THESIS

ANALYSIS OF THE IMPACT ON THE STOCK MARKET OF CHEMICAL DISASTERS: PETROCHEMICAL COMPANIES IN INDUSTRIAL COMPLEX IN KOREA

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ABSTRACT

ANALYSIS OF THE IMPACT ON THE STOCK MARKET OF CHEMICAL DISASTERS: PETROCHEMICAL COMPANIES IN INDUSTRIAL COMPLEX IN KOREA

The chemical industries in Korea have the industrial structure of a developing country focused more on basic chemical compounds and wider use of products rather than fine chemical goods. The chemical industry is composed of 10% knowledge (pharmaceuticals), 30% specialty (consumer products, agricultural chemicals, coatings, and fine chemicals), and 60% basic (polymers, synthetic rubber and fibers, basic inorganic chemicals, and basic organic chemicals).

This study examined 18 different petrochemical, food chemical and steel companies with 26 chemical disasters. Capelle-Blancard, Laguna (2010) showed the problems related to providing robust empirical evidences on the stock market reaction to chemical disasters. This analysis which was based on using abnormal returns (ARs) and cumulative abnormal returns (CARs) concluded that chemical disasters like explosions, plant fires, and chemical leaks caused both negative and positive stock market reaction. Most of the companies that I tried to test the hypotheses showed negative ARs and CARs after the event as I expected.

I thought that the effects on stock market reactions were different according to the type, extent, and number of casualties in the accident. When I performed the event study with the topic, I got the results from 15 cases of the relationships between the ARs or CARs and the extent, type, and the number of casualties. However, all of the cases did not show the same results. The 16

cases revealed that the degree of severity of the chemical accidents was not really related to the market reaction. The reason why the unmatched results arose was because of the exposure of the event information. Hamilton (1995) mentioned that the market is influenced by the leak of information.

I have concluded that the relationship between the ARs/CARs and the extent, type, and the number of casualties are not seriously related to each other. There is a limitation to this conclusion because of the leak of information to the market (Hamilton, 1995). Korajczyk, Lucas, and McDonald (1990) mentioned the asymmetry should be of greatest concern to potential buyers of common stock. That means there should be a factor(s) affect(s) the market and its behavior. The country like Korea is likely to conceal or control the information of the chemical disasters.

According to the Center for Occupational Environmental Health (COEH) in Korea, there was a briefing session in June 2013 about the current state of concealment of fires, explosions and chemical spills in industrial complexes at the congress. The statistical data investigation in the accident has a couple of problems. First, there is no report of the accident to local authority if the petrochemical plant doesn’t have death casualties. Second, there are differences in the accident statistics between the central and the local government. Lastly, the classification of industrial accidents is not established precisely.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Chemical & Engineering News (C&EN) published in 2008 by American Chemical Society (ACS), revealed, through its analysis results on chemical corporations; the remarkable development of businesses focused on commodity goods and synthetic chemicals and the slump in businesses focused on specialty goods. Furthermore, it noted that new corporations in Asia are leading the development of the chemical industry.

The chemical industry in Korea has shown the industrial structure of a developing country focused more on basic chemical compounds and a wider use of products rather than fine chemical goods. The chemical industry is composed of 10% knowledge (pharmaceuticals), 30% specialty (consumer products, agricultural chemicals, coatings, and fine chemicals), and 60% basic (polymers, synthetic rubber and fibers, basic inorganic chemicals, and basic organic chemicals) (C&EN, 2008).

Outputs of the chemical industry include petroleum products like gasoline and diesel, synthetic resins, and rubbers, and textiles. Additionally, the base materials contained in electronics such as smartphones, light emitting diode (LED) TVs, and automotives are made from chemical materials. The chemical industry is the most important cutting edge field, so developed countries push for further research and development of technologies like solar cells, bio plastics, and so forth.

Chemical disasters affect firms' profit structures by the market reaction, and also generate negative externalities on health and ecosystems (Capelle-Blancard & Laguna, 2010). The Deepwater Horizon oil spill in 2010 was an oil spill in the Gulf of Mexico, considered the largest accidental marine oil spill in the history of the petroleum industry, and estimated to be between 8 and 31% larger in volume than previous oil spills (Wikipedia.org). BP's stock price, as of the writing of this paper, is still down about a third from its $60 price before the spill, a loss of about $60 billion in market value.

The Exxon Valdez oil spill occurred in Prince William Sound, Alaska, on March 24, 1989, when Exxon Valdez, an oil tanker bound for Long Beach, California, struck Prince William Sound's Bligh Reef and spilled 260,000 to 750,000 barrels of crude oil (Wikipedia.org). Initially the Exxon Valdez oil spill in 1989 was financially much worse for Exxon Mobil than for BP (huffingtonpost.com). An Alaska jury ordered Exxon to pay $5 billion in punitive damages, matching a full year's profit in 1990. The total cost of cleaning up the Exxon Valdez spill has been estimated at $7 billion, a little more than a year's profit for Exxon.

The chemical industry is the core industry in Korea, valued at around $77.7 billion and accounting for 14% of the total exports in 2011. This study focuses on the impact on the stock market of occurrences such as explosions, fires, and chemical leaks in the Ulsan and Yeosu petrochemical industrial complexes in Korea.

RESEARCH OBJECTIVES

The first objective of this study is to identify the relationship between Korean chemical accidents related to explosions, fires, and chemical leaks, and Korean daily stock market returns of target companies. The impact of the daily returns is estimated by the difference between actual returns and expected returns.

The second objective is to determine the relationship between stock market reactions and the extent of accidents and the number of casualties. This study deals with 26 different cases from 18 chemical and petrochemical firms. It is important to identify any significant patterns of market reactions as this information can be used to predict future responses to accidents.

Generally, the accidents related to petrochemical materials are likely to be occurred in summer and winter than the other two. In my study I don’t focus on some specific season in which the accident occurred but there should be the one we can specifically call it. However, there is a limitation of collecting the data of all the accidents I deal with. It is important to look into specific seasons but I collect the data without considering of specific seasons in this study.

BACKGROUND ON CHEMICAL DISASTERS AND CHEMICAL INDUSTRY IN KOREA

The petrochemical industry manufactures ethylene, propylene, and so on using crude oil or natural gas and then synthetic resin, synthetic rubber, and chemical products result from these processes. The safety conditions in petrochemical industries are considered to be general safety requirements applicable to the initial design, plant safety, and environmental safety.

Such safety requirements consist of a factory site, fire detectors, the building's architectural design, pipe layout, and electric power layout. Safety requirements for manufacturing processes use a distribution control system that controls fuel and heat sources and responds to mal-functional operations. There are several control systems to perform decompression such as interlocking system and safety valves. To protect the environment, petrochemical plants are advised to construct waste water disposal facilities. This facility treats wastewater that results from plant.[1]

Chemical accidents refer to an event resulting in the release of a substance or substances that are hazardous to human health and/or the environment in the short or long term (IPCS, OECD, UNEP, and WHO, 1994). In December 2001, the World Health Organization (WHO), through the International Programme on Chemical Safety (IPCS), convened an expert consultation group on the public health response to chemical incidents.

After consulting with experts, it was recognized that many countries had a limited capacity to respond to chemical incidents. In May 2002, the 55th World Health Assembly agreed

[1] The chemical plant which manufactures synthetic resin petrochemical products emits waste gas, and the gas goes to flare stack then burns itself. Dust collecting facility is also needed to protect environment.

upon a resolution expressing concern about the global public health implications of a possible release, or deliberate use of biological, chemical, or radiological nuclear agents. In August 2002, IPCS started to compile a database of global chemical incidents, compiled from various sources and includes details of the types and the extent of accidents (WHO.int).

Through the IPCS, WHO works to establish the scientific basis for the sound management of chemicals, and to strengthen national capabilities and capacities for chemical safety. Chemical safety is achieved by undertaking all activities involving chemicals in such a way as to ensure the safety of human health and the environment. There are ten primary chemicals of major public health concern: air pollution, arsenic, asbestos, benzene, cadmium, dioxin and dioxin-like substances, inadequate or excess fluoride, lead, mercury, and highly hazardous pesticides (WHO.int).

That chemical processing plants are not safe is true, as the plants themselves have a high probability of exploding and product materials greatly affect the environment. There are many industrial complexes in Korea such as the Ulsan petrochemical industrial complex, Yeosu petrochemical industrial complex, Banwol-shiwha industrial complex, Incheon industrial complex, and Daesan petrochemical industrial complex. Most industrial complexes have been in operation for more than 30 years with the exception of the Daesan industrial complex. This means that old facilities have a high possibility for negligent accidents, to occur. Because of this, I chose the Ulsan and Yeosu industrial complexes to test the hypothesis that there is a relationship between chemical disasters and the market reaction.

The industrial complex of Korea began with the ‘The First 5 years Economic Development Plan’, which was one of the government led economic development models in

1962. The Korean government gave priority to light industries such as textiles, plywood, electrical products, and shoe industries in the 1960s, carried forward the development of large scale industrial complexes in local areas with heavy chemical industries in order to prevent the industrial centralization of capital in the 1970s. The Korean government focused on technologically-intensive industries to increase national competitiveness in semiconductors, electronics, and automotive industries in the 1980s, information and communications, semiconductor industries, and fine chemistry in the 1990s, and established the political base to foster technology fusion and green technology industries in the 2000s.

Ulsan industrial complex is the first industrial complex developed to foster iron manufacturing, oil refinery, and fertilizer in the 1960s, and shipbuilding, and the automotive industry in the 1980s. Ulsan has favorable water levels for the development of ports, large tidal ranges, industrial water from the Taehwa river, accessibility to Pusan port, and inexpensive land due to its advantageous location (National Archives of Korea).

There are 878 companies with 90,584 people working in the Ulsan industrial complex; 785 of these companies are operational, and specialize in food, textiles, lumber, petrochemicals, steel, machinery, electrical engineering, and transportation equipment industries in 2012.[2] Additionally, there are 273 companies with 17,591 people in the Yeosu industrial complex; 225 of these companies are operational, and specialize in food, lumber, petrochemicals, steel, machinery, and electrical engineering in 2012. The Ulsan, and Yeosu industrial complexes have contributed to economic development for the past 50 years, but there have been general accidents

[2] The statistics of the Ulsan and the Yeosu industrial complexes are from the Chemical Market Research Inc. (CMRI) 2003-2004.

such as chemical leaks, explosions, and fires due to the absence of manpower for maintenance of the facilities.

With the groundbreaking ceremony of the Ulsan industrial center in February of 1962, the construction of the factory site and supporting facilities began by 1966. The Ulsan oil refinery was expanded over the petrochemical industrial complex through regional extension announcement in July of 1967. Twenty-one large scale factories were constructed in the Jansangpo and Yeocheon areas and social overhead capital facilities by 1971. Therefore major industries changed from petrochemical to car manufacturing and ship building, which were mechanical device industries. In spite of the deterioration of facilities, the chemical plants in Korea are not ready to prevent the accidents. With each industrial complex's environmental contamination, negligent accidents have occurred frequently with property damage and casualties and as increase in social issues.

There is a noticeable point within the Yeosu industrial complex where many of deaths and casualties have been caused by hazardous chemical leaks, and explosions of line operations which put subcontract workers in danger. The death rate of subcontract workers has increased from 77.8% (2001) to 66.7% (2002) and 80.0% (2003) (Chemical Market Research Inc., 2004). The number of deaths of subcontract workers over a year was the percent ratio. It means that the proportion of subcontract workers to main workers was relatively high. For example, there was an explosion in Daelim Industry on March 14, 2013. Six deaths and 11 injuries were caused, and 15 people were subcontract workers among the 17 casualties (The Progressive Labor News, 2013).

According to the parliamentary inspection report of the Environment and Labor Committee, 97 casualties and 168 injuries resulted from 203 chemical accidents in the Yeosu industrial complex over the last 35 years (Chemical Market Research Inc., 2004).

LITERATURE REVIEWS

The literature review is divided into three sections. The first section describes the literature that identifies how the economy is influenced by chemical disasters. The second section examines the literature that has studied event study methodology and has applied it in the petrochemical industry sector. The third section describes studies that have examined the economic impacts of the chemical disasters or environmental accidents in Korea.

Chemical Disasters Influencing the Economy

There are some factors that influence the national economy such as chemical disasters from petrochemical plants or environmental accidents such as oil spills. Souza Porto and Freitas (1995) showed the serious health hazards and irreversible environmental damage from the examples of Seveso (1976) and Bhopal (1984) by using the concept of the socio-political amplification of risk. The chemical accident of Seveso in Italy resulted in the exposure to 2, 3, 7, and 8-tetrachlorodibenzo-p-dioxin (TCDD)[3] in most of the population and the Bhopal accident in India consisted of was a gas leak considered the worst industrial disaster.

Over 500,000 people were exposed to methyl isocyanate gas and the official immediate death toll was 2,259. The point of view of this paper is that the social, political and economic structures in developing countries make them more vulnerable to accidents (Wikipedia.org). The

[3] Within days a total of 3,300 animals were found dead, mostly poultry and rabbits. Emergency slaughtering commenced to prevent TCDD from entering the food chain. The most evident adverse health effect ascertained was chloracne, and other reversible effects were peripheral neuropathy and liver enzyme induction.

more developed the country, the lower the deaths per accident in spite of many accidents, and the less developed the country, the higher the death rate.

Vilchez, Sevilla, Montiel, and Casal (1994) estimated the impact of accidents involving hazardous materials and divided the chemical disasters into several types. The data showed the percentage of accidents involving transport (39%), process plants (24.5%) and storage (17.4%), and the frequency of occurrence of accidents in highly populated areas (66%), lowly-populated areas (12%) and rural areas (22%). They tried to figure out the cause and effect of accidents through population density, the origin of the accident, type of chemicals, and type of accident. However, they argued that the economic losses from the accidents are only very limited. The reason why it is limited pertains to the difficulty in evaluating these losses, and the low tendency of industries to publish this information.

Event Study Methodology in Chemical Disasters

The stock prices reflect all available information and expectations about the future prospects of firms. Researchers can investigate the relevance of a particular event for a firm's future prospects by examining its impact on the firm's stock price. Event study analysis differentiates between the normal returns and the abnormal returns. The normal return in finance is known as return on investment (ROI) and the rate of profit. The rate of profit (ROI) is the ratio of money gained or lost on an investment. The abnormal return is the same as a normal return technically, but occurs due to an event. The events are mergers, dividend announcements, company earnings announcements, and lawsuits. This study deals with the abnormal return associated with chemical disasters.

Capelle-Blancard and Laguna (2010) examined the stock market reaction to industrial disasters across the entire world. They selected 200 events and excluded two thirds of events, since the firms did not involve publicly-traded companies. They finally identified 38 publicly traded companies with 64 accidents. They found that petrochemical firms in their sample experienced a drop in market value of 1.3% over the two days immediately following the disaster. The losses are significantly related to the magnitude of accidents, the number of casualties and the amount of chemical pollution. They built an original sample of the 64 explosions in chemical plants and refineries that occurred from 1990 to 2005 and performed a daily event study as implemented by MacKinlay (1997). Abnormal returns were computed given the market model parameters estimated with OLS through the estimation period ranges of 180 trading days. They also calculated an individual t-statistic for each firm's abnormal return for each accident day and concluded that the stock market reacted negatively after the accidents.

Fields and Janjigian (1989) investigated US public electric-utility stock price reactions to the Chernobyl nuclear-power accident. They analyzed 89 public-electric-utility firms with event study methodology and drew results of significant negative abnormal returns during the twenty day period after the accident. There were 89 firms in the sample including 57 nuclear firms and 32 nonnuclear firms and abnormal returns for the entire sample declined almost 3% during the three day period following the accident. They concluded that firms using nuclear power especially experienced greater losses than did nonnuclear firms.

Hamilton (1995) examined the pollution data, in the Toxics Release Inventory (TRI), released by the United States Environmental Protection Agency (EPA). Pollution figures reported in the TRI provide "news" to the financial community to the extent that the data diverged from expectations about a firm's pollution patterns. Hamilton chose the model developed by Dodd and Warner (1983) and concluded that the average of the abnormal returns for companies was not statistically significant. Hamilton also pointed out that why the abnormal returns occurred the day before the official announcement was not significant as the data not being leaked to the market. Lastly, he argued that the event study methodology is especially well suited for studying the impact of the TRI.

Grand and D'Elia (2005) showed that positive environmental news has no impact, while negative news does have an effect on average rates of return a few days following its appearance. They tried to find the same results with different types of positive news such as ISO certification, but it had no effect. However, investment decisions do have a positive significant influence on returns. They used the estimation window of 165 working days and ran sensitivity analysis for 120 and 210 working days. This paper concludes that the markets react negatively to court and government rulings.

Applied Event Study Methodology Environmental accidents in Korea

Dasgupta, Hong, Laplante, and Mamingi (2006) examined the reaction of investors to the publication of national environmental laws and regulations, and tried to show that the enterprises appearing on the lists have experienced a significant decline in their market valuation. They used the market model which assumes a linear relationship between the return of any security to the return of the market portfolio. The 96 environmental news events were used to figure out the returns, and they concluded that the investors on the Korean Stock Exchange do strongly react to the disclosure of such news.

