{it} is the abnormal return for stock i at time t, R_{it} is stock i's actual return at date t. $\hat{\alpha}_{it}$ is the estimator of the intercept of ordinary lest square (OLS) for the market model regression. $\hat{\beta}_{it}$ is the OLS estimator of the market model regression' slope from **equation (2)**, and R_{mt} is market portfolio's return at date t.

Summing up the abnormal returns yields the cumulative abnormal return (CAR) which tells the performance of individual firms in the event period. CAR of each individual firm i can be calculated using the formula below:

$$CAR_{i(t_1,t_2)} = AR_{it_1} + \ldots + AR_{it_2} = \sum_{t_1}^{t_2} AR_{it} \quad (4)$$

Step 2: Estimation of Average Abnormal Returns

The average abnormal returns ($\mathrm{AAR_t}$) is the mean of the cross-sectional abnormal returns at time t. $\mathrm{AAR_t}$ is calculated using the formula below:

$$AAR_t = \frac{\sum_{i=1}^{N} AR_{it}}{N} \quad (5)$$

Where AAR_t is the average abnormal return of the auto recall announcement and N is the sum of the events of recalling firms at a day t. AAR_t gives the information about the reaction of the stock market to the recall announcements of the combined auto manufacturers at a specific time.

Similarly, the average impact of recalls can be measured by the mean of CAR_i over N recall events in the sample. The average cumulative abnormal return (ACAR) is informative as it reflects the average variations of firm value over the event window. It can be calculated by taking the mean of the CAR.

$$ACAR_{i(t_1,t_2)} = \frac{1}{N} \sum_{i=1}^{N} CAR_{i(t_1,t_2)} \quad (6)$$

4.2 The OLS Regression of CAR

The obtained accumulative abnormal returns (CARs) can then be used to investigate Hypothesis 2 and Hypothesis 3. Referring to the previous literature (Kong et al., 2019), I use the regression **equation (7)** to test the Hypothesis 2:

$$CAR_{i,t} = \beta_0 + \beta_1 Severity_{i,t} + \beta_2 Size_{i,t-1} + \beta_3 LEV_{i,t-1} + \beta_4 ROA_{i,t-1} + \beta_5 MTB_{i,t-1} + \beta_6 Current_{i,t-1} + Country + Year + \varepsilon_{i,t} \quad (7)$$

To examine the moderating effect of brand concept in Hypothesis 3, I use:

$$CAR_{i,t} = \beta_0 + \beta_1 Severity_{i,t} + \beta_2 Functional_{i,t} + \beta_3 Severity_{i,t} \times Functional_{i,t} + \beta_4 Size_{i,t-1} + \beta_5 LEV_{i,t-1} + \beta_6 ROA_{i,t-1} + \beta_7 MTB_{i,t-1} + \beta_8 Current_{i,t-1} + Country + Year + \varepsilon_{i,t} \quad (8)$$

The dependent variable *CAR* is the accumulative abnormal returns over different event windows. Following the study of Kong et al. (2019), I use CAR [-3, 3] as the benchmark for this study, which is defined as the cumulative excess return for the announcement period [-3, 3]. It is computed by adding the daily excess returns for the three days before and after the event day. $Severity$ is a dummy variable indicating the severity of a recall — equals to "1" if a recall is considered severe, otherwise is "0". I developed the criteria for severity based on prior studies. A recall is considered severe when it satisfies both of the following conditions:

1. "The recall is due to major quality defects, such as brake failure, faulty airbags, poor visibility, steering problems, acceleration problems, or fuel leakage" (Gao et al., 2015; Topaloglu & Gokalp, 2018).
2. The consequence of the product failure would result in car crash, injury to the occupant, or fire. (Liu & Varki, 2021)

Based on Hypothesis 2, the sign of $Severity$ is expected to be negative, indicating a severe recall is going to hurt the stock price. *Functional* is a dummy variable to denote whether a recalled vehicle brand has either a functional (i.e., *Functional = 1*) or luxury (i.e., *Functional* =

0) brand concept. $Severity \times Functional$ denotes the interaction effects between severity of the recall and brand concept, which is expected to be negative as recalling functional vehicles is hypothesized to suffer more from a severe recall. I also controlled several important factors of the market reactions to the car recall announcements in the regression, which are annual financial ratios from 1999 to 2021. *Size* denotes firm size, which is measured by the natural logarithm of total assets – measurement scaling issue can be solved with the use of nature logarithm*;* LEV is the debt-to-equity ratio, which is expected to be negative as leverage ratio indicates a company has more debt, therefore more vulnerable to negative events such as recall announcements. *ROA* is the ratio of return on assets, which is expected to be positive because a firm with higher ROA is expected to recover from a negative event more quickly. *MTB* is the ratio of market to book value of equity, which may have a negative sign because higher MTB ratio may indicate the firm is overvalued, and a recall announcement may be seen as a setback of investors' expectations. *Current* is the current ratio, which is expected to be positive because a higher current ratio may be treated as a positive indicator of a company's ability to handle unexpected events. *Country* is the country specified fixed effect, $Year$ is the fixed effects of years, and $\varepsilon_{i,t}$ is the error term. All data regarding each firm's financial characteristics are of the fiscal year preceding the recall announcement (Ni et al., 2016).

5. Results

5.1 AAR and ACAR Analysis by Countries

Fig. 4 presents the variations of firm value over the event window [-3, 10], in which I use AAR and ACAR to represent the average effect of recall events in U.S., Japan, Korea, and Germany respectively. The horizontal line in the middle of the graph represents zero, meaning no average (cumulative) abnormal return. Positive values above the line indicate that the stock's performance is better than expected, while negative values below the line indicates a negative impact. A downward-sloped line indicates a negative impact on the stock performance. **Table 3** shows the significance statistics of AAR and ACAR in each country.