Hong and Hwang (2001) investigated the causes and effects of major Korean environmental accidents in the 90s, and the relationship between public information on polluting behavior and capital market responses. They calculated average abnormal returns on event windows from -10 days to +10 days and also tried to devise alternative approaches to investigate the relationship between market reactions and environmental accidents. They concluded that major environmental accidents have had huge impacts on the various shareholders, including the environmental consciousness of the general public, government and companies. The damaging effects on companies are illustrated in terms of financial compensation, and a loss in market share. The contribution of this paper is to provide information for firms and shareholders of petrochemical companies. The information herein will help companies build strategies to prevent the investors from making negative movements.

STUDY METHOD

This section shows how an event study methodology is conducted within this study. Discussions of the event, methodology, sample companies, and data occur in this section. Measurements of abnormal returns, cumulative abnormal returns, and testing for significance are also explained.

Event Study Methodology

The event study method is a tool that can help examine the economic impact of events such as earning announcements, changes in the severity of regulations, and money supply announcements (Binder, 1998). He showed the two reasons why the event study methods have been used: (1) to test the null hypothesis that the market efficiently incorporates information and (2) under the maintained hypothesis of market efficiency.

Henderson (1990) showed that the steps to follow in the design of the event study: (1) define the date of the news which can be the event, (2) characterize the returns of each firm in the absence of the news, (3) measure the difference between observed returns and "no-news" returns, (4) aggregate the abnormal returns across firms and across time, and (5) statistically test the aggregated returns to determine whether the abnormal returns are significant. This study uses the procedure showed in MacKinlay (1997) based on the concept of Henderson (1990).

Identifying Event

Identifying an event and event window is the initial step in conducting an event study. MacKinlay (1997) showed the event is any objective event of interest, and the event window specifies the period of the stock prices of the firms involved in the event. This study includes 26 chemical disasters including explosions, chemical leaks and fires, 22 cases in the Ulsan and the Yeosu industrial complexes, and four cases from the other complexes in Korea. The accidents occurred between 2001 and 2013. Table 1 summarizes dates and types of accidents in the events.

This study defines the event window as larger than a period of interest since it allows an examination of the period surrounding the event (Armitage, 1995 & MacKinlay, 1997). Armitage (1995) showed that two-way event windows are common in finance literature, if the event date can be determined with precision. Two-way event windows should be supplemented by cumulative abnormal returns for longer periods after the event window.

As in Capelle-Blancard and Laguna (2010), within this study the abnormal and cumulative abnormal returns are examined with the estimation window of 190 trading days before the event day in chemical disaster accidents, and the event window is to be -10 trading days and +10 trading days of the event day of day zero. The topic that I am interested in is chemical disasters in Korea, so the measuring periods of the estimation and event windows is follows Capelle-Blancard and Laguna (2010)'s methods. The types, and extent of chemical accidents varies and the time of dealing with the accidents is not expected. I therefore refer the periods of estimation and event window to Capelle-blancard and Laguna (2010).

Table 1. Summary of the Each Dates and Duration of the Events

Company	Industry	Event Date	Accident Type	Casualties	Location
Hanwha Chemical (HW)	Chemical	Sep 24, 2001 Oct 15, 2001	Explosion Explosion	1 death / 1 injured 1 death / 2 injured	Yeosu
Lotte Chemical (LT)	Chemical	Oct 5, 2001 Oct 3, 2003	Fire Explosion	3 deaths 1 death / 6 injured	Yeosu
LG Petrochemical (LG)	Chemical	Mar 17, 2002 Aug 25, 2004 Nov 12, 2005	Fire Explosion Fire	Unknown* 1 death / 1 injured Unknown*	Yeosu
Kumho Petrochemical (KH)	Chemical	Oct 20, 2003	Fire	Unknown*	Yeosu
Cheil Industries (CH)	Chemical	Jan 22, 2006	Fire	Unknown*	Yeosu
Daelim Industry (DL)	Chemical	Oct 15, 2001 Mar 14, 2013	Explosion Explosion	1 death / 2 injured 6 deaths / 11 injured	Yeosu
SK Co., Ltd. (SK)	Chemical	Oct 20, 2003	Fire	Unknown*	Ulsan
Hyosung (HS)	Chemical	Sep 21, 2004 Feb 24, 2008	Fire Fire	No casualties No casualties	Ulsan
S-Oil (SO)	Petrochemical	Apr 9, 2004	Fire	Unknown*	Ulsan
SK Energy (SKE)	Petrochemical	Oct 26, 2010 Dec 20, 2010	Explosion Explosion	1 death 1 death / 6 injured	Ulsan
Korea Petrochemical (KP)	Petrochemical	Feb 8, 2011	Explosion	2 deaths / 2 injured	Ulsan
Hyundai EP (HD)	Chemical Plastic	Aug 17, 2011	Explosion	8 injured	Ulsan
Samyang Genex (SY)	Food Chemical	Apr 22, 2004 Feb 27, 2011	Explosion Explosion	3 deaths No casualties	Ulsan
KG Chemical (KG)	Chemical	Apr 28, 2004	Chemical Leaks	Unknown*	Gyeonggi
Kumyang (KY)	Fine Chemical	Apr 21, 2005	Explosion	Unknown*	Pusan
DSR	Steel	Mar 10, 2006	Chemical Leaks	Unknown*	Suncheon
Samsung Electronics (SE)	Electronic	Jan 27, 2013	Chemical Leaks	1 death / 4 injured	Hwasung
Samsung Fine Chemical (SFC)	Fine Chemical	Apr 14, 2013	Chemical Leaks	Unknown*	Ulsan

* The number of casualties of those accidents is unknown.

Determining Firms for Event Study

The companies collected from three different regions in Korea are the Ulsan industrial complex, the Yeosu industrial complex, and the industrial complex located Gyoung-gi. Those firms experienced the chemical disasters that were initially chosen from the casebook of hazardous chemicals of the Ministry of Environment. Then, each firm is categorized according to its business type such as chemical, petrochemical, food chemical, fine chemical, and steel.

Hypotheses of the Stock Market Reaction

The hypotheses related to stock price reaction to the accidents of each company can be tested under hypotheses of showing negative abnormal returns (AR) and cumulative abnormal returns (CAR) after the accidents. To be clear in statistics, there is no relationship between the market reaction and the chemical accidents as a null hypothesis. If these kinds of incidents like explosions, fires, and chemical leaks are unexpectedly occurring in industrial complexes, any investors and member firms are likely to sell their shares due to the companies' reliability and reputation or lack thereof.

Estimating Normal Returns

Evaluating impacts of the events on stock values requires a measure of abnormal returns. The abnormal return is an actual ex-post return of the security over the event window minus the normal return of a firm over the event window (MacKinlay, 1997). The normal return is defined as the expected return which is the return of investments in the absence of the events. The abnormal return is estimated as follows:

$$AR_{it} = R_{it} - E(R_{it}|X_t) \quad (1)$$

where AR_{it}, R_{it}, and $E(R_{it}|X_t)$ are the abnormal return, actual, and normal returns respectively for firm *i* and time period *t*. X_t is the market return in OLS market model which assumes a stable linear relation between the market return and the individual stock return (MacKinlay, 1997).

Armitage (1995) and MacKinlay (1997) reviewed different models for the normal return estimation and concluded that the market model by an OLS is the most suitable model to estimate the normal returns. This study uses the OLS market model:

$$R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it} \quad (2)$$

$$\mathrm{E}(\varepsilon_{it}) = 0, var(\varepsilon_{it}) = \sigma^2 \quad (3)$$

where R_{it} and R_{mt} are the return of the event time *t* on stock of firm *i* and the market portfolio, respectively. α_i and β_i are the estimated coefficients, and ε_{it} is the error term and is assumed to have a zero mean and constant variance.

The actual return can be calculated between the day's stock price and the day before's stock price of an individual firm on the event window; the day's stock price minus the day before's stock price and divided by the day before's stock price (actual return = today's stock price – yesterday's stock price / yesterday's stock price)[4]. The normal return is defined as the expected return can be calculated from $(\alpha_i + \beta_i R_{mt})$ of the equation (4). a) The alpha and beta

[4] The actual return is the change of stock prices from the market reaction to the incidents such as a firm's earning announcement or lawsuits. The normal return is the return assumed a firm has "no news".

are from the OLS regression model equation (2) on estimation window. b) The two values (alpha, beta) with the market return (peer-group market return: R_{mt})[5] of each event day go to $(\alpha_i + \beta_i R_{mt})$ of the equation (4). The abnormal return is the value of the actual return minus the expected return.

The problems of Event Study

Henderson Jr. (1990) showed a few possible and potentially important problems; (1) The timing of an event. The issue is not when an event occurred, but when the market was informed. The topic dealt with in this study is a chemical accident. (2) A concrete definition of the estimation and event windows. The estimates are derived from the estimation window and these are used to define expected or normal returns. (3) The calculation of excess returns which is the difference between observed returns and the returns predicted. (4) Abnormal returns must be aggregated both across firms and across time. What Henderson Jr. (1990) mention is to check the average abnormal returns from the companies affected by the news at the same time. (5) Statistical tests to see the market reaction to the accidents. Henderson Jr. (1990) shows the way to check the reaction with the graphics. However, there are a lot of methods to test statistical significant now.[6]

The market model that this study applies to is the OLS regression model, and there are a number of statistical assumptions. Henderson Jr. (1990) shows that the residuals are normally distributed with a mean of zero, and not serially correlated, have a constant variance, and are not

[5] The market return (peer-group market return: R_{mt}) is the daily return of market index which consists of chemical companies. This study uses the chemical index in KOSPI to calculate the returns.
[6] The ways to test statistical significant are explained in the next section.

correlated with the explanatory variables. Binder (1998) explains that the potential problems in the hypothesis test are the abnormal return estimators are not independent, and the estimators do not have identical variance. These two problems occur: (1) the estimators are cross-sectionally correlated, (2) there are have different variances across firms, (3) the estimators are not independent across time for a given firm, and (4) have greater variance during the event period.

When we try to predict with the plausible explanation using OLS regression in the study, there are unexpected problems. Greene (2003) showed a possible model we can apply to use called Tobit Model. If we face the problems with regression when the dependent variable is incompletely observed and regression when the dependent variable is completely observed but is observed in a selected sample that is not representative of the population. These models share the feature that OLS regression leads to inconsistent parameter estimates because the sample is not representative of the population. The reason why the leading causes of incompletely observed data is truncation and censoring. Truncation occurs when some observations on both the dependent variable and regressors are lost. Censoring occurs when data on the dependent variable is lost but not data on the regressors.

In my study I use OLS regression using stock prices of petrochemical companies. It does not fit the first problem of unobserving of dependent variable that is an individual company’s stock return. However, we can dispute a possibility of being a problem of representativeness of samples. I use the peer-market stock prices returns as an explanatory variable and there might be a suspicion of representativeness of the population. The stock price data all I use from the KOSPI that actually the securities are traded and it announces the index every day.

Calculation of Abnormal Returns and Cumulative Abnormal Returns

As shown in the previous section, the abnormal return (AR) is calculated by subtracting the expected return from the actual return. The equation for calculating AR is;

$$AR_{it} = R_{it} - (\alpha_i + \beta_i R_{mt}) \quad (4)$$

where AR_{it}, R_{it}, and $(\alpha_i + \beta_i R_{mt})$ are the abnormal return, actual return, and expected return, respectively, for firm *i* and event date *t*. The test period is 21 days from -10 days to +10 days from an event date, designating the event date as day 0.

Cumulative abnormal return (CAR) is an aggregation of multiple-day ARs of the post-estimation window. MacKinlay (1997) mentioned that CAR is important to monitor periodical inferences for the event of interest. The CAR is calculated using the following equation:

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

where $CAR_i(t_1, t_2)$ and $\sum_{t=t_1}^{t_2} AR_{it}$ are the cumulative abnormal return and summation of the abnormal return between t_1 to t_2, respectively. Salin and Hooker (2001) choose four post-event CAR windows: 5, 10, 20, and 30 day windows to be applied to food recall. I chose 5, 10, 20, and 30 day windows in this study. In considering the handling of an accident, the duration of the chemical accidents is largest variable in the extent and type of the accident. Moreover, there is no information of the period, so I applied the four post-event CAR windows.

Cumulative abnormal return is the sum of the differences between the expected return on a stock and the actual return often used to evaluate the impact of news or specific incidents on a stock price. The initial action to dealing with chemical accidents takes anywhere from a little time to a couple of days depending on the types of incidents. However, the complete restoration of plant processes may need a lot of time. I attempted to find data on the initial action and restoration, but there is no valid information about this in the government's case book and the media.

Test of Significance for Abnormal Returns and Cumulative Abnormal Returns

There are two different types of measuring statistical significant: (1) parametric tests and (2) nonparametric tests. Parametric tests assume that individual firm's abnormal returns are normally distributed, whereas nonparametric tests do not rely on any such assumptions (Eventstudytools.com). Each test has a various type of tests by test level. Depending on the null hypothesis tested, there are AR t-test to H_0: AR=0, AAR t-test to H_0: AAR=0, CAR t-test to H_0: CAR=0, and CAAR t-test to H0: CAAR=0 in parametric tests.[7] In nonparametric tests, we know that GRANK-test to H_0: AAR=0, GRANK-test and SIGN-test to H_0: CAR=0, and GRANK-test and GSIGN-test to H_0: CAAR=0.[8]

Luoma (2011) argued that there are numerous tests for evaluating the statistical significance of abnormal returns. The most widely used parametric test statistics are ordinary t-statistic and test statistics derived by Patell (1976). A one-day event period that includes the announcement day is the best choice, if the announcement date is known exactly. However, it is not always possible to pinpoint the time when the new information reaches investors. Many parametric tests, like the tests derived by Patell (1976) and Boehmer, Musumeci, and Poulsen (1991), and the ordinary t-statistic can be applied to testing CARs over multiple day windows.

[7] Patell-test, BMP-test, and J-test can be used to test H_0: AAR=0 and H_0: CAAR=0. (AAR: Average Abnormal Return, CAAR: Cumulative Average Abnormal Return)
[8] All of the methods to test statistical significant are sorted into parametric/nonparametric tests in the Eventstudytools.com.

Brown and Warner (1985) and Armitage (1995) showed that a standard *t*-test is appropriate for a significance test for ARs and CARs. The tests seek to test whether ARs and CARs are significantly different from zero and will be performed with null hypotheses as:

$$H_0: AR_{it} = 0, H_1: AR_{it} \neq 0 \quad (6)$$

$$H_0: CAR_{it} = 0, H_1: CAR_{it} \neq 0 \quad (7)$$

MacKinlay (1997) pointed out that the test of these hypotheses can be conducted under an assumption that the distributions of AR and CAR are normally distributed as

$$AR_{it} \sim N\left(0, \sigma_i^2(AR_{it})\right) \quad (8)$$

$$CAR_i(t_1, t_2) \sim N\left(0, \sigma_i^2(t_1, t_2)\right) \quad (9)$$

Brown and Warner (1985) showed that the test statistic for AR is the ratio of an abnormal return of event day *t* to its estimated standard deviation of the normal return estimation period while the CAR test statistic is the ratio of a cumulative abnormal return to its estimated standard deviation.

$$AR: t - statistics = AR_{it}/\sigma(AR_{it}) \quad (10)$$

$$where\ \sigma(AR_{it}) = \sqrt{\sum_{t=-200}^{t=-10}(AR_{it} - \overline{AR_{it}}) \Big/ (N-1)}$$

$$CAR: t - statistics = {CAR_{it}} \Big/ {\sigma(CAR_{it})} \quad (11)$$

$$where\ \sigma(CAR_{it}) = \sqrt{\sum_{t=0}^{t=N}(CAR_{it} - \overline{CAR_{it}}) \Big/ (N-1)}$$

The test statistics of AR and CAR can be calculated from equations (10) and (11). The standard deviation of AR is derived from the estimation window and the standard deviation of CAR is derived from the two different equations. First, the standard deviation of CAR can be calculated from the CARs of each event day such as in equation (11) and it is also derived from the square root of the length of the event window multiplied by the standard deviation of AR[9]. The *t*-statistic is the coefficient divided by the standard error of the coefficient. The standard error is an estimate of the standard deviation of the coefficient. The *t*-statistic is an indicator of the precision of the regression coefficient of the model.

The standard deviation of CAR can be calculated from the ordinary standard deviation equation or the length of the event window multiplied by the standard deviation of AR. We can get the *t*-statistics of ARs and CARs with AR or CAR of each event day divided by the standard deviation of AR or CAR.

Data

The entire information of chemical incidents of target companies was obtained from the accident casebook of toxic chemicals in the Ministry of Environment (ME) and National Institute of Environmental Research (NIER).

[9] This is parametric test and the equation is from the Event Study Methodology. (www.eventstudytools.com)

The Korean stock market is operated by the Korea Exchange (KRX), which is the sole securities exchange operator in Korea. As of July 2011, the Korea Exchange had 1,785 publically traded companies with a combined market capitalization of $1.24 trillion (KRX, 2013). There are several indices in the Korea Exchange: KOSPI, KOSPI 200, KRX 100, and other indices in the Derivatives Market Division. The Korea Composite Stock Price Index (KOSPI) is the index in which all common stocks are traded on the stock market division. It is the representative stock market index of Korea similar to the Dow Jones Industrial Average or S&P 500 in the US. Daily stock prices and the peer-group market index are collected from the Korea Information System Value (KISVALUE) and KOSPI.