Fig. 4 shows that the AAR and ACAR of U.S. recalling firms with respective to the day difference to the event date. It shows that one day after T_0, the AAR dropped by around 0.1% and continue to decrease for the rest of the event window, except a temporary minor bounce back on date $T_0 + 3$. As a result, the ACAR of recalling U.S. firms is gradually decreasing in the period [0, 10]. However, the negative response of AAR is only significant on date $T_0 + 2$ at 5% significance level. Although the average cumulative abnormal returns in U.S. companies are negative, the results are not significant. It shows that the AAR and ACAR of Japanese recalling firms gradually decreased in the period [-1, 4], and bounced back to positive on date $T_0 + 5$. Their Average abnormal returns are negative at 5% significance level on day $T_0 - 3$ and day $T_0 + 7$. There is some volatility for the post-announcement period. The ACAR of Japanese auto companies stays negative except day $T_0 + 6$, but their ACAR is only negative and significant at the 5% level on $T_0 - 3$.

For German automakers, their AAR and ACAR is volatile around zero until five days after the announcement day. Starting from day $T_0 + 5$, their AARs stay negative and their ACAR is going downward from [4, 10]. **Table 3** shows that there is a $-$ 0.25% AAR on day $T_0 + 5$ at 1% significance level, but the results of German companies' ACARs are not significant.

When it comes to the Korean automakers, they suffer loss and retain its downward trend over event window [-1, 7]. Their average AR mostly remain negative until the eighth day after the event date. **Table 3** shows that on day $T_0 + 6$, the Korean auto firms' average abnormal returns is negative and statistically significant at the 5% level. Their Average CARs remain negative in the post-event period. **Table 3** suggests that there is a $-$ 1.14% ACAR in the event window [-3, 7], and the result is statistically significant at the 5% level.

To sum up, this study found no statistically significant evidence in U.S., Japanese, German, or Korean companies that the automobile recalls would lead to a negative impact on recalling firms' stock prices in the event window [-3, 3]. Therefore, it supports the Hypothesis 1 as the impact of stock prices is not significantly different from zero. However, the ACAR generated in Korean companies is - 1.1% when the event window is extended to [-3, 7], and is significant at the 5% level. The insignificant result can be explained by the fact that over the past two decades, the recall systems in the U.S. have had the opportunity to develop and mature, the high frequency and regulated recall events in the automobile sector has prepared shareholders to expect automobile recalls occurring. Consequently, they have considered the likelihood of recalls when participate in the stock market.

5.2 the OLS Regression Results of CAR

Fig. 5 shows the combined average AR and CAR for the sample ten firms. The graph presents that the AAR stays negative in the event window [1, 7], and the average CAR remains negative and goes downward until day $T_0 + 7$. The descriptive statistics of the regression equation are presented in **Table 5.** The average CAR of the recalling companies over the event window [-3, 3] is - 0.15%. Average CARs of severe, nonsevere, functional and luxury recalls are also shown in **Table 4**. It shows the mean CAR[-3,3] of severe recalls is 0.51% lower than that of nonsevere recalls. The correlation matrix is presented in **Table 5**, which shows weak correlations in explanatory variables (under 0.4). There are moderate correlations between leverage ratio and market-to-book ratio, as well as the current ratio. To test whether there is a multicollinearity problem, I employ the variation inflation factor (VIF) in the regression models. The values of VIF are under 5 for all variables with an average VIF equals to 2.96, indicating that there was little problem of multicollinearity.

The first three columns of **Table 6** present the OLS regression result of **equation (7)**. The heteroskedasticity-consistent standard errors are used in the regression, and is shown in the parenthesis of coefficients (White, 1980). The dependent variables are the aggregate cumulative abnormal return over the benchmark window CAR [-3, 3]. The first column is the regression result of CAR [-3, 3] on the dummy variable *Severity* without including control variables. The coefficient of *Severity* indicates there is a statistically insignificant -0.51% change in CAR [-3, 3] compared to nonsevere recalls. The second column includes the regression result of CAR [-3, 3] on *Severity* after controlling a series of firms' financial characteristics and the year fixed effect. The coefficient of *Severity* then reduced to -0.58% ($p< 0.1$). After controlling both year and country fixed effect, the new regression result is presented in the third column. It shows that the conclusion of negative impact on CAR [-3, 3] from severe recalls remains the same, with a -0.59% drop significant in the 10% level. I also regressed the aggregate CAR over three extended windows: CAR [-3, 5], and CAR [-3, 10], and the results are shown in **Table 7** from column (6) to column (7). Although the coefficients of *Severity* are negative in the extended event windows, they are not statistically significant, which indicates such influence does not last long. To ensure the robustness of the results, I also use CAR [-1, 3], CAR [-1, 5], CAR [-2, 2], and CAR [-2, 5] to retest Hypothesis 2. The results are presented in the first three columns of **Table 7,** which are found to be similar with CAR [-3, 3], where the coefficients on the variable *Severity* are negative and significant. These findings support Hypothesis 2 and suggest that severe recalls cause significantly negative excess return in a short period around the event day.

The coefficient of the last three columns of **Table 6** includes the regression results of **equation (8)** with CAR [-3, 3] as the benchmark dependent variable. The heteroskedasticity-consistent standard errors are used in the regression (White, 1980). The fourth column includes the result of regression CAR [-3, 3] over the main explanatory variables. The coefficient of the interaction term *Severity*×*Functional* is -1.76% and is significant at the 1% level. The fifth column of **Table 6**. presents the results including other control variables and the year fixed effect. The coefficient changed to -1.95% ($p < 0.01$). After controlling both year and country-specific fixed effect, the regression result is shown in the last column of **Table 6**. The coefficient of the interaction term *Severity*×*Functional* changed to -1.97% and is significant at the 1% level, which suggests that functional car brands are associated with lower stock prices compared to luxury car brands in the event of severe automotive recalls. Regressions over other event windows were also tested and were presented in **Table 8**. This conclusion holds when use CARs in the extended event periods, with the interaction coefficient -1.61% when regressed on CAR [-3, 5], and -1.76% on CAR [-3, 10]. These coefficients are significant on the 5% level. These results collectively support Hypothesis 2 that recalls that are associated with a functional concept are more susceptible to stock price loss in the case of severe recalls. Similarly, I use CAR [-1, 3], CAR [-1, 5], CAR [-2, 2], and CAR [-2, 5] to retest Hypothesis 3 for robustness, and the results are presented in the first four columns of **Table 8**. However, although the coefficients are negative, they are not statistically significant in the retested windows. The coefficients of other control variables are not statistically significant, demonstrating that severity and brand concepts are major influencers of abnormal returns, regardless of firm characteristics.