Capelle-Blancard and Laguna (2010) showed the problems related to providing robust empirical evidence on the stock market reaction to chemical disasters. This study selected 18 different petrochemical food chemical and steel companies with 26 events. The casebook of toxic chemicals from ME and NIER included the 42 chemical accidents that occurred between 2001 and 2006 in industrial complexes. However, the casebook named the company's initials and it was hard to find concrete information about the accident. The only 17 accidents that had clear data were those that had a firm's name listed on the Korea stock market and were gathered after comparing the event summary with the printed media articles. The other nine accidents were from searching the web with the keyword of "plant explosion" and "chemical plant fire". This was the same method that Capelle-Blancard and Laguna (2010) used.

All 18 companies are in petrochemical, petroleum, and food chemical compound sectors of industries. There are Hanwha Chemical (HW), Lotte Chemical (LT), LG Petrochemical (LG), Kumho Petrochemical (KH), Cheil Industries (CH), and Daelim Industries (DL) in the Yeosu industrial complex, and SK, S-Oil (SO), Hyosung (HS), SK Energy (SKE), Korea Petrochemical

(KP), Hyundai EP (HD), Samyang Genex (SY), and Samsung Find Chemicals (SFC) in the Ulsan industrial complex. KG Chemical (KG), Kumyang (KY), DSR Corp. (DSR), and Samsung Electronics (SE) are located in different industrial locations.

This research uses the chemical industry field stock index in the Korea Composite Stock Price Index (KOSPI) as the market portfolio (R_{mt}) because it compiled all the petrochemical and chemical compound companies. The estimation period differs by researcher; Peterson's (1989) estimation period ranges from 100 to 300 days while Armitage (1995) recommends 250 trading days or one calendar year. However, in advanced research, Capelle-Blancard and Laguna (2010) used 190 trading days. In this study, I use an estimation window of -200 to -11 days and an event window of -10 to +10 days.

Of 26 different accidents, five cases have insufficient estimation and test period and three accidents did not have enough data to estimate, since the Korea Exchange (KRX) did not provide the chemical industry field stock index before the year of 2001. The three incidents of Hanwha Chemical in September 24, 2001, Lotte Chemical in October 5, 2001, and Yeochun NCC[10] in October 15, 2001 have the estimation periods of 169, 175, and 181 trading days respectively. The other two accidents' test periods overlap the previous event of the same company. I use the estimation period's coefficient data of the first event for these two cases.

[10] Yeochun NCC is the consolidate company of naphtha cracking centers of Hanwha Chemical and Daelim Industry. I measured abnormal and cumulative abnormal returns by using the stock prices of both companies.

RESULTS AND DISCUSSION

This section shows and discusses the results of this study. First, the normal return regression results are presented with a summary of statistics of the daily returns. Second, abnormal returns and cumulative abnormal returns of each company are discussed by the accidents of theirs.

Summary Statistics of the Daily Returns of the Estimation Periods

As I mentioned in previous section, I applied the normal return estimation period of 190 trading days to obtain normal regression results. The summary statistics of the daily return of the estimation windows are shown in Table 2, Table 3, and Table 4. We can see the results of normal regression of each company's in the tables.   Some of companies experienced both the upper and lower price limit. According to the Korea Exchange making concerted efforts to establish an orderly capital market and achieves, the price limits for both upper and lower have changed from 4.6 (before 1995), 6 (1995), 8 (1996), 12(1998) to 15% (1998).[11]

Hanwha Chemical (HW) showed only upper price limit, second out of three accidents of LG Petrochemical (LG) experienced lower price limit, first out of two events of Daelim Industry (DL) experienced upper price limit, and the other three firms Lotte Chemical (LT), Kumho Petrochemical (KH), and Cheil Industry (CH) did not showed both upper and lower price limits in the Yeosu Industrial Complex.

[11] Daily price limit is upper and lower bound to which the price of each issues can move on a certain day. Thus any investors or member firms cannot place orders or quotations that exceed the upper or lower price limit.

SK experienced both upper and lower price limits, Hyosung (HS) showed lower price limit, and S-Oil (SO), Korea Petrochemical (KP), and Hyundai EP (HD) experienced upper price limits. The other three companies SK Energy (SKE), Samyang Genex (SY), and Samsung Fine Chemical (SFC) showed only not reaching upper or lower price limits in the Ulsan Industrial Complex. KG Chemical (KG), Kumyang (KY), and DSR experienced both upper and lower price limits, and Samsung Electronics (SE) did not show both limits.

LG (Nov 12, 2005), KH, CH, DL (Mar 14, 2013) in the Yeosu showed relatively smaller variability of 1.56, 2.21, 2.14, and 2.46 respectively. SKE in the Ulsan showed relatively smaller variability of 2.23. SY showed the smallest variability of 1.49, and LG (Mar 17, 2002), DL (Oct 15, 2001) showed higher average daily return of 0.44, 0.45 %, and KP showed the highest average daily return of 0.58 %. The estimation window of each company is 190 market trading days, but four cases had only 169, 181 of HW, 175 of LT, and 181 trading days of DL respectively because the peer group stock index data of chemical and petrochemical field was only available at after 2001.

Table 2. Summary Statistics on Daily Returns of Estimation Period of Each Event, 190 Days Before the Event Period in Yeosu

Company	HW	LT	LG	KH	CH	DL
Event Date	Sep 24, 2001 Oct 15, 2001[b]	Oct 5, 2001 Oct 3, 2003[c]	Mar 17, 2002[c] Aug 25, 2004 Nov 12, 2005[c]	Oct 20, 2003	Jan 22, 2006[c]	Oct 15, 2001 Mar 14, 2013
Maximum Returns (%)	15.00	13.45 12.41	10.28 10.82 7.35	9.65	8.01	14.99 7.77
Minimum Returns (%)	-10.37	-12.74 -12.5	-14.83 -14.64 -3.58	-7.61	-6.17	-10.61 -9.70
Average Returns (%)	0.30	0.20 0.33	0.44 -0.07 0.10	-0.03	0.36	0.45 0.04
Standard Deviation (%)	4.46	3.69 3.24	3.36 3.13 1.56	2.21	2.14	3.99 2.46
Sample Number	169[a] 181[a]	175[a] 190	190 190 190	190	190	181[a] 190

[a] It didn’t have enough estimation window to test of 190 trading days.

[b] The first and second event use the same result of estimation window, since the second event day is on the event window of the first event.

[c] The event day is assumed to be next Monday, because the accident occurred on weekend.

Table 3. Summary Statistics on Daily Returns of Estimation Period of Each Event, 190 Days Before the Event Period in Ulsan

Company	SK	HS	SO	SKE	KP	HD
Event Date	Oct 20, 2003	Sep 21, 2004 Feb 24, 2008[c]	Apr 9, 2004	Oct 26, 2010 Dec 20, 2010[b]	Feb 8, 2011	Aug 17, 2011
Maximum Returns (%)	15.00	10.12 14.40	15.00	7.20	14.87	14.98
Minimum Returns (%)	-14.95	-9.18 -14.17	-7.38	-6.88	-6.47	-12.77
Average Returns (%)	0.17	-0.05 0.23	0.42	0.14	0.58	0.31
Standard Deviation (%)	4.88	2.58 3.33	3.31	2.23	2.86	3.81
Sample Number	190	190 190	190	190	190	190

[b] The first and second event use the same result of estimation window, since the second event day is on the event window of the first event.

[c] The event day is assumed to be next Monday, because the accident occurred on weekend.

Table 4. Summary Statistics on Daily Returns of Estimation Period of Each Event, 190 Days Before the Event Period in Ulsan and the other industrial complexes

Company	SY	KG	KY	DSR	SE	SFC
Event Date	Apr 22, 2004 Feb 27, 2011[c]	Apr 28, 2004	Apr 21, 2005	Mar 10, 2006	Jan 27, 2013[c]	Apr 14, 2013[c]
Maximum Returns (%)	5.19 6.15	14.29	14.93	14.91	5.20	5.54
Minimum Returns (%)	-4.48 -3.98	-15.00	-14.48	-14.48	-7.45	-4.39
Average Returns (%)	-0.09 -0.06	-0.71	0.55	0.03	0.09	-0.02
Standard Deviation (%)	1.32 1.36	5.32	4.53	4.64	1.97	1.51
Sample Number	190 190	190	190	190	190	190

[c] The event day is assumed to be next Monday, because the accident occurred on weekend.

Summary of Normal Return Regression Results

This study estimated the normal returns with using the OLS market model and the results of normal returns of each company are shown in Table 5, Table 6, and Table 7. Every company was tested for serial correlation and heteroskedasticity: the tables include Durbin-Watson *d*-statistics and White test χ^2-statistics. When the tests detected and I corrected for serial correlation and heteroskedasticity, corrected parameters and other values such as model *F*-statistics and R^2 replaced the original regressions. Only the KY case showed statistically insignificant based on the zero value of *F*-statistics and R^2.

Most of the estimated beta's in the regression results were statistically significant at 1 and 5% significance level, but the KY case was not significant at 1, 5, and 10% significant level. Every company but KY was also statistically significant at 1% and 5% significant level in *F*-statistics. There were only four companies of SK, HS, KG and SE which showed positive serial correlation then corrected, and heteroskedasticity was detected in ten companies of HW, LT (Oct 5, 2001), LG (Aug 25, 2004 and Nov 12, 2005), DL (Oct 15, 2001 and Mar 14, 2013), SO, SY, KG, DSR, SE, and SFC with 1 and 5% of significance level.

The beta's in the regression results meaning is in terms of statistical and economic interpretation; for example, the company in the Ulsan industrial complex shows that the percent change of HW's daily stock returns increase by an estimated 1.8781 % for each one percentage increases in the peer-group market returns in the statistical interpretation. In finance, the beta of a stock or portfolio is a number describing the correlated volatility of an asset in relation to the volatility of the peer-group market index that said asset is being compared to.

In economic interpretation, the beta of HW can be interpreted the movement of the asset is generally in the same direction, but more than the movement of the peer-group market. In considering of the other cases, the economic interpretation is different from the beta's size. If the beta is less than zero, the asset generally moves in the opposite direction as compared to the peer-group market. The example of this case is gold market which often moves opposite to the movement of the stock market. If the beta is equal to zero, the movement of asset is uncorrelated with the movement of the peer-group market.

If the beta is between zero and one, the movement of asset is generally in the same direction, but less than the movement of the peer-group market. This kind of movement from a company can be shown making soap, but less susceptible to day-to-day fluctuation. If the beta is equal to one, the movement of the asset is generally in the same direction, and the same amount of movement can be seen in the peer-group market. If the beta is greater than one, the movement of the asset is generally the same direction, but more than the movement of the peer-group market (Wikipedia.org). The example of this case can be seen in the voltaic stock such as tech stock or stocks which are strongly influenced by day-to-day market news. In this study, there are 11 firms (HW, LT, LG's 1st and 2nd cases, DL, SK, SO, SKE, DSR) on beta's range from zero to one and eight firms (LG's 3rd case, KH, CH, HS, KP, HD, SY, KG, KY, SE, SFC) are over one.

Table 5. Normal Return Regression Results of Each Company in the Ulsan

Company	HW[c]	LT	LG	KH	CH	DL
Event Date	Sep 24, 2001 Oct 15, 2001	Oct 5, 2001 Oct 3, 2003	Mar 17, 2002 Aug 25, 2004 Nov 12, 2005	Oct 20, 2003	Jan 22, 2006	Oct 15, 2001 Mar 14, 2013
Beta	1.8781**	1.3629** 1.0714**	1.29** 1.0401** 0.6457**	0.5612**	0.8532**	1.2834** 1.6745**
(t-statistics)	(11.73)	(11.13) (9.58)	(12.59) (12.15) (8.03)	(6.75)	(6.34)	(9.02) (13.78)
Constant	-0.0001	0.0009 0.0026	0.0015 -0.002 0.0003	-0.0005	0.003	0.0032 0.0004
Model F-statistics	137.70**	123.94** 91.73**	158.47** 147.54** 64.51**	45.59**	40.15**	81.43** 189.95**
R^2	0.4519	0.4175 0.3279	0.4574 0.4397 0.2555	0.1952	0.1760	0.3127 0.5026
D-Watson *d*-statistics [a]	1.9852	1.8114 1.8944	2.1049 1.9450 1.8426	2.2724	2.1629	1.7685 1.9943
White Test χ^2-statistics [b]	7.34*	6.02* 0.25	1.79 4.03* 6.47*	1.76	0.64	5.16* 4.56*

* Statistically significant at 5% significance level

* Statistically significant at 1% significance level

*

[a] Significant points of d_L and d_U at 5% significance level is 1.758, 1.779 when k=1. (k is the number of regressors excluding the intercept.)

[b] White Test χ^2-statistics with * and ** indicate that the original regression results were detected to contain heteroskedasticity at 5% and 1% significance levels, respectively.

[c] The two accidents of Hanwha (HW) used the same results, since the event day of the second event was on the event period of the first event.

Table 6. Normal Return Regression Results of Each Company in the Yeosu

Company	SK	HS	SO	SKE[c]	KP	HD
Event Date	Oct 20, 2003	Sep 21, 2004 Feb 24, 2008	Apr 9, 2004	Oct 26, 2010 Dec 20, 2010	Feb 8, 2011	Aug 17, 2011
Beta	1.5051**	0.6881** 0.973**	1.1988**	1.299**	0.8745**	0.8778**
(t-statistics)	(8.71)	(8.24) (11.3)	(9.00)	(12.00)	(5.36)	(5.40)
Constant	0.001	-0.0014 0.0014	0.0018	-0.0007	0.0035	0.0013
Model F-statistics	75.79**	67.84** 127.7**	80.93**	144.00**	28.72**	29.14**
R^2	0.2873	0.2652 0.4045	0.3009	0.4337	0.1325	0.1342
D-Watson *d*-statistics [a]	1.7344 (2.0126)	2.0193 1.7493 (1.9629)	2.11	1.8619	1.9134	1.8741
White Test χ^2-statistics [b]	1.27	0.36 10.12**	17.71**	0.29	1.18	0.94

* Statistically significant at 5% significance level

** Statistically significant at 1% significance level

[a] Significant points of d_L and d_U at 5% significance level is 1.758, 1.779 when k=1. (k is the number of regressors excluding the intercept.)

[b] White Test χ^2-statistics with * and ** indicate that the original regression results were detected to contain heteroskedasticity at 5% and 1% significance levels, respectively.

[c] The two accidents of SK Energy (SKE) used the same results, since the event day of the second event was on the event period of the first event.

Table 7. Normal Return Regression Results of Each Company in the Yeosu and the other complexes

Company	SY	KG	KY	DSR	SE	SFC
Event Date	Apr 22, 2004 Feb 27, 2011	Apr 28, 2004	Apr 21, 2005	Mar 10, 2006	Jan 27, 2013	Apr 14, 2013
Beta	0.2855** 0.2328**	0.5324*	0.0045	1.0866**	0.7609**	0.5620**
(t-statistics)	(4.77) (2.90)	(2.13)	(0.02)	(3.42)	(6.78)	(5.08)
Constant	-0.0016 -0.0011	-0.0085	0.0055	-0.0007	0.0011	-0.0001
Model F-statistics	22.77** 8.41**	4.53*	0.00	11.69**	46.01**	25.81**
R^2	0.1080 0.0428	0.0236	2.07E-06	0.0585	0.1966	0.1207
D-Watson *d*-statistics [a]	2.0578 1.8671	1.3179 (2.1290)	1.8301	1.7755	1.7477 (1.9692)	2.2602
White Test χ^2-statistics [b]	1.33 5.07	2.32	0.45	2.42	2.46	0.84

* Statistically significant at 5% significance level

** Statistically significant at 1% significance level

[a] Significant points of d_L and d_U at 5% significance level is 1.758, 1.779 when k=1. (k is the number of regressors excluding the intercept.)

[b] White Test χ^2-statistics with * and ** indicate that the original regression results were detected to contain heteroskedasticity at 5% and 1% significance levels, respectively.

Summary of Abnormal Returns and Cumulative Abnormal Returns

This section shows the calculated abnormal returns (ARs) and cumulative abnormal returns (CARs). Table 8 through Table 11 details the results. Tables show the values of ARs and CARs by company and event, attaching *t*-statistics of each AR and CAR.

We know the concept of AR and CAR and how to calculate the values from the method section. For example, this is how to derive AR of day -10 (10 days before the event day) and CAR of 5 days (The adding up value during the 5 days' ARs from the event day) of Daelim Industry (DL). a) Collect the adjusted stock price data of DL from the Korea Information System Value (KISVALUE) and the peer-group stock index data (Chemical Industry) from the Korea Exchange (KRX). b) Calculate the returns of DL's daily adjusted stock price and peer-group's daily index of each day.

c) Run the OLS regression with the DL's daily stock price returns as an explanatory variable and the peer-group stock index returns as a predictor variable. d) Get the results of alpha of 0.0004 and beta of 1.6745 and the day -10's peer-group stock return value of -0.00246. e) Put the three value of alpha, beta, and the day -10's stock return into the equation (2) [$\text{Expected Return} = 0.0004 + 1.6745 \times (-0.00246)$], then get the day -10's expected return value of -0.004. f) Put the day -10's peer-group expected stock return value into the equation (4) with the DL's daily stock price return of day -10 [$\text{AR} = -0.01255 - (-0.004) = -0.0086$], then we get the abnormal return of 0.86% of day -10.

To get the CAR of 5 days, a) do the same processes from day -10 to day 5. b) The value of CAR during 5 days after the event is the value of sum of ARs from day -10 to day 5. c) The values of ARs are -0.86 (day -10), 1.02 (day -9), 0.55 (day -8), -0.29 (day-7), 0.19 (day -6), -0.46

(day -5), -2.23 (day -4), -0.31 (day -3), -0.37 (day -2), -0.66 (day -1), 0.52 (day 0:The Event Day), 0.21 (day 1), 0.92 (day 2), 1.21 (day 3), -0.25 (day 4), -1.36 (day 5), then the sum of ARs is -2.18 which is the same to the value of CAR during 5 days of DL.

The Chemical disasters in the Yeosu Industrial Complex between 2001 and 2013

There are 11 chemical accidents from six different companies of HW, LT, LG, KH, CH, and DL, and ARs and CARs of each company's event indicates that the explosions, fires, and chemical leaks had impacts on the firm's stock price.

The companies tested in the study showed significant ARs in the each event. LT's the second accident showed statistically significant negative ARs on day 0, day 4, and day 5 after the event and positive AR on day 7. LG's the first event on Mar 17, 2002 showed statistically significant negative AR on day 4, but it rebounded positive ARs on day 5 and day 6 which means the accident had an impact on the company's stock price. The third accident of LG showed significant negative ARs on day 2 and day 8, but positive ARs on day 3, day 5, and day 10.

CH showed significant negative ARs on day 5 and positive ARs on day 2, day 7, and day 8. I saw positive market reaction on day 2 after the event, because the information of the accident did not spread out to the public (Hamilton 1995) that the market and shareholders did not place orders after the accident. The first accident of DL showed statistically significant positive ARs on day 1 and day 2. Unlike the first one of LG, the second accident showed significant negative AR on day 8 not after the accident. KH showed statistically significant negative AR on day 6 after significant positive AR on day 5.

Generally, the market reaction to chemical disasters is to be negative, but some of cases showed statistically significant positive ARs. The statistically significant positive AR means that the investors did not have negative movements because the extent of accident was small the shareholders did not worry about their financial losses.

After the event occurring, each company showed different directions of CARs. LT showed statistically significant negative CAR in 5 day post-event windows while the 10, 20, and 30 day post-event windows showed insignificant negative CARs. The second event of LG showed statistically significant positive CARs in 5, 10, 20, and 30 day post-event windows. KH showed statistically significant negative CAR in 10 days since then the event occurred, but presented significant positive CARs in 20 and 30 day post-event windows. The rest of companies in the Yeosu industrial complex showed statistically insignificant negative CAR results because the CAR captures the total firm-specific stock movement for an event period when the market responses to the information of the accident. The reason the CARs are insignificant is that the information is not being leaked to the market according to Hamilton (1995).

Table 8. Abnormal Returns of Each Company in Yeosu

Company	Day	DL	SK	HS	HS	SO	SKE[a]	KP	HD	SY
Event Date		Mar 14, 2013	Oct 20, 2003	Sep 21, 2004	Feb 24, 2008	Apr 9, 2004	Oct 26, 2010 Dec 20, 2010	Feb 8, 2011	Aug 17, 2011	Apr 22, 2004
Abnormal Return (%)	-10	-0.86	-2.28	-0.16	0.03	5.79**	1.03	-4.33**	0.76	-1.34
		(-0.46)	(-0.62)	(-0.07)	(0.01)	(2.25)	(0.58)	(-1.97)	(0.26)	(-0.93)
	-9	1.02	0.88	1.31	-0.25	-0.13	-0.20	-2.20	-1.99	-2.82**
		(0.54)	(0.24)	(0.58)	(-0.09)	(-0.05)	(-0.11)	(-1.00)	(-0.68)	(-1.97)
	-8	0.55	-0.99	-2.80	-2.36	0.54	-3.86**	0.22	-0.10	-0.97
		(0.29)	(-0.27)	(-1.23)	(-0.84)	(0.21)	(-2.19)	(0.10)	(-0.03)	(-0.68)
	-7	-0.29	0.84	1.38	-4.48*	-0.35	0.54	-4.80**	-4.24	0.39
		(-0.15)	(0.23)	(0.61)	(-1.59)	(-0.14)	(0.31)	(-2.19)	(-1.46)	(0.27)
	-6	0.19	-2.94	0.76	2.53	-0.81	-0.64	0.78	-6.20**	-0.57
		(0.10)	(-0.80)	(0.33)	(0.90)	(-0.32)	(-0.36)	(0.36)	(-2.13)	(-0.40)
	-5	-0.46	1.52	0.27	1.86	-4.18*	0.38	6.80***	9.40***	0.98
		(-0.24)	(0.41)	(0.12)	(0.66)	(-1.62)	(0.21)	(3.10)	(3.22)	(0.68)
	-4	-2.23	-6.35*	-1.55	3.99	-1.08	-2.11	-4.26**	2.60	0.46
		(-1.18)	(-1.74)	(-0.68)	(1.42)	(-0.42)	(-1.20)	(-1.94)	(0.89)	(0.32)
	-3	-0.31	0.13	4.31*	0.00	-1.12	-0.22	-2.55	-0.96	-1.83
		(-0.17)	(0.03)	(1.90)	(0.00)	(-0.44)	(-0.13)	(-1.16)	(-0.33)	(-1.28)
	-2	-0.37	0.85	0.90	-1.32	-0.44	1.35	-2.11	1.25	0.64
		(-0.20)	(0.23)	(0.40)	(-0.47)	(-0.17)	(0.76)	(-0.96)	(0.43)	(0.45)
	-1	-0.66	1.99	-1.94	2.49	5.10**	2.34	-0.39	0.02	0.12
		(-0.35)	(0.54)	(-0.85)	(0.89)	(1.98)	(1.33)	(-0.18)	(0.01)	(0.09)
	0	0.52	2.85	1.98	-2.25	1.41	-0.69	-5.16**	-1.16	-0.26
		(0.28)	(0.78)	(0.87)	(-0.80)	(0.55)	(-0.39)	(-2.35)	(0.40)	(-0.18)
	+1	0.21	3.47	2.63	-2.63	7.06***	-0.99	0.31	-8.36***	-1.81
		(0.11)	(0.95)	(1.16)	(-0.94)	(2.75)	(-0.56)	(0.14)	(-2.87)	(-1.26)

	+2	0.92	-0.55	4.07*	4.49*	-0.30	-2.46	0.35	-5.61**	0.62
		(0.49)	(-0.15)	(1.79)	(1.76)	(-0.11)	(-1.40)	(0.16)	(-1.93)	(0.43)
	+3	1.21	6.65*	2.21	-0.66	-2.89	-0.06	-1.05	3.89	3.37**
		(0.64)	(1.82)	(0.97)	(-0.23)	(-1.12)	(-0.03)	(-0.48)	(1.34)	(2.35)
	+4	-0.25	-1.03	-1.08	0.90	-4.48*	0.11	-5.51***	4.77*	-0.69
		(-0.13)	(-0.28)	(-0.48)	(0.32)	(-1.74)	(0.06)	(-2.51)	(1.64)	(-0.48)
	+5	-1.36	-1.80	0.03	-1.10	-1.11	2.73*	4.40**	-3.20	1.16
		(-0.72)	(-0.49)	(0.01)	(-0.39)	(-0.43)	(1.55)	(2.01)	(-1.10)	(0.81)
	+6	1.92	-3.07	-0.87	-1.22	-2.03	-1.44	-1.91	-3.58	2.07
		(1.02)	(-0.84)	(-0.38)	(-0.43)	(-0.79)	(-0.82)	(-0.87)	(-1.23)	(1.44)
	+7	1.27	4.73	-0.29	3.81	3.51	-1.63	0.08	3.25	2.06
		(0.67)	(1.29)	(-0.13)	(1.36)	(1.37)	(-0.92)	(0.03)	(1.12)	(1.44)
	+8	1.10	1.21	4.27**	5.41**	0.44	4.95***	-1.11	-2.15	1.18
		(0.58)	(0.33)	(2.07)	(1.93)	(0.17)	(2.80)	(-0.51)	(-0.74)	(0.82)
	+9	-0.65	2.94	-3.97*	0.87	-0.95	0.05	-0.83	1.06	-3.93***
		(-0.34)	(0.80)	(-1.74)	(0.31)	(-0.37)	(0.03)	(-0.38)	(0.36)	(-2.74)
	+10	0.55	5.06	2.81	-0.25	-2.88	0.34	0.27	-1.85	-1.02
		(0.29)	(1.38)	(1.24)	(-0.09)	(-1.12)	(0.19)	(0.12)	(-0.64)	(-0.71)

Day 0 is the event day.
Values in parentheses are t-statistics.

*** Statistically significant at 1% significance level (AR>2.60)

** Statistically significant at 5% significance level (AR>1.97)

* Statistically significant at 10% significance level (AR>1.65)

[a] The two accidents of SK Energy (SKE) used the same results, since the event day of the second event was on the event period of the first event.

The Chemical disasters in Ulsan Industrial Complex between 2001 and 2013

There are 11 accidents with eight different firms of SK, HS, SO, SKE, KP, HD, SY, and SFC. SK showed statistically significant positive AR on day 3, and the first accident of HS showed statistically significant positive ARs on day 2 and day 8, and negative ARs on day 9. The second case of HS showed significant positive ARs on day 2 and day 8 after the event. SO presented statistically significant positive ARs on day 1 and significant negative ARs on day 4. SKE showed statistically significant positive ARs on day 5 and day 8 after the event. KP presented statistically significant negative ARs on day 0 and day 4 and significant positive AR on day 5 after the event.

HD showed statistically significant negative ARs on day 1 and day 2 and significant positive ARs on day 4. The first case of SY showed statistically significant negative ARs on day 9 and significant positive ARs on day 3. The second accident of SY did not presented statistically significant negative or positive ARs. SFC showed statistically significant positive AR on day 1 after the event and significant negative AR on day 2.

The first event of HS showed statistically significant positive CAR in 20 day post-event windows and insignificant positive CARs in 5, 10, and 30 days since then the event occurred. KP presented statistically distinct results of significant negative CARs in 10, 20, and 30 day post-event windows. SK, the second event of HS, and SO showed insignificant positive CARs, but SKE, HD, and SY showed negative CARs. The reason why the firms showed significantly/insignificantly positive ARs and/or CARs is because of the leak of information (Hamilton 1995).

Table 9. Abnormal Returns of Each Company in Ulsan

Company	Day	HW[a]	LT	LT	LG	LG	LG	KH	CH	DL
Event Date		Sep 24, 2001 Oct 15, 2001	Oct 5, 2001	Oct 3, 2003	Mar 17, 2002	Aug 25, 2004	Nov 12, 2005	Oct 20, 2003	Jan 22, 2006	Oct 15, 2001
Abnormal Return (%)	-10	0.38	-0.76	0.52	-2.93	0.07	-1.13	-1.92	0.24	-1.03
		(0.11)	(-0.26)	(0.20)	(-1.10)	(0.03)	(-0.81)	(-0.97)	(0.14)	(-0.33)
	-9	1.49	-1.96	-0.75	-0.40	1.64	0.00	-1.05	1.48	-0.97
		(0.45)	(-0.68)	(-0.29)	(-0.15)	(0.62)	(0.00)	(-0.53)	(0.88)	(-0.32)
	-8	2.33	2.59	-4.40*	2.77	5.62**	0.98	0.16	-2.11	0.50
		(0.70)	(0.90)	(-1.69)	(1.03)	(2.14)	(0.70)	(0.08)	(-1.25)	(0.16)
	-7	5.42*	0.70	2.85	0.11	0.67	1.11	-5.58***	-1.07	-4.14
		(1.62)	(0.24)	(1.10)	(0.04)	(0.25)	(0.79)	(-2.81)	(-0.63)	(-1.35)
	-6	-2.52	0.58	4.04*	1.45	0.88	1.80	-1.32	-1.48	-2.56
		(-0.75)	(0.20)	(1.55)	(0.54)	(0.33)	(1.29)	(-0.67)	(-0.88)	(-0.83)
	-5	-10.96***	-0.48	-1.83	1.62	1.69	-1.40	1.77	4.48***	-1.89
		(-3.28)	(-0.17)	(-0.70)	(0.61)	(0.64)	(-1.00)	(0.89)	(2.65)	(-0.61)
	-4	3.61	-0.47	-2.47	3.04	-0.51	1.79	-1.00	-1.43	-0.34
		(1.08)	(-0.16)	(-0.95)	(1.14)	(-0.20)	(1.28)	(-0.50)	(-0.85)	(-0.11)
	-3	-4.41	-1.52	2.37	-3.20	0.86	2.20*	0.47	-2.29	-1.87
		(-1.32)	(-0.53)	(0.91)	(-1.19)	(0.33)	(1.57)	(0.24)	(-1.35)	(-0.61)
	-2	4.43	-0.75	-2.51	-6.01**	-0.64	-0.11	-2.46	-0.96	-1.55
		(1.33)	(-0.26)	(-0.97)	(-2.24)	(-0.24)	(-0.08)	(-1.24)	(-0.57)	(-0.50)
	-1	2.75	0.91	1.97	-1.60	-0.96	2.19*	1.53	-4.08***	3.96
		(0.82)	(0.32)	(0.76)	(-0.60)	(-0.37)	(1.57)	(0.77)	(-2.41)	(1.28)
	0	0.28	0.70	-4.22*	1.98	1.12	-0.66	-2.03	2.49	-0.46
		(0.08)	(0.24)	(-1.62)	(0.74)	(0.43)	(-0.47)	(-1.03)	(1.47)	(-0.15)
	+1	-4.26	-2.11	-1.06	-0.23	1.89	0.66	-0.64	2.36	4.83*
		(-1.27)	(-0.73)	(-0.41)	(-0.09)	(0.72)	(0.47)	(-0.32)	(1.40)	(1.57)

	+2	-2.14	-1.41	-1.15	-0.32	1.77	-3.43***	0.21	6.14***	6.14**
		(-0.64)	(-0.49)	(-0.44)	(-0.12)	(0.67)	(-2.45)	(0.11)	(3.63)	(1.99)
	+3	-2.29	-1.27	-2.32	-1.06	1.44	4.29***	-0.45	1.98	0.63
		(-0.68)	(-0.44)	(-0.89)	(-0.40)	(0.55)	(3.07)	(-0.23)	(1.17)	(0.21)
	+4	-2.99	2.46	-5.14**	-14.51***	-0.74	-0.51	0.35	-0.12	-2.67
		(-0.89)	(0.85)	(-1.98)	(-5.41)	(-0.28)	(-0.36)	(0.18)	(-0.07)	(-0.87)
	+5	2.98	1.29	-4.98**	14.73***	-2.31	2.84**	3.04*	-3.10*	-0.40
		(0.89)	(0.45)	(-1.91)	(5.50)	(-0.88)	(2.03)	(1.53)	(-1.83)	(-0.13)
	+6	0.72	-1.32	1.39	4.37*	-0.84	-0.30	-2.96*	-0.40	-0.78
		(0.22)	(-0.46)	(0.53)	(1.63)	(-0.32)	(-0.21)	(-1.49)	(-0.24)	(-0.25)
	+7	3.26	-1.38	4.17*	0.44	1.32	0.13	0.20	2.87*	-1.71
		(0.97)	(-0.48)	(1.60)	(0.16)	(0.50)	(0.09)	(0.10)	(1.69)	(-0.55)
	+8	-0.78	1.91	-1.48	0.61	-3.56*	-1.95*	-0.55	5.66***	2.83
		(-0.23)	(0.66)	(-0.57)	(0.23)	(-1.36)	(-1.40)	(-0.28)	(3.35)	(0.92)
	+9	0.84	-0.12	3.07	-0.16	-1.38	0.21	-0.88	-1.34	-1.60
		(0.25)	(-0.04)	(1.18)	(-0.06)	(-0.53)	(0.15)	(-0.44)	(-0.79)	(-0.52)
	+10	2.21	0.90	0.16	2.89	0.63	2.53**	-1.44	0.12	-3.39
		(0.66)	(0.31)	(0.06)	(1.08)	(0.24)	(1.81)	(-0.73)	(0.07)	(-1.10)

Day 0 is the event day.

Values in parentheses are t-statistics.

*** Statistically significant at 1% significance level (AR>2.60)

** Statistically significant at 5% significance level (AR>1.97)

* Statistically significant at 10% significance level (AR>1.65)

[a] The two accidents of Hanwha (HW) used the same results, since the event day of the second event was on the event period of the first event.

The Chemical disasters in The Other Industrial Complex between 2001 and 2013

There are four accidents with four different companies of KG, KY, DSR, and SE. KY located in Gyeonggi in Korea showed statistically significant negative ARs on day 5 and day 6, and significant positive AR on day 7. DSR presented statistically significant negative AR on day 3 after the event. SE showed statistically significant negative AR on day 0 of the event date.

KG showed statistically insignificant positive CARs in 5, 10, and 20 day, and significant positive CAR in 30 day post-event windows. KY presented statistically significant CARs in 5, 20, and 30 days since then the accident occurred. The other companies of DSR and SE showed statistically insignificant negative CARs in post-event windows.