6. Conclusion

This paper examines the impact of product recalls on the stock performance of the recalling companies in the U.S. automotive industry on the level of manufacturers from four different countries. This study found small and statistically insignificant Average Cumulative Abnormal Returns (ACAR) for automakers from U.S., Japan, Germany, and Korea. In addition, it examines any possible moderating effects of functional versus luxury brand concepts. The findings demonstrate that severe recalls have a detrimental effect on stock prices in a short period around the announcement day, and that this effect is exacerbated when the brand of the affected cars is functional in the event window [-3, 3].

This paper makes contributions to the literature in three parts. First, it extends the findings in previous literature regarding the effect of product recalls on automobile firm's value by looking at a more recent period. Second, it separates severe recalls from non-severe recalls and finds severity pays a role in affecting stock prices. Third, despite prior research has shown that brand concept would influence the decision-making process of consumers as well as the following sales in the car industry, whether such a relation exists in the stock market remain unstudied. Therefore, this study contributes to the current study by considering brand concepts as moderators of the relationship between severe recalls and the stock market’s response to the listed companies. This study found that compared to car brands with a luxury brand concept, those associated with a functional brand concept suffered a higher loss in stock prices during severe recalls.

There are limitations in this study. First, this research focused solely on the link between automotive recalls and the brand concept of sample firms, finding a significant association with CAR. However, this prompts the inquiry of whether other interactions exist that could be also important to affect investor’s decisions, such as a public relations crisis that has the potential to damage the esteemed reputation of a luxury auto brand. Besides, there are other explanatory variables of CAR have not been included such as social media engagement and ESG initiatives. In addition, this study is limited to the automobile industry, analysis across a wider range of industries should be carried out in future studies.

7. Appendices

List of Figures

Fig. 1 Number of cars affected in the U.S. from 2000 to 2021. Unit in 10,000

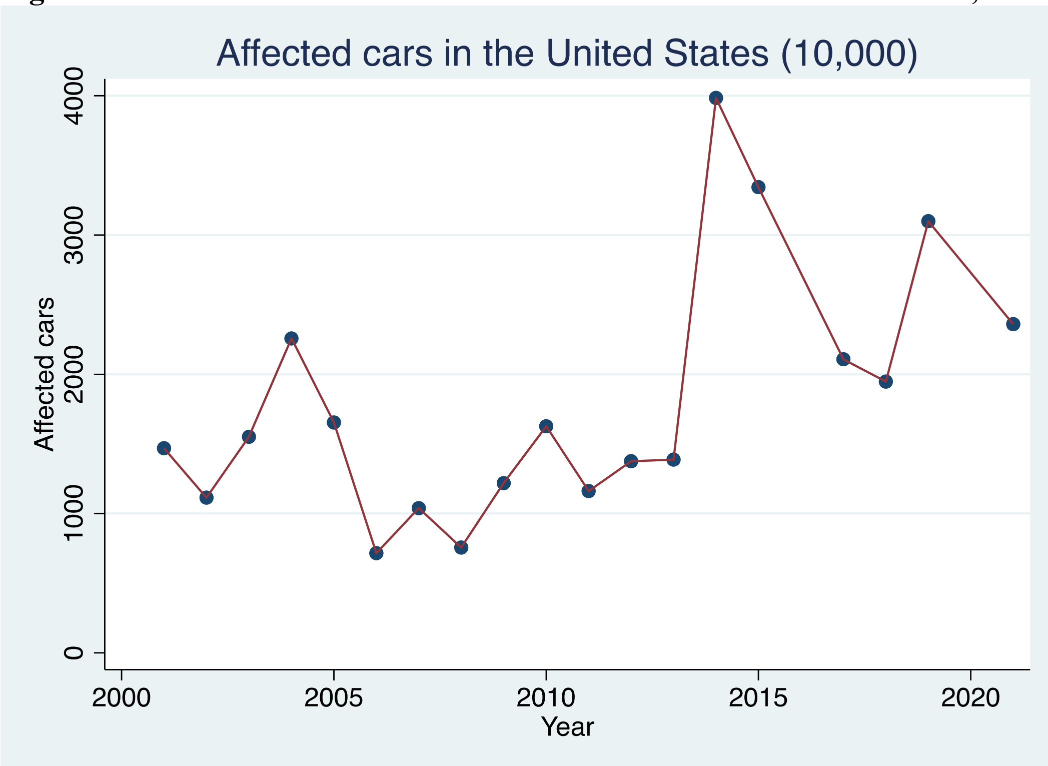


Fig. 2 Number of cars affected in the U.S. by manufacturers' countries from 2000 to 2021. Unit in 10,000