There is a factor that affects the market reaction of statistically insignificant CARs of the firms: if the media coverage is low, the investors cannot get the data of the firms. Hamilton (1995) explained that the accessibility to the information is the cause of statistical significance. The factors which decide the movement of stock price are the size of firm, the type of accident and casualty, and the number of accident occurrence of same company. When the results of ARs and CARs of each firm, we see the major market influencing factor is the size of company and the next is the type of accident, then the number of accident occurrence of same company.

Table 10. Abnormal Returns of Each Company in Yeosu and the other complexes

Company	Day	SY	KG	KY	DSR	SE	SFC
Event Date		Feb 27, 2011	Apr 28, 2004	Apr 21, 2005	Mar 10, 2006	Jan 27, 2013	Apr 14, 2013
Abnormal Return (%)	-10	0.18	-0.23	-2.70	2.99	1.87	-0.78
		(0.14)	(-0.06)	(-0.80)	(0.89)	(1.16)	(-0.62)
	-9	3.74***	0.71	5.28*	5.10*	-2.27	-1.49
		(2.89)	(0.18)	(1.57)	(1.52)	(-1.41)	(-1.18)
	-8	-1.17	1.02	-4.69	-0.12	-0.81	1.82
		(-0.90)	(0.26)	(-1.39)	(-0.03)	(-0.50)	(1.45)
	-7	0.05	1.47	-0.55	-0.76	-1.77	-0.56
		(0.04)	(0.37)	(-0.16)	(-0.23)	(-1.10)	(-0.45)
	-6	-0.67	0.07	2.33	-2.62	0.25	-0.63
		(-0.52)	(0.02)	(0.69)	(-0.78)	(0.15)	(-0.50)
	-5	-1.42	0.48	-4.73	4.79	-1.60	-1.40
		(-1.10)	(0.12)	(-1.40)	(1.42)	(-0.99)	(-1.12)
	-4	-0.03	1.37	-3.47	1.74	2.25	-2.28*
		(-0.02)	(0.35)	(-1.03)	(0.52)	(1.40)	(-1.81)
	-3	-0.06	4.58	-10.31***	0.10	0.42	0.95
		(-0.04)	(1.16)	(-3.06)	(0.03)	(0.26)	(0.75)
	-2	1.20	-0.61	2.77	7.47**	-1.20	0.23
		(0.93)	(-0.15)	(0.82)	(2.22)	(-0.74)	(0.18)
	-1	0.18	-1.26	-1.37	-0.18	-2.11	-0.65
		(0.14)	(-0.32)	(-0.41)	(-0.05)	(-1.31)	(-0.52)
	0	-0.11	2.20	2.70	4.07	-3.06*	-0.22
		(-0.09)	(0.56)	(0.80)	(1.21)	(-1.90)	(-0.17)
	+1	-0.58	0.33	2.60	-1.22	1.95	3.41***
		(-0.45)	(0.08)	(0.77)	(-0.36)	(1.21)	(2.71)

	+2	0.84	1.41	-2.08	-4.79	2.30	-2.01*
		(0.65)	(0.36)	(-0.62)	(-1.43)	(1.43)	(-1.60)
	+3	-0.69	3.53	-4.43	-10.71***	0.50	-1.75
		(-0.53)	(0.90)	(-1.32)	(-3.19)	(0.31)	(-1.39)
	+4	-1.12	1.82	-2.16	-2.27	0.26	-1.77
		(-0.86)	(0.46)	(-0.64)	(-0.68)	(0.16)	(-1.41)
	+5	0.05	1.4	-7.1**	-3.39	0.04	1.31
		(0.04)	(0.35)	(-2.11)	(-1.01)	(0.02)	(1.04)
	+6	-0.37	0.29	-8.44***	-0.30	0.51	-0.24
		(-0.29)	(0.07)	(-2.51)	(-0.09)	(0.32)	(-0.19)
	+7	-1.17	2.07	13.73***	1.07	0.06	1.88
		(-0.91)	(0.52)	(4.08)	(0.32)	(0.04)	(1.50)
	+8	0.40	-2.79	0.28	-2.00	-0.71	-1.44
		(0.31)	(-0.71)	(0.08)	(-0.59)	(-0.44)	(-1.15)
	+9	-0.88	1.38	-0.57	3.59	2.49	0.43
		(-0.68)	(0.35)	(-0.17)	(1.07)	(1.55)	(0.34)
	+10	-0.79	2.89	-2.22	-4.19	0.29	0.91
		(-0.61)	(0.73)	(-0.66)	(-1.25)	(0.18)	(0.72)

Day 0 is the event day.
Values in parentheses are t-statistics.

*** Statistically significant at 1% significance level (AR>2.60)

** Statistically significant at 5% significance level (AR>1.97)

* Statistically significant at 10% significance level (AR>1.65)

Table 11. Cumulative Abnormal Returns of Each Company

Company	Day	HW[b]	LT	LT	LG	LG	LG	KH	CH	DL
Event Date		Sep 24, 2001 Oct 15, 2001	Oct 5, 2001	Oct 3, 2003	Mar 17, 2002	Aug 25, 2004	Nov 12, 2005	Oct 20, 2003	Jan 22, 2006	Oct 15, 2001
Cumulative Abnormal Returns (%)	5 Days	-5.88	-1.50	-19.07*	-4.57	12.47	10.62*	-8.93	2.52	-1.84
		(-0.38)	(-0.11)	(-1.60)	(-0.37)	(1.04)	(1.66)	(-0.98)	(0.33)	(-0.13)
	10 Days	0.37	-1.51	-11.77	3.57	8.63	11.24*	-14.56*	9.43	-6.48
		(0.02)	(-0.11)	(-0.99)	(0.29)	(0.72)	(1.75)	(-1.60)	(1.22)	(-0.46)
	20 Days	-10.35	-4.03	-5.40	3.53	10.26	12.28*	31.50***	5.67	-7.15
		(-0.68)	(-0.30)	(-0.45)	(0.29)	(0.85)	(1.91)	(3.46)	(0.73)	(-0.51)
	30 Days	1.32	8.35	-3.61	2.69	8.43	18.86***	66.46***	6.41	-2.30
		(0.09)	(0.63)	(-0.30)	(0.22)	(0.70)	(2.94)	(7.31)	(0.83)	(-0.16)
Company		DL	SK	HS	HS	SO	SKE[b]	KP	HD	SY
Event Date		Mar 14, 2013	Oct 20, 2013	Sep 21, 2004	Feb 24, 2008	Apr 9, 2004	Oct 26, 2010 Dec 20, 2010	Feb 8, 2011	Aug 17, 2011	Apr 22, 2004
Cumulative Abnormal Returns (%)	5 Days	-2.18	3.23	12.31	1.70	3.00	-2.76	-19.51	-9.15	-2.56
		(-0.25)	(0.19)	(1.18)	(0.13)	(0.25)	(-0.34)	(-1.94)	(-0.69)	(-0.39)
	10 Days	2.00	14.11	14.71	10.33	1.09	-0.50	-23.03**	-12.42	-2.19
		(0.23)	(0.84)	(1.41)	(0.80)	(0.09)	(-0.06)	(-2.46)	(-0.93)	(-0.33)
	20 Days	-7.28	14.83	33.60***	12.53	1.53	-1.70	-29.17***	-8.03	-4.34
		(-0.84)	(0.88)	(3.22)	(0.97)	(0.13)	(-0.21)	(-2.90)	(-0.60)	(-0.66)
	30 Days	-8.81	18.59	14.86	7.15	4.42	-0.11	-24.95**	-4.51	-5.12
		(-1.02)	(1.11)	(1.43)	(0.55)	(0.37)	(-0.01)	(-2.48)	(-0.34)	(-0.78)

Values in parentheses are t-statistics.
Significant at 1% significance level (CAR 5-day>4.60, CAR 10-day>3.25, CAR 20-day>2.86, CAR 30-day>2.75)
Significant at 5% significance level (CAR 5-day>2.78, CAR 10-day>2.26, CAR 20-day>2.09, CAR 30-day>2.04)
Significant at 10% significance level (CAR 5-day>2.13, CAR 10-day>1.83, CAR 20-day>1.72, CAR 30-day>1.69)
[a] Not enough data
[b] The two accidents of Hanwha (HW) and SK Energy (SKE) used the same results, since the event day of the second event was on the event period of the first event.

Table 11. Cumulative Abnormal Returns of Each Company, continued

Company	Day	SY	KG	KY	DSR	SE	SFC
Event Date		Feb 27, 2011	Apr 28, 2004	Apr 21, 2005	Mar 10, 2006	Jan 27, 2013	Apr 14, 2013
Cumulative Abnormal Returns (%)	5 Days	0.38	18.31	-27.91*	0.18	-2.97	-5.83
		(0.06)	(1.01)	(-1.81)	(0.01)	(-0.40)	(-1.01)
	10 Days	-2.43	22.14	-25.12	-1.65	-0.32	-4.29
		(-0.41)	(1.23)	(-1.63)	(-0.11)	(-0.04)	(-0.74)
	20 Days	6.81	20.44	-39.99**	-3.70	0.52	-8.03
		(1.15)	(1.130	(-2.59)	(-0.24)	(0.07)	(-1.39)
	30 Days	5.33	34.11*	-47.33***	-4.25	0.81	[a]
		(0.90)	(1.89)	(-3.07)	(-0.28)	(0.11)	

Values in parentheses are t-statistics.
Significant at 1% significance level (CAR 5-day>4.60, CAR 10-day>3.25, CAR 20-day>2.86, CAR 30-day>2.75)
Significant at 5% significance level (CAR 5-day>2.78, CAR 10-day>2.26, CAR 20-day>2.09, CAR 30-day>2.04)
Significant at 10% significance level (CAR 5-day>2.13, CAR 10-day>1.83, CAR 20-day>1.72, CAR 30-day>1.69)
[a] Not enough data

The Graphs of Each Industrial Complex's CARs +10 after the Event Day

We see two graphs (Figure 1. ~ Figure 2.) of CARs of each industrial complex which graphically explain the market reaction to the chemical disasters. Most of firm which I tried to test the hypotheses showed negative CARs after the event as I expected. We confirm the results from each figure shows statistically significant or insignificant negative CARs. According to the types, extent, and a number of casualties of accidents, the height of bar are different from case by case.

The four cases (LT^{1st}, LT^{2nd}, KH, DL^{1st}) in the Yeosu industrial complex showed statistically significant negative CARs on day +10 after the event. The six accidents (SKE, KP, HD, SY^{1st}, SY^{2nd}, SFC) in the Ulsan industrial complex presented the statistically significant negative CARs on day +10 after the accident. From the graphs, the Ulsan industrial complex showed more negative market reaction than the Yeosu.

We can see Figure 3. ~ Figure 26 showing the ARs and CARs of each company. Some of them show negative abnormal returns after the event day and some of them don't. There can be a lot of factors affecting the stock price returns and it is mentioned at the conclusions and implications.

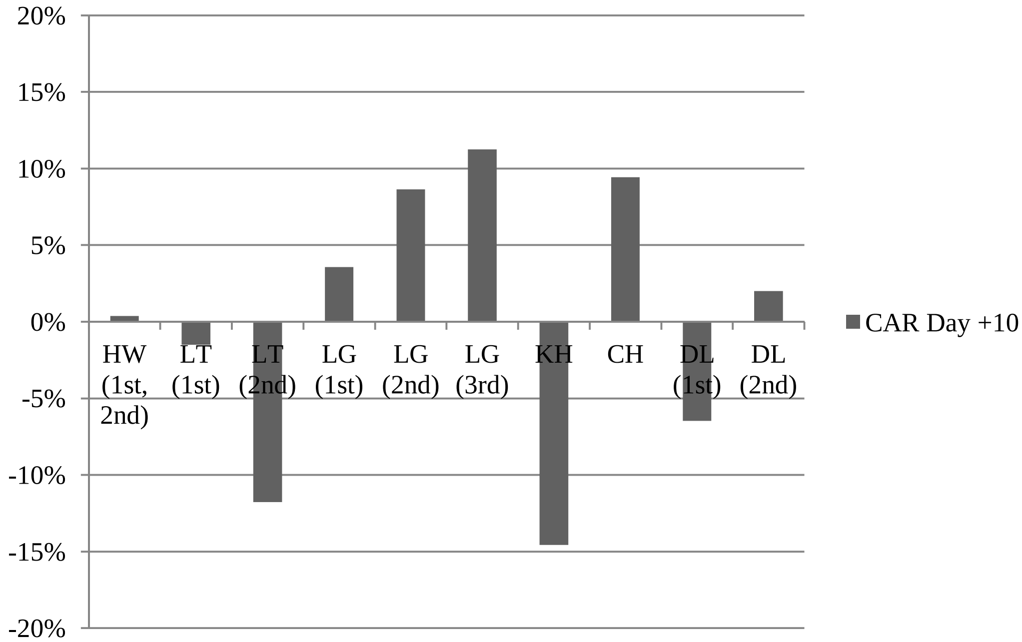

Figure 1. CAR Day +10 of Each Company in the Yeosu Industrial Complex

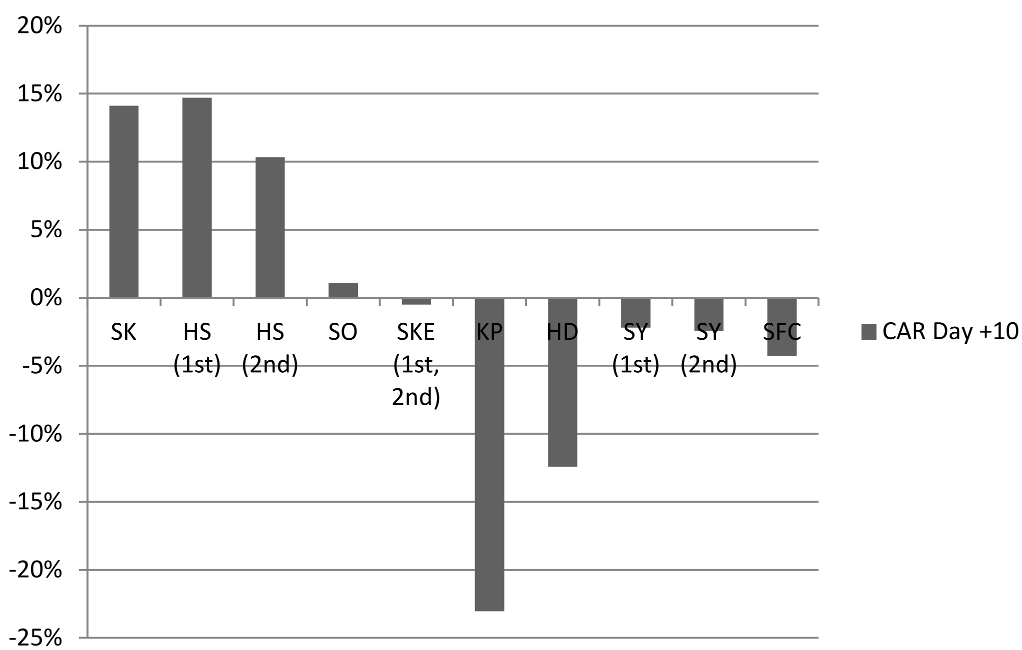

Figure 2. CAR Day +10 of Each Company in the Ulsan Industrial Complex

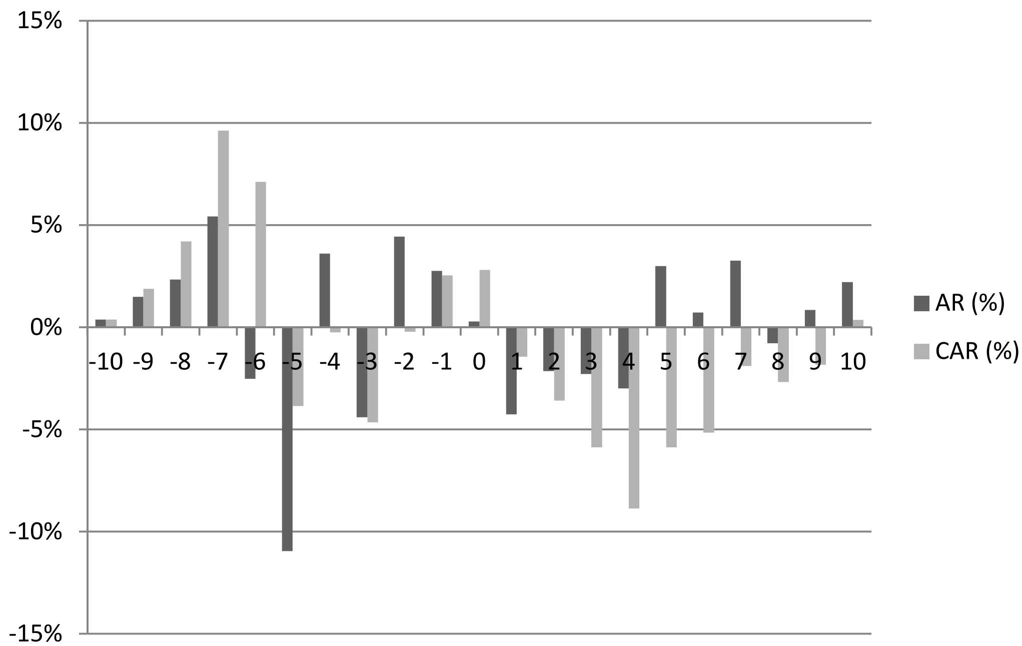

Figure 3. Hanwha Chemical (The Event Date: 09/24/01, 10/15/01)

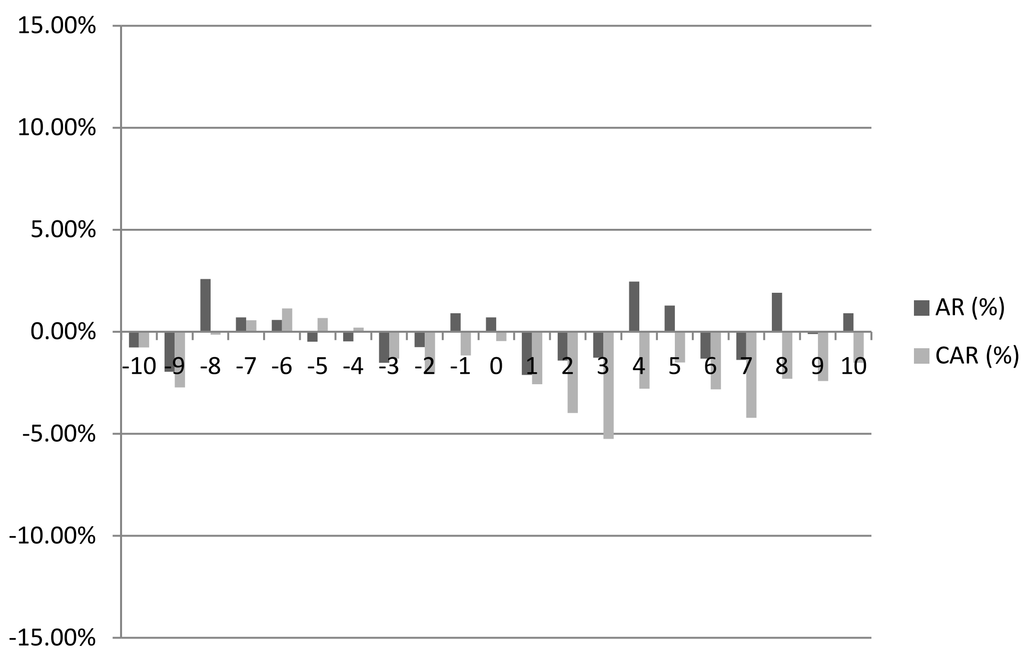

Figure 4. Lotte Petrochemical (The Event Date: 10/05/01)

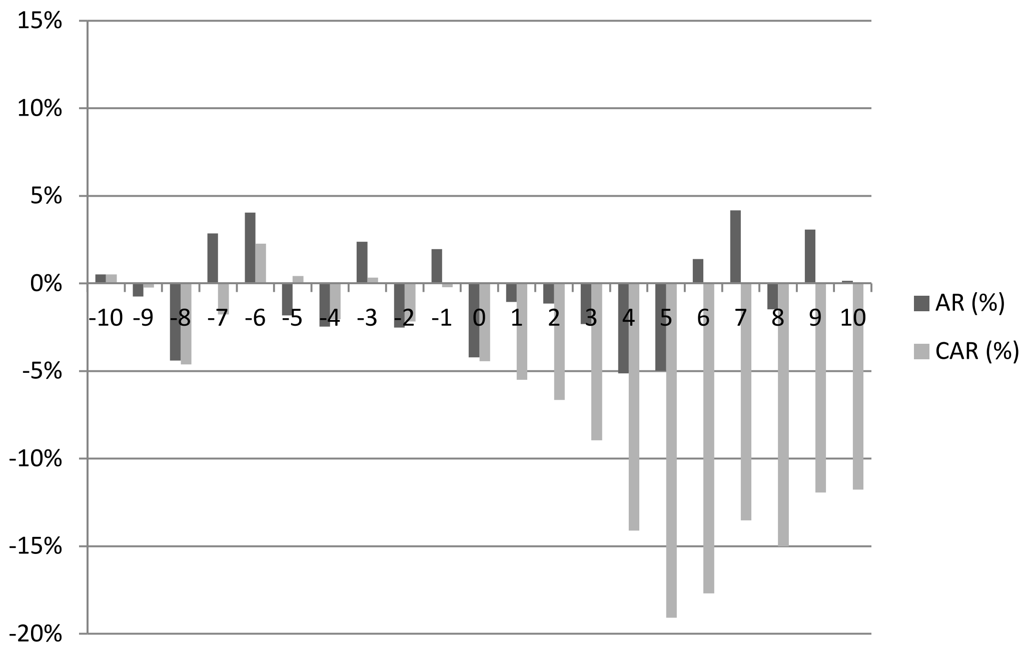

Figure 5. Lotte Petrochemical (The Event Date: 10/03/03)

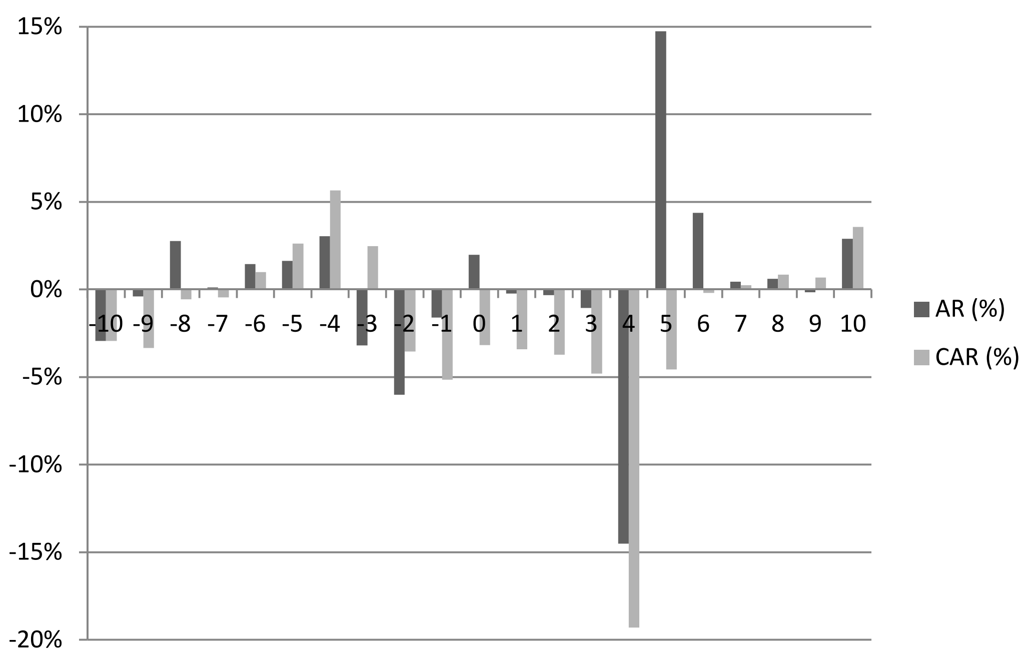

Figure 6. LG Petrochemical CO., Ltd. (The Event Date: 03/17/02)

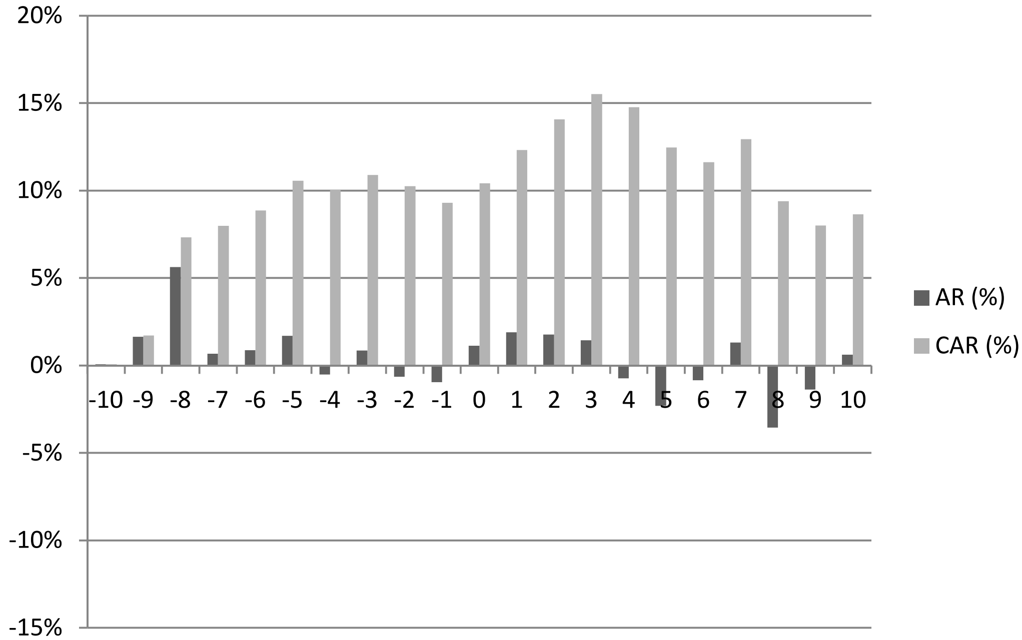

Figure 7. LG Petrochemical CO., Ltd. (The Event Date: 08/25/04)

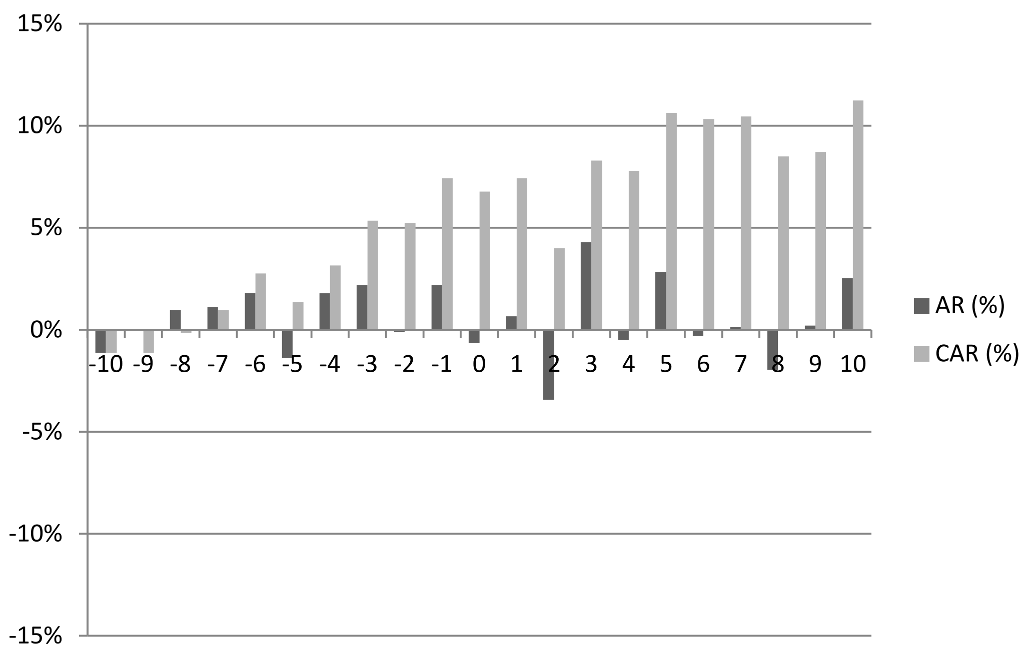

Figure 8. LG Petrochemical CO., Ltd. (The Event Date: 11/12/05)

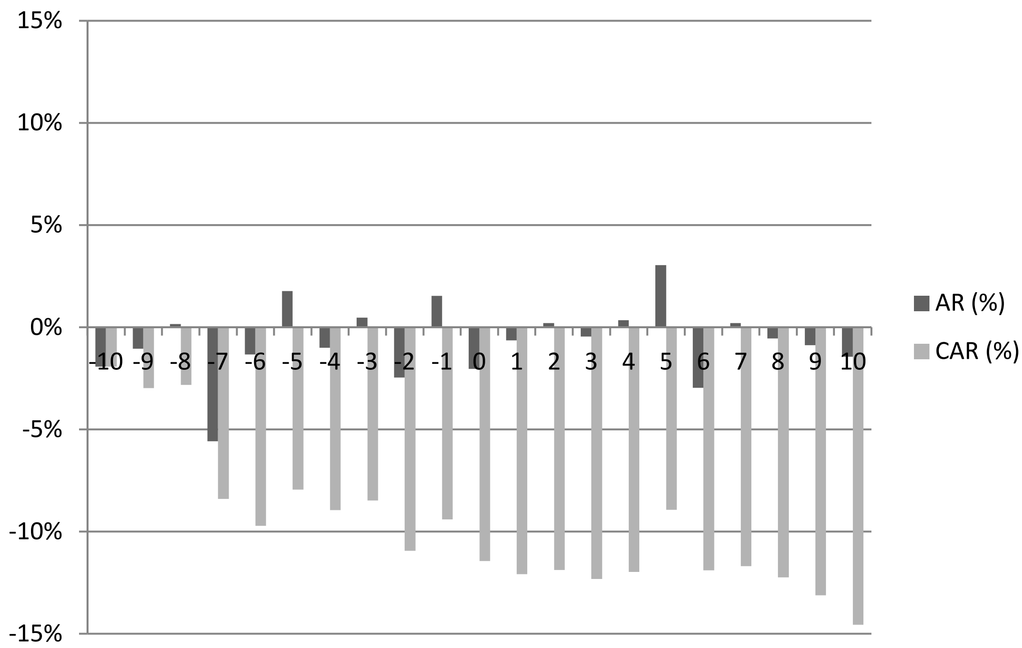

Figure 9. Kumho Petrochemical (The Event Date: 10/20/03)

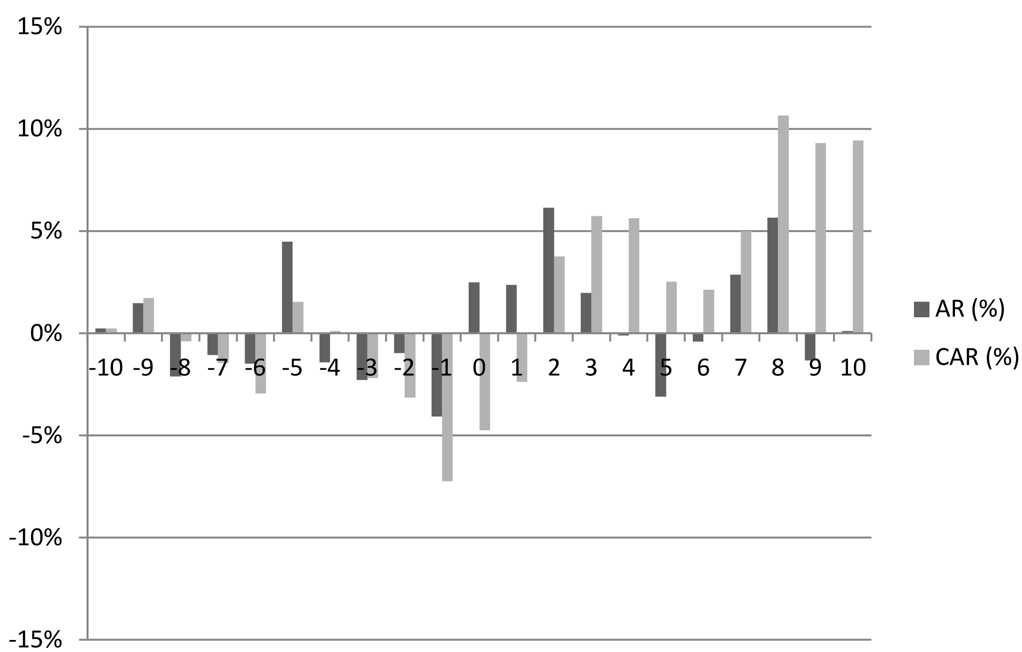

Figure 10. Cheil Industry (The Event Date: 01/22/06)

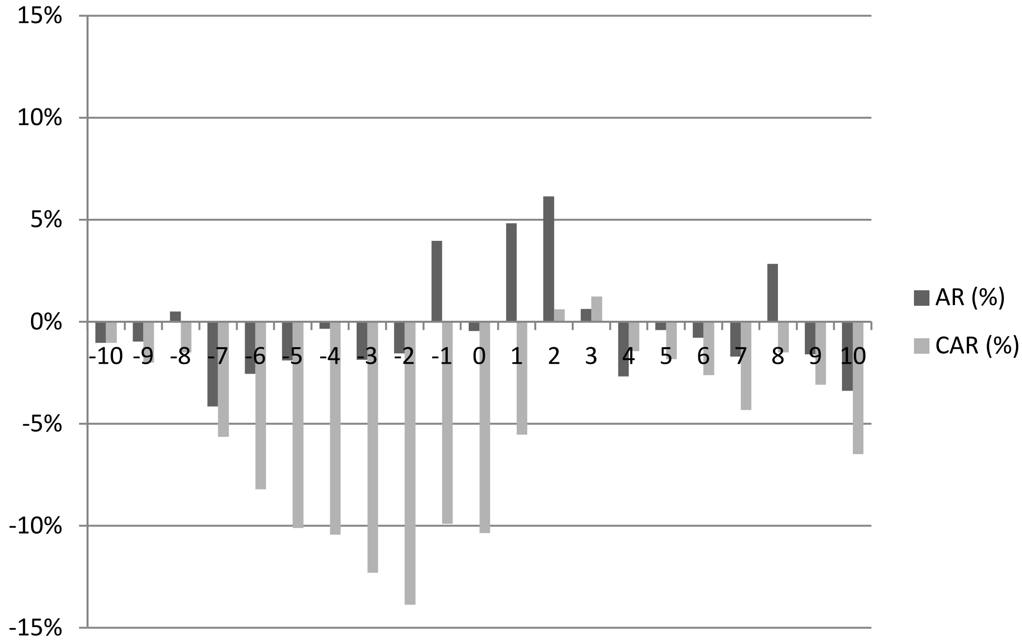

Figure 11. Daelim Industry (The Event Date: 10/15/01)