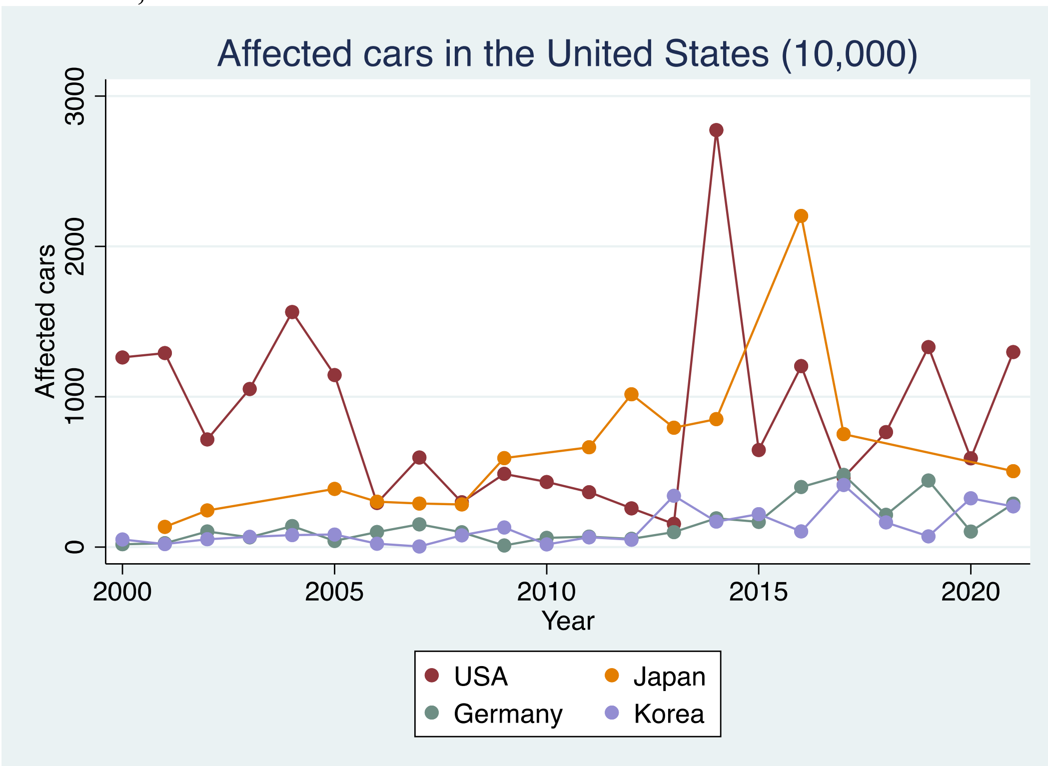


Fig. 3 Number of cars affected in the U.S. by manufacturers' countries from 2000 to 2021. Unit in 10,000

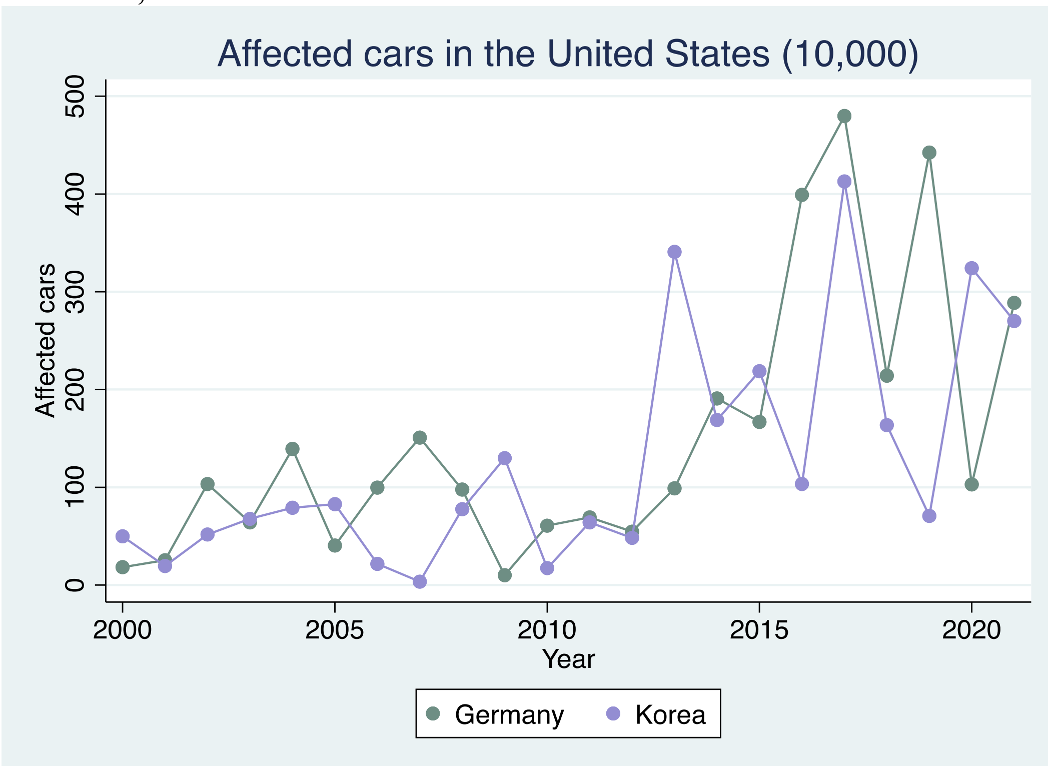
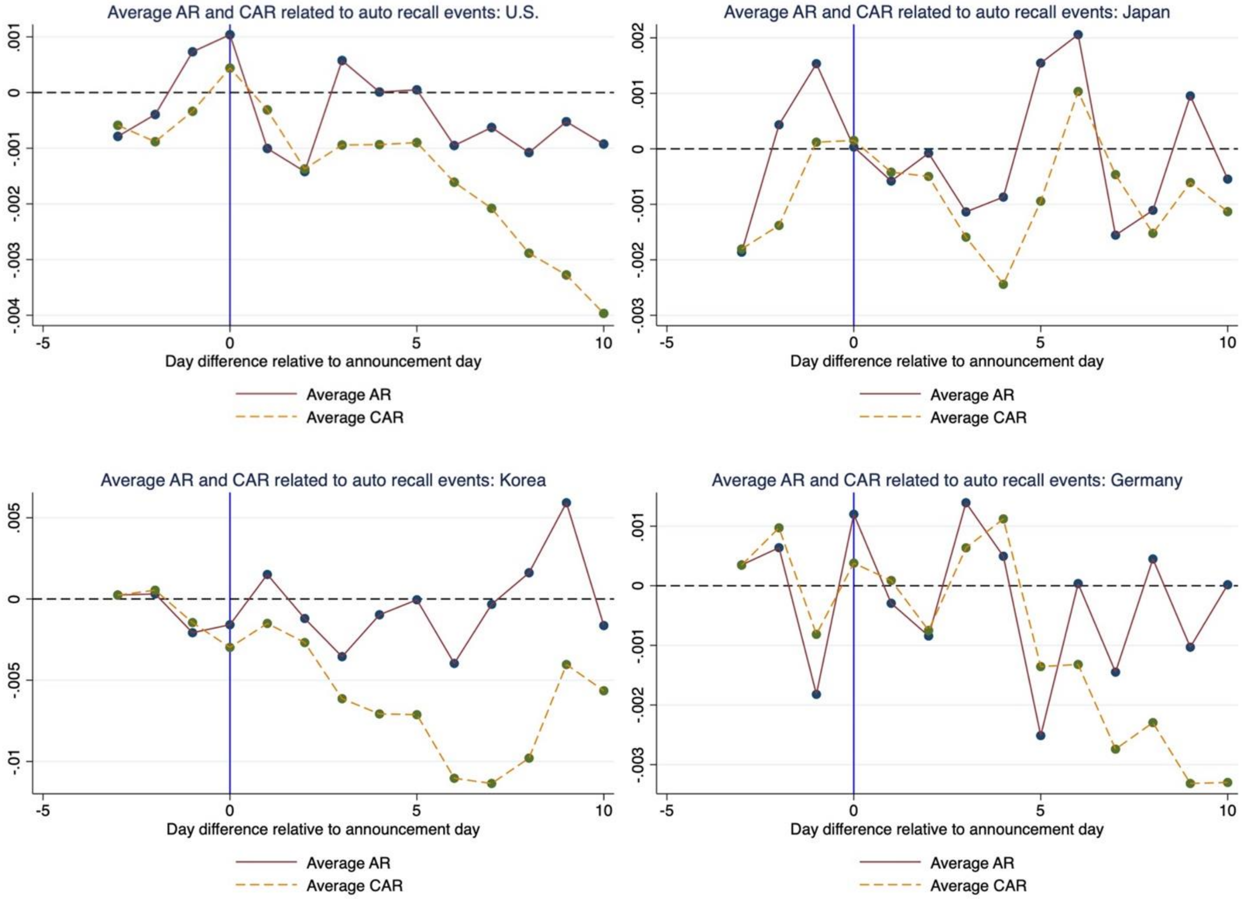
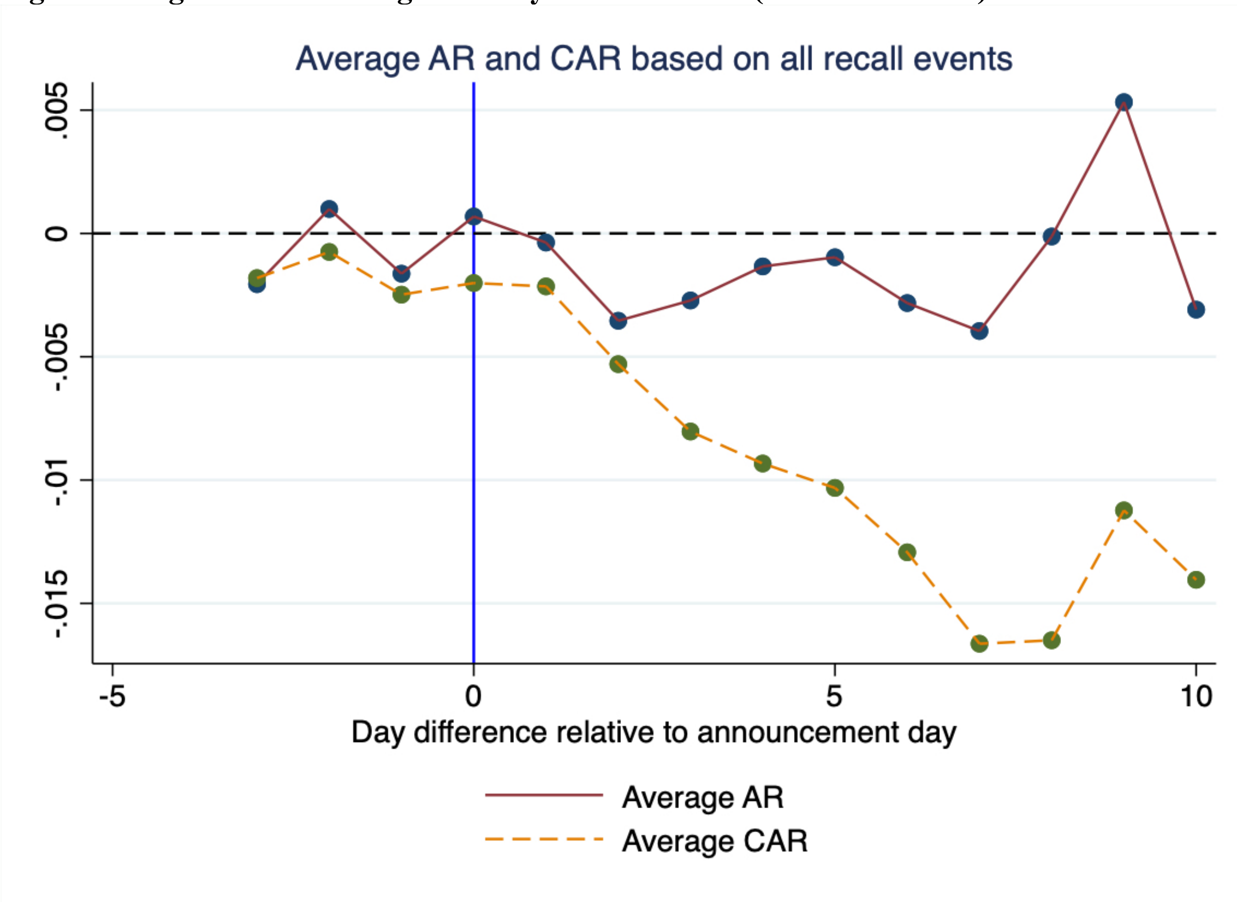


Fig. 4 Average AR and CAR by event timeline (U.S., Japan, Korea, Germany)



Note: Order of countries rom left-to-right, top-to-bottom: U.S., Japan, Korea, Germany. Scale of y-axis is different in each panel for better presentation. The y-axis represents the average abnormal return (AAR) and the average cumulative abnormal return (ACAR); the x-axis represents the number of day difference relative to the event day.