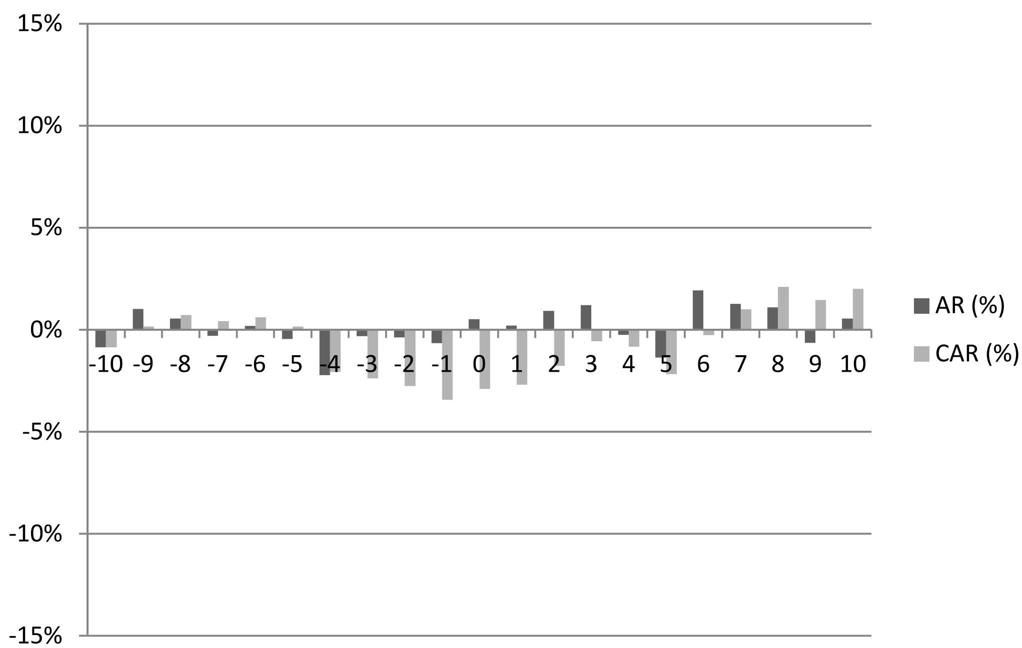

Figure 12. Daelim Industry (The Event Date: 03/14/13)

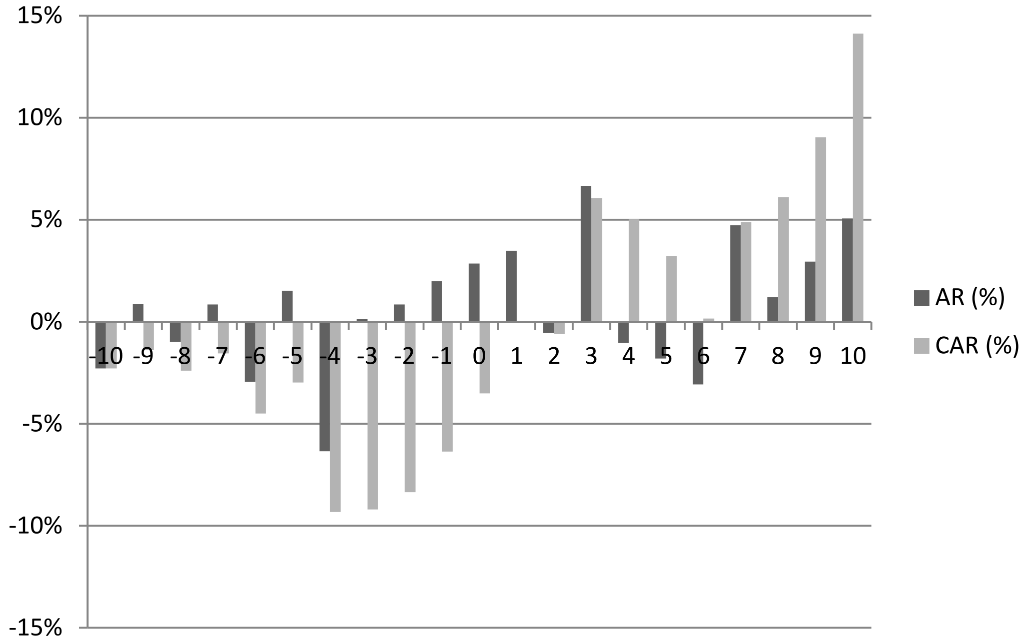

Figure 13. SK CO., Ltd. (The Event Date: 10/20/03)

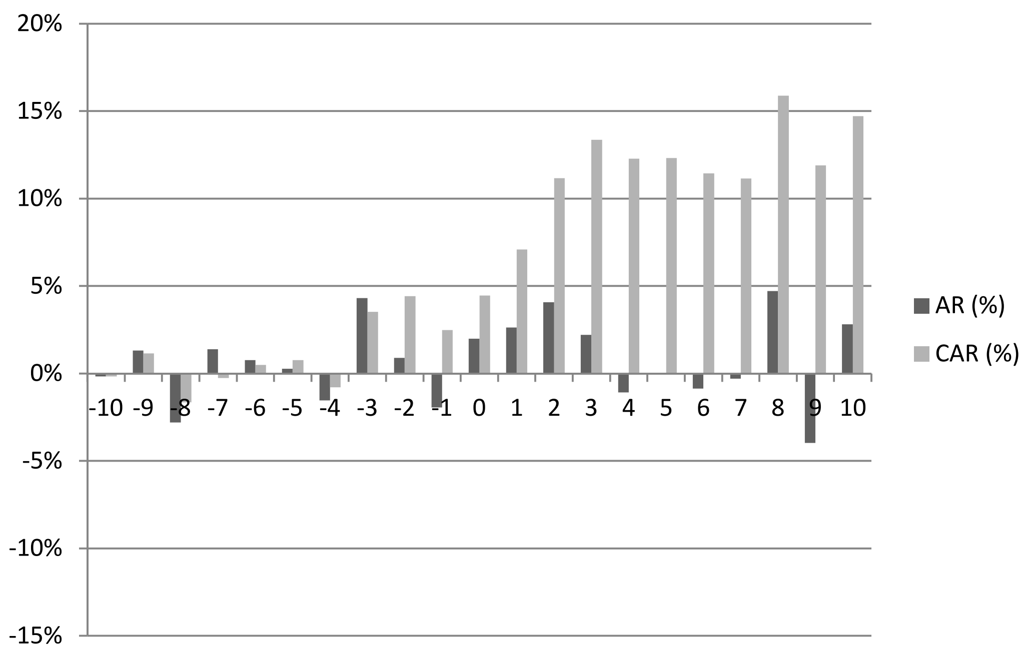

Figure 14. Hyosung (The Event Date: 09/21/04)

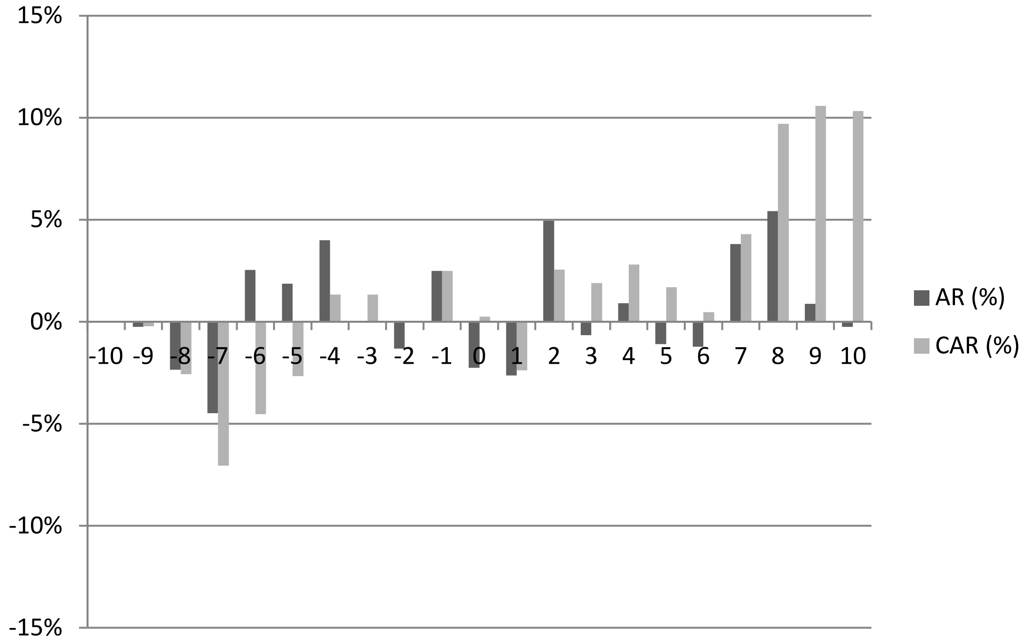

Figure 15. Hyosung (The Event Date: 02/24/08)

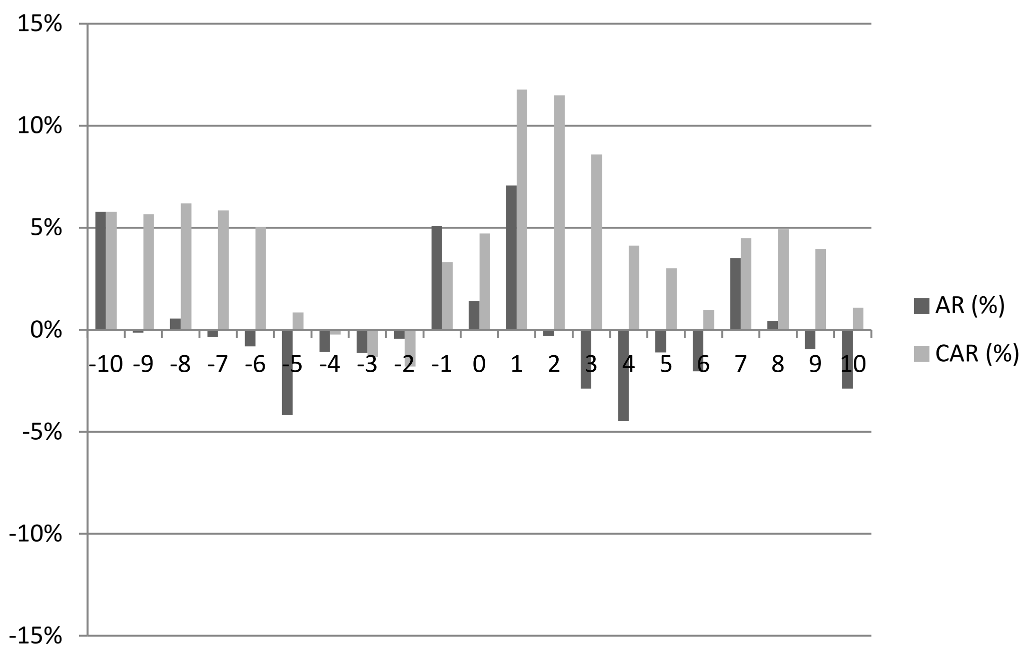

Figure 16. S-Oil (The Event Date: 04/09/04)

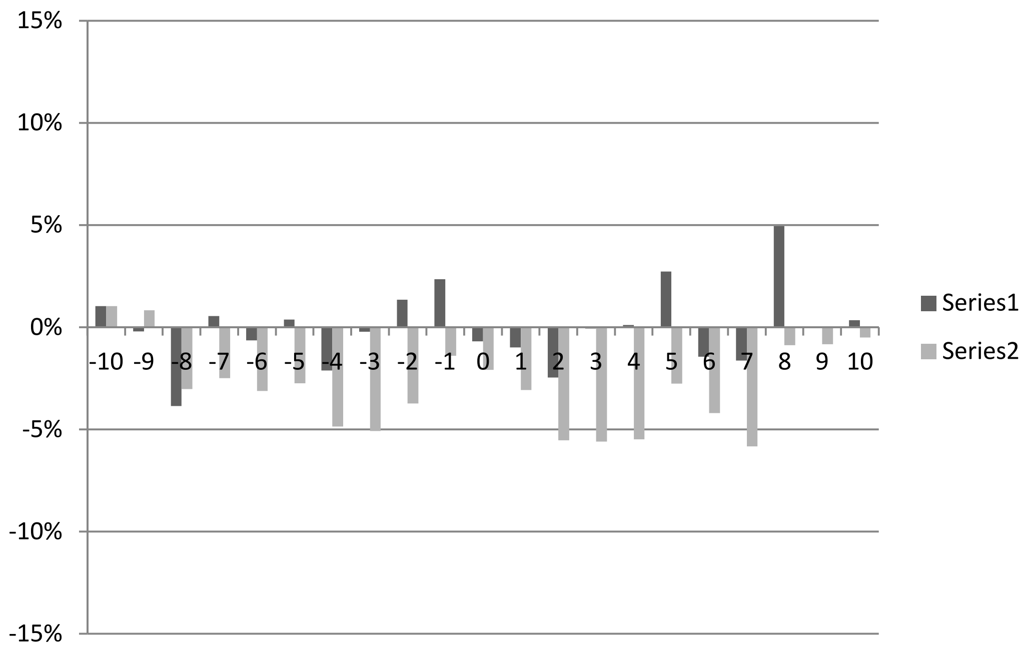

Figure 17. SK Energy (The Event Date: 10/26/10, 12/20/10)

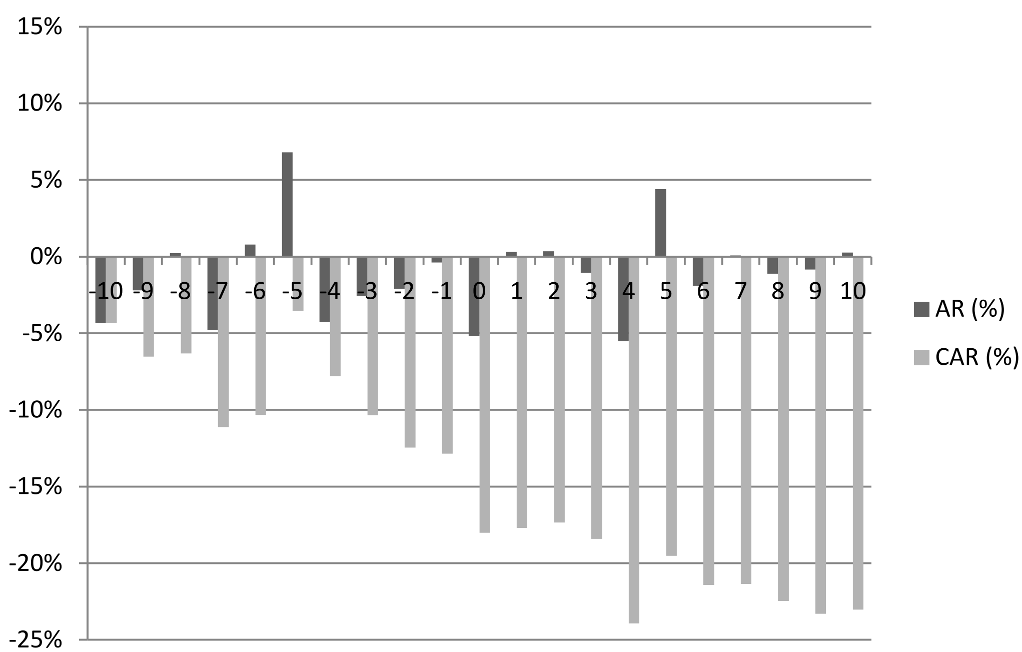

Figure 18. Korea Petrochemical (The Event Date: 02/08/11)

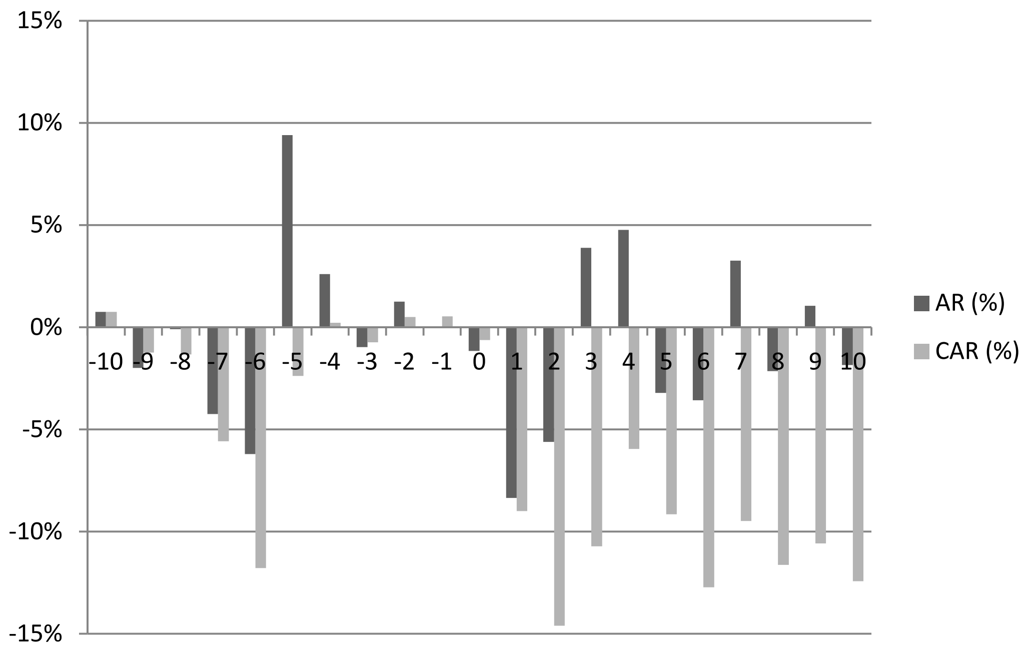

Figure 19. Hyundai EP (The Event Date: 08/17/11)