Fig. 5 Average AR and average CAR by event timeline (combined firms)



Note: The y-axis represents the average abnormal return (AAR) and the average cumulative abnormal return (ACAR); the x-axis represents the number of day difference relative to the event day.

List of Tables

Table 1. Information of sample companies

Company	Brand Name	Country	Brand Concept
Kia	Kia	Korea	Functional
Hyundai	Hyundai	Korea	Functional
Hyundai	Genesis	Korea	Luxury
Nissan	Infiniti	Japan	Luxury
Nissan	Nissan	Japan	Functional
Toyota	Lexus	Japan	Luxury
Toyota	Toyota	Japan	Functional
Honda	Acura	Japan	Luxury
Honda	Honda	Japan	Functional
GM	Cadillac	U.S.	Luxury
GM	Buick	U.S.	Luxury
GM	Chevrolet	U.S.	Functional
GM	GMC	U.S.	Functional
Ford	Lincoln	U.S.	Luxury
Ford	Ford	U.S.	Functional
BMW	BMW	Germany	Luxury
Benz	Benz	Germany	Luxury
Volkswagen	Audi	Germany	Luxury
Volkswagen	Volkswagen	Germany	Functional

Note: Sample companies were selected following previous studies as they make up about 90% of U.S. vehicles sales (Gao et al., 2015; Liu & Varki, 2021). Brand concepts are manually assigned according to Topaloglu & Gokalp (2018).

Table 2. Number of recalls by company 2000-2021

Company Name	Recall Frequency	Severe Recall	Non-severe Recall	Recall of Functional Brand	Recall of Luxury Brand	Average Vehicles Affected	Market Cap as of 2021
Nissan	130	16	114	118	12	226,947	18.90
Toyota	117	31	86	98	19	520,356	252.84
Honda	116	25	91	98	18	472,196	48.04
Kia	60	3	57	60	0	154,532	27.72
Hyundai	93	15	78	86	7	195,586	41.58
BWM	66	18	48	0	66	135,165	65.11
Benz	42	13	29	0	42	172,479	81.88
Volkswagen	103	26	77	61	42	155,366	105.27
Ford	218	50	168	150	18	436,184	81.47
GM	220	60	160	185	35	422,046	87.95
Total	1,165	257	908	856	259		

Note: Market cap is calculated as of the end of year 2021, in billions of U.S. dollars.

Table 3. AAR and ACAR around recall announcement dates by manufacturers' country

	US		Japan		Germany		Korea	
Date	*AAR*	*ACAR*	*AAR*	*ACAR*	*AAR*	*ACAR*	*AAR*	*ACAR*
-3	-0.0008	-0.0006	**-0.0019****	**-0.0018****	0.0003	0.0003	0.0002	0.0002
	(-1.0230)	(-0.7643)	(-2.5717)	(-2.4922)	(0.3695)	(0.3659)	(0.1404)	(0.1375)
-2	-0.0004	-0.0009	0.0004	-0.0014	0.0006	0.0010	0.0003	0.0005
	(-0.5127)	(-0.8113)	(0.5987)	(-1.3472)	(0.6763)	(0.7278)	(0.1802)	(0.2203)
-1	0.0007	-0.0003	0.0015	0.0001	**-0.0018***	-0.0008	-0.0021	-0.0015
	(0.9500)	(-0.2526)	(2.1184)	(0.0955)	(-1.9287)	(-0.4979)	(-1.1973)	(-0.4831)
0	0.0010	0.0004	0.0000	0.0002	0.0012	0.0004	-0.0016	-0.0030
	(1.3491)	(0.2852)	(0.0448)	(0.1047)	(1.2702)	(0.2008)	(-0.9131)	(-0.8594)
1	-0.0010	-0.0003	-0.0006	-0.0004	-0.0003	0.0001	0.0015	-0.0015
	(-1.3053)	(-0.1810)	(-0.8014)	(-0.2597)	(-0.3110)	(0.0419)	(0.8695)	(-0.3878)
2	**-0.0014****	-0.0014	-0.0001	-0.0005	-0.0008	-0.0007	-0.0012	-0.0027
	(-1.8442)	(-0.7277)	(-0.1088)	(-0.2801)	(-0.8918)	(-0.3241)	(-0.6925)	(-0.6309)
3	0.0006	-0.0009	-0.0011	-0.0016	0.0014	0.0006	**-0.0035****	-0.0061
	(0.7474)	(-0.4627)	(-1.5686)	(-0.8306)	(1.4747)	(0.2547)	(-2.0457)	(-1.3363)
4	0.0000	-0.0009	-0.0009	-0.0024	0.0005	0.0011	-0.0010	-0.0071
	(0.0117)	(-0.4297)	(-1.2001)	(-1.1917)	(0.5243)	(0.4200)	(-0.5602)	(-1.4413)
5	0.0000	-0.0009	0.0015	-0.0009	**-0.0025*****	-0.0014	0.0000	-0.0071
	(0.0630)	(-0.3895)	(2.1343)	(-0.4341)	(-2.6622)	(-0.4787)	(-0.0285)	(-1.3680)
6	-0.0010	-0.0016	0.0021	0.0010	0.0000	-0.0013	**-0.0040****	**-0.0110****
	(-1.2366)	(-0.6616)	(2.8413)	(0.4513)	(0.0382)	(-0.4422)	(-2.2857)	(-2.0108)
7	-0.0006	-0.0021	**-0.0016****	-0.0005	-0.0014	-0.0027	-0.0003	**-0.0114****
	(-0.8152)	(-0.8145)	(-2.1467)	(-0.1933)	(-1.5339)	(-0.8752)	(-0.1891)	(-1.9727)
8	-0.0011	-0.0029	-0.0011	-0.0015	0.0004	-0.0023	0.0016	-0.0098
	(-1.4003)	(-1.0818)	(-1.5295)	(-0.6067)	(0.4758)	(-0.7020)	(0.9291)	(-1.6296)
9	-0.0005	-0.0033	0.0010	-0.0006	-0.0010	-0.0033	0.0059	-0.0040
	(-0.6801)	(-1.1803)	(1.3163)	(-0.2322)	(-1.0911)	(-0.9741)	(3.4132)	(-0.6448)
10	-0.0009	-0.0040	-0.0005	-0.0011	0.0000	-0.0033	-0.0016	-0.0056
	(-1.2022)	(-1.3774)	(-0.7527)	(-0.4176)	(0.0175)	(-0.9340)	(-0.9431)	(-0.8699)

Note: The calculated t-values are shown in parenthesis with null hypothesis AAR(ACAR) = 0.
*Indicate $p< 0.1$ ** Indicate $p < 0.05$ *** Indicate $p <0.01$

Table 4. Summary Statistics

Variables	Obs	Mean	SD	P25	P75	Min	Max
CAR [-3,3]	1139	-0.0015	0.0393	-0.021	0.018	-0.206	0.170
CAR [-3,3] (Severe Recalls)	253	-0.0055	0.0426	-0.022	0.017	-0.206	0.119
CAR [-3,3] (Nonsevere Recalls)	886	-0.0004	0.0383	-0.020	0.018	-0.177	0.170
CAR [-3,3] (Functional Brand)	874	-0.0014	0.0404	-0.020	0.018	-0.206	0.170
CAR [-3,3] (Luxury Brand)	265	-0.0018	0.0354	-0.023	0.017	-0.119	0.115
Severity	1,165	0.2206	0.4148	0.000	0.000	0.000	1.000
Functional	1,165	0.7691	0.4216	1.000	1.000	0.000	1.000
Size	1,065	12.0386	0.7381	11.811	12.507	8.908	13.316
LEV	1,049	2.8827	4.4096	1.020	2.490	0.160	30.030
ROA	1,061	0.0389	0.0978	0.014	0.042	-0.107	0.921
MTB	1,037	1.2765	0.6047	0.825	1.571	0.343	3.363
Current	1,065	1.3375	0.4772	1.060	1.430	0.590	2.890

Note: *Size, LEV, ROA, MTB, Current* are firm's financial characteristics used as control variables. Data frequency is year, from 1999 to 2021. *Size* is defined as the natural logarithm of firm's total asset; *ROA* is return on assets; *MTB* is market-to-book ratio; *Current* is current ratio; *Severity* is a dummy variable that equals to 1 if the recall is due to major quality defect and will cause injury or car crash, equals to 0 otherwise; *Functional* is a dummy variable, which equals to 1 if the announcement is recalling a functional car brand, equals to 0 otherwise.

Table 5. Correlation Matrix

	CAR [-3,3]	*Size*	*LEV*	*ROA*	*MTB*	*Current*
CAR [-3,3]	1					
Size	-0.0064	1				
LEV	0.0236	0.2318	1			
ROA	0.0259	-0.2899	-0.3166	1		
MTB	0.0371	-0.0464	0.5312	0.1331	1	
Current	0.0123	0.1894	0.5975	-0.1138	0.3935	1

Note: *Size, LEV, ROA, MTB, Current* are firm's financial characteristics used as control variables. Data frequency is year, from 1999 to 2021. *Size* is defined as the natural logarithm of firm's total asset; *ROA* is return on assets; *MTB* is market-to-book ratio; *Current* is current ratio; *Severity* is a dummy variable that equals to 1 if the recall is due to major quality defect and will cause injury or car crash, equals to 0 otherwise; *Functional* is a dummy variable, which equals to 1 if the announcement is recalling a functional car brand, equals to 0 otherwise.

Table 6. Regression of aggerate CAR [-3, 3] on severity and brand concept in severe recalls

Coefficients (Robust s. e.)	(1) CAR[-3,3]	(2) CAR[-3,3]	(3) CAR[-3,3]	(4) CAR[-3,3]	(5) CAR[-3,3]	(6) CAR[-3,3]
Severity	-0.0051	-0.0058*	-0.0059*	0.0072	0.0071	0.0073
	(0.0031)	(0.0034)	(0.0034)	(0.0045)	(0.0046)	(0.0047)
Functional				0.0061	0.0047	0.0076*
				(0.0038)	(0.0034)	(0.0041)
Severity×Functional				-0.0176***	-0.0195***	-0.0197***
				(0.0060)	(0.0065)	(0.0065)
Size		0.0007	-0.0035		0.0010	-0.0032
		(0.0022)	(0.0028)		(0.0022)	(0.0028)
LEV		0.0005	0.0007		0.0006	0.0007
		(0.0006)	(0.0007)		(0.0006)	(0.0007)
ROA		0.0080	0.0307		0.0095	0.0282
		(0.0807)	(0.0850)		(0.0808)	(0.0854)
MTB		0.0015	0.0000		0.0013	-0.0000
		(0.0036)	(0.0044)		(0.0036)	(0.0044)
Current		-0.0040	-0.0016		-0.0045	-0.0022
		(0.0050)	(0.0051)		(0.0050)	(0.0051)
Constant	0.0102	0.0060	0.0555	0.0051	-0.0011	0.0468
	(0.0070)	(0.0316)	(0.0376)	(0.0096)	(0.0318)	(0.0375)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	No	Yes	Yes	No	Yes
N	1139	1019	1019	1139	1019	1019
R^2	0.024	0.024	0.029	0.031	0.033	0.037

Note: The robust heteroskedasticity-consistent standard errors are in parenthesis. *Size, LEV, ROA, MTB, Current* are firm's financial characteristics used as control variables. Data frequency is year, from 1999 to 2021. *Size* is defined as the natural logarithm of firm's total asset; *ROA* is return on assets; *MTB* is market-to-book ratio; *Current* is current ratio; *Severity* is a dummy variable that equals to 1 if the recall is due to major quality defect and will cause injury or car crash, equals to 0 otherwise; *Functional* is a dummy variable, which equals to 1 if the announcement is recalling a functional car brand, equals to 0 otherwise. **Indicate p< 0.1 ** Indicate p < 0.05 *** Indicate p <0.01*

Table 7. Regression of aggerate CAR on severity (robustness check)

Coefficients (Robust s. e.)	(1) CAR[-1, 3]	(2) CAR[-1, 5]	(3) CAR[-2, 2]	(4) CAR[-2, 5]	**benchmark CAR[-3, 3]**	(6) CAR[-3, 5]	(7) CAR[-3, 10]
Severity	-0.0063**	-0.0057*	-0.0047*	-0.0064*	**-0.0059***	-0.0053	-0.0043
	(0.0029)	(0.0035)	(0.0028)	(0.0038)	**(0.0034)**	(0.0040)	(0.0044)
Size	-0.0024	-0.0023	-0.0030	-0.0030	**-0.0035**	-0.0033	-0.0014
	(0.0027)	(0.0029)	(0.0025)	(0.0029)	**(0.0028)**	(0.0030)	(0.0041)
LEV	0.0006	0.0010	0.0008	0.0012	**0.0007**	0.0012	0.0011
	(0.0006)	(0.0007)	(0.0005)	(0.0007)	**(0.0007)**	(0.0008)	(0.0010)
ROA	0.0112	0.0189	-0.0104	-0.0113	**0.0307**	0.0374	-0.0374
	(0.0729)	(0.0848)	(0.0795)	(0.0951)	**(0.0850)**	(0.1011)	(0.1318)
MTB	0.0004	-0.0051	0.0039	-0.0027	**0.0000**	-0.0053	-0.0043
	(0.0035)	(0.0041)	(0.0040)	(0.0048)	**(0.0044)**	(0.0049)	(0.0063)
Current	-0.0041	-0.0033	-0.0069	-0.0053	**-0.0016**	-0.0009	-0.0021
	(0.0050)	(0.0051)	(0.0048)	(0.0055)	**(0.0051)**	(0.0055)	(0.0077)
Constant	0.0545	0.0518	0.0487	0.0594	**0.0555**	0.0523	0.0181
	(0.0377)	(0.0386)	(0.0366)	(0.0408)	**(0.0376)**	(0.0400)	(0.0564)
Year FE	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
N	1019	1019	1019	1019	**1019**	1019	1019
R^2	0.033	0.030	0.038	0.031	**0.029**	0.025	0.033

Note: The robust heteroskedasticity-consistent standard errors are in parenthesis. *Size, LEV, ROA, MTB, Current* are firm's financial characteristics used as control variables. Data frequency is year, from 1999 to 2021. *Size* is defined as the natural logarithm of firm's total asset; *ROA* is return on assets; *MTB* is market-to-book ratio; *Current* is current ratio; *Severity* is a dummy variable that equals to 1 if the recall is due to major quality defect and will cause injury or car crash, equals to 0 otherwise; *Functional* is a dummy variable, which equals to 1 if the announcement is recalling a functional car brand, equals to 0 otherwise.

Table 8. Regression of aggerate CAR on brand concept in severe recalls (robustness check)

Coefficients	(1)	(2)	(3)	(4)	**benchmark**	(6)	(7)
(Robust s. e.)	CAR[-1,3]	CAR[-1, 5]	CAR[-2, 2]	CAR[-2, 5]	**CAR[-3, 3]**	CAR[-3, 5]	CAR[-3, 10]
Severity	-0.0004	-0.0023	-0.0013	-0.0017	**0.0073**	0.0056	0.0080
	(0.0046)	(0.0053)	(0.0044)	(0.0051)	**(0.0047)**	(0.0051)	(0.0066)
Functional	0.0011	0.0012	0.0014	0.0029	**0.0076***	0.0079*	0.0138***
	(0.0036)	(0.0041)	(0.0037)	(0.0041)	**(0.0041)**	(0.0045)	(0.0053)
Severity×Functional	-0.0091	-0.0053	-0.0053	-0.0070	**-0.0197*****	-0.0161**	-0.0176**
	(0.0059)	(0.0069)	(0.0057)	(0.0072)	**(0.0065)**	(0.0075)	(0.0087)
Size	-0.0022	-0.0021	-0.0029	-0.0029	**-0.0032**	-0.0032	-0.0016
	(0.0027)	(0.0029)	(0.0025)	(0.0030)	**(0.0028)**	(0.0030)	(0.0041)
LEV	0.0006	0.0010	0.0008	0.0012	**0.0007**	0.0012	0.0010
	(0.0006)	(0.0007)	(0.0005)	(0.0007)	**(0.0007)**	(0.0008)	(0.0010)
ROA	0.0134	0.0194	-0.0101	-0.0125	**0.0282**	0.0330	-0.0494
	(0.0734)	(0.0854)	(0.0799)	(0.0956)	**(0.0854)**	(0.1015)	(0.1321)
MTB	-0.0000	-0.0052	0.0037	-0.0026	**-0.0000**	-0.0051	-0.0034
	(0.0035)	(0.0042)	(0.0040)	(0.0048)	**(0.0044)**	(0.0050)	(0.0064)
Current	-0.0044	-0.0035	-0.0070	-0.0055	**-0.0022**	-0.0013	-0.0023
	(0.0050)	(0.0051)	(0.0049)	(0.0055)	**(0.0051)**	(0.0055)	(0.0077)
Constant	0.0501	0.0493	0.0463	0.0563	**0.0468**	0.0455	0.0114
	(0.0376)	(0.0387)	(0.0366)	(0.0409)	**(0.0375)**	(0.0401)	(0.0567)
Year FE	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
N	1,019	1,019	1,019	1,019	**1,019**	1,019	1,019
R^2	0.036	0.030	0.039	0.032	**0.037**	0.029	0.039

Note: The robust heteroskedasticity-consistent standard errors are in parenthesis. *Size, LEV, ROA, MTB, Current* are firm's financial characteristics used as control variables. Data frequency is year, from 1999 to 2021. *Size* is defined as the natural logarithm of firm's total asset; *ROA* is return on assets; *MTB* is market-to-book ratio; *Current* is current ratio; *Severity* is a dummy variable that equals to 1 if the recall is due to major quality defect and will cause injury or car crash, equals to 0 otherwise; *Functional* is a dummy variable, which equals to 1 if the announcement is recalling a functional car brand, equals to 0 otherwise.

7. References

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