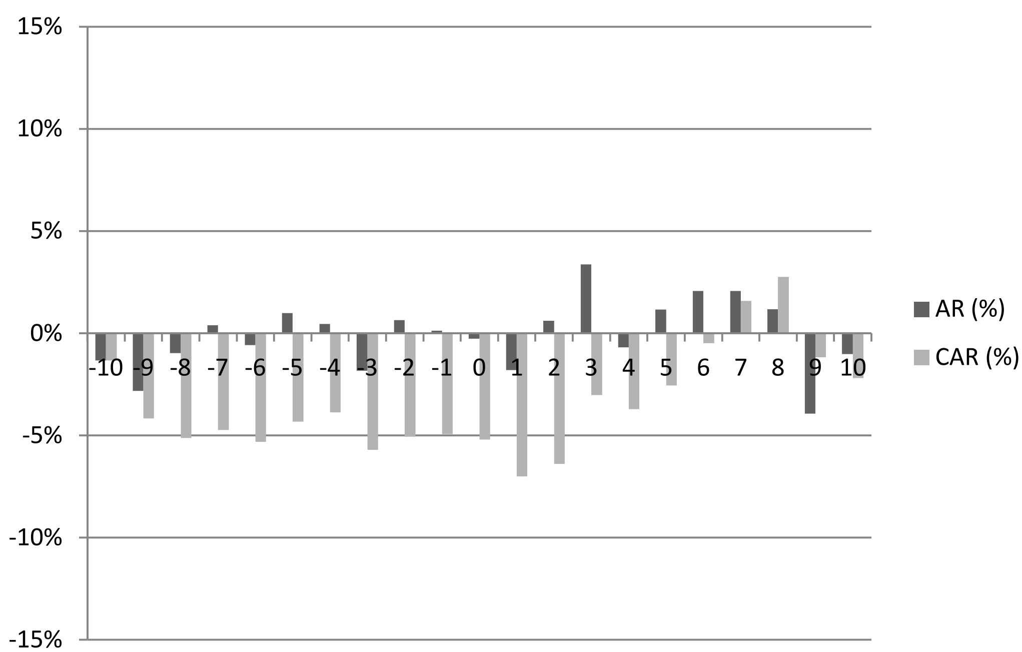

Figure 20. Samyang Genex (The Event Date: 04/22/04)

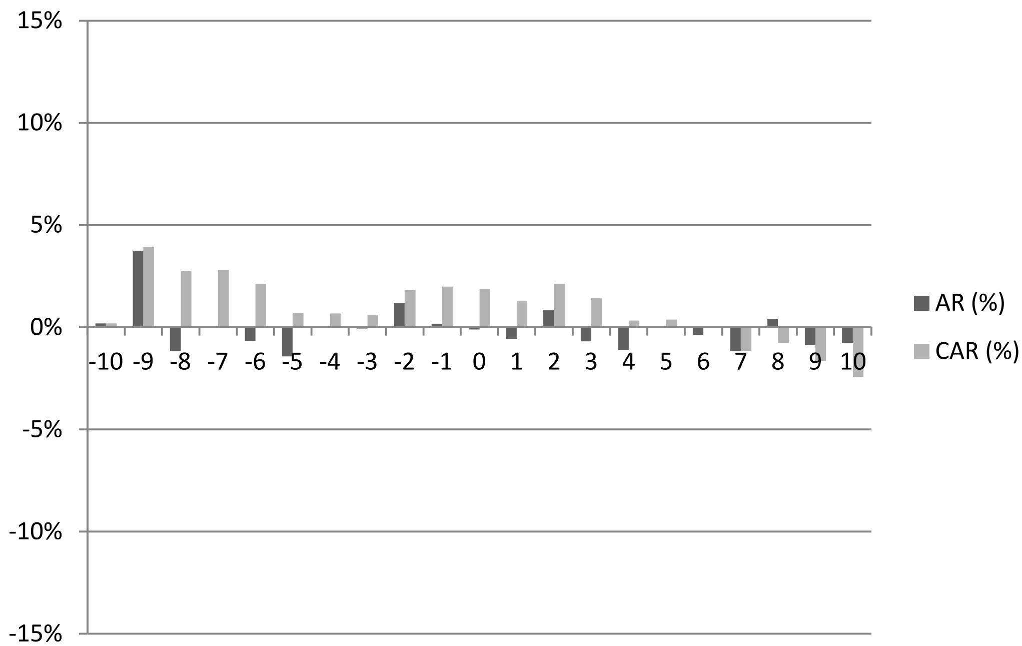

Figure 21. Samyang Genex (The Event Date: 02/27/11)

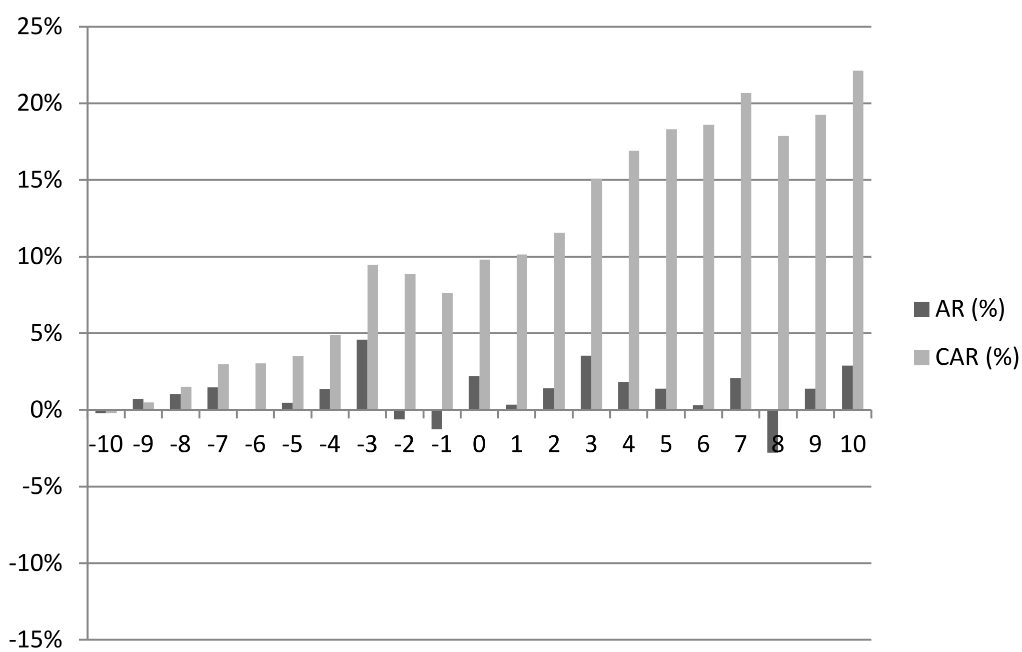

Figure 22. KG Chemical (The Event Date: 04/28/04)

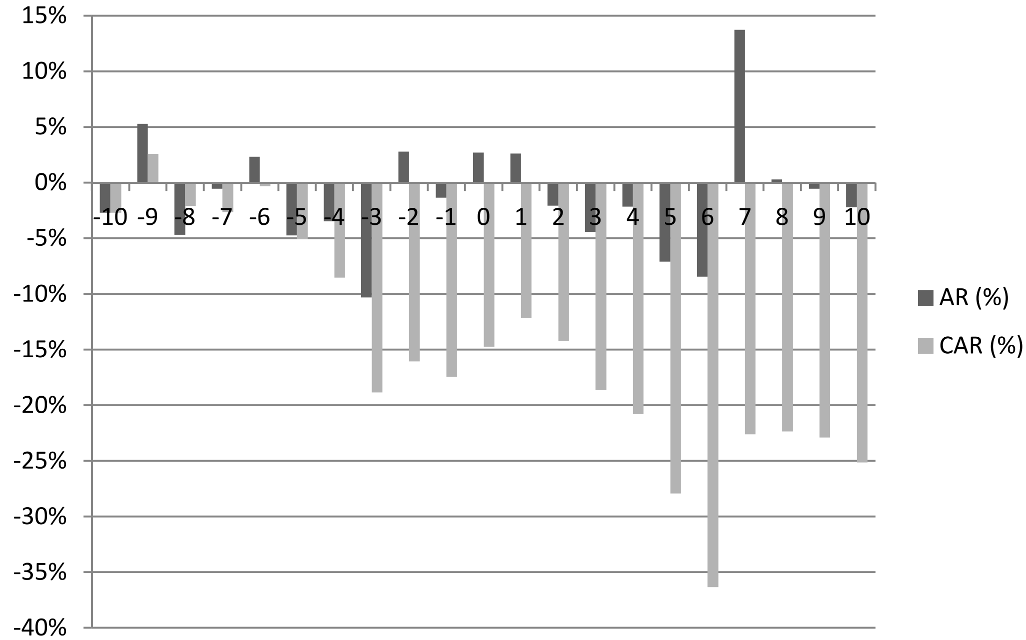

Figure 23. Kumyang (The Event Date: 04/21/05)

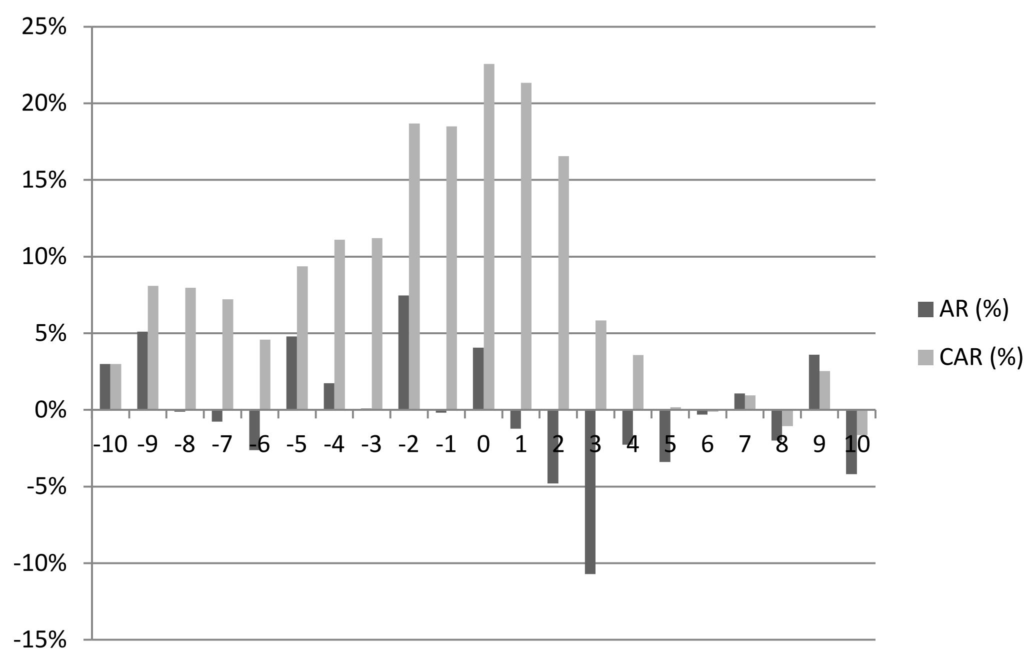

Figure 24. DSR (The Event Date: 03/10/06)

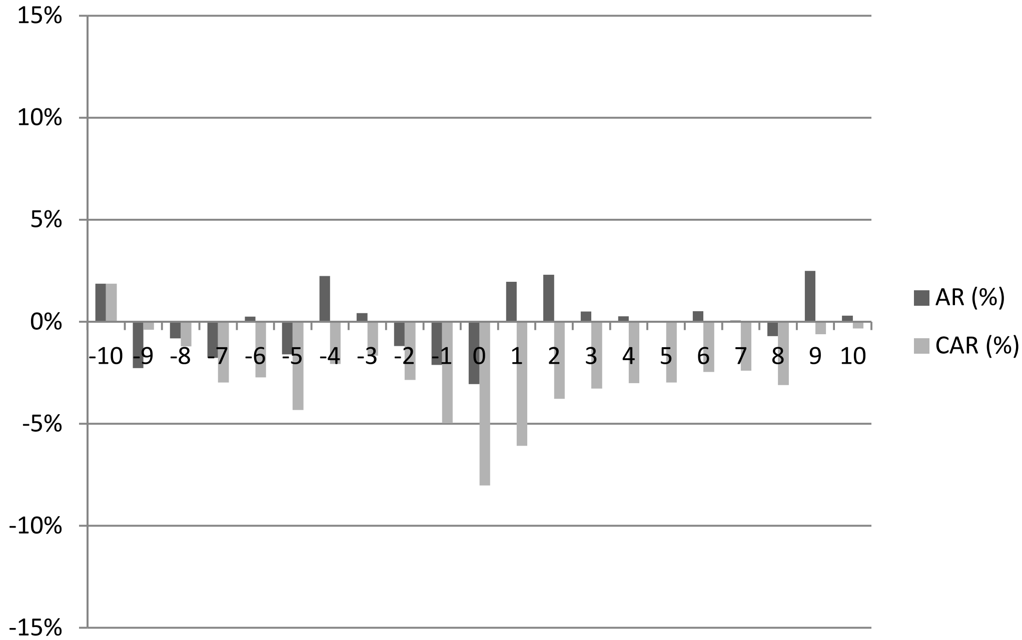

Figure 25. Samsung Electronics (The Event Date: 01/27/13)

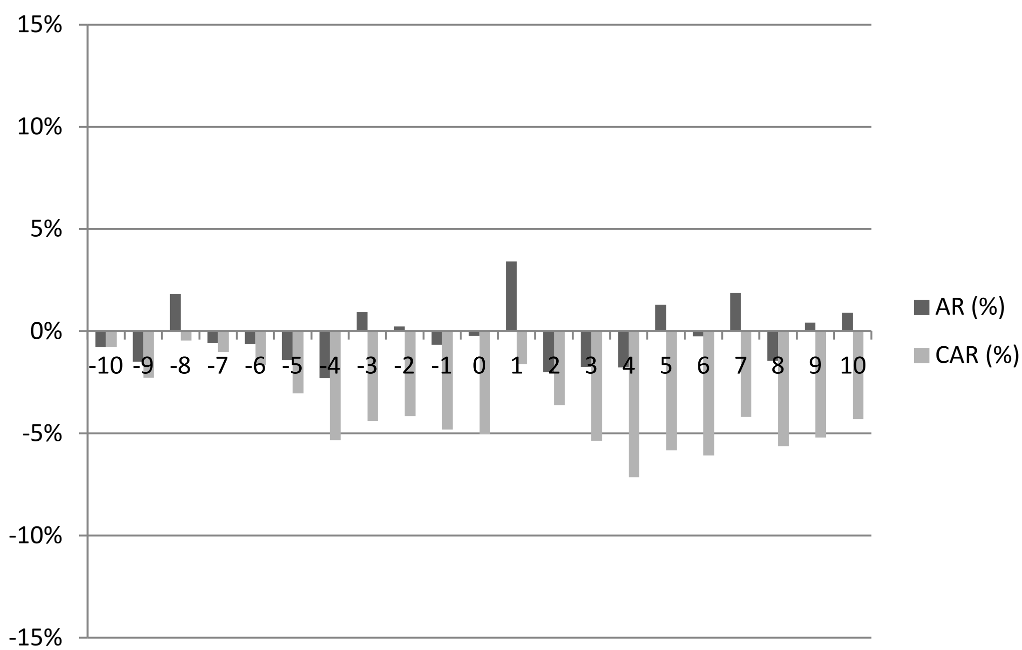

Figure 26. Samsung Fine Chemical (The Event Date: 04/14/13)

CONCLUSION AND IMPLICATIONS

The chemistry corporations in Korea are not large enough to have conditions applicable to global firms: capital, resources, innovation, and the market. The companies do not have business portfolios which make them global with regard to capital, competitive with the oligopoly of oil-producing countries and international oil companies' control of natural resources, lack the petrochemical technology of Japan and the American companies, and the market share for national chemical companies' expansion. The life cycle of the chemical industry is relatively longer than the other industries due to high investment costs and lengthy product life cycles (PLC). The productive firms in chemical industries are likely to take action on the objectives and business portfolios great insight.

This analysis which was based on using abnormal returns (ARs) and cumulative abnormal returns (CARs) concluded that chemical disasters like explosions, plant fires, and chemical leaks caused the both negative and positive stock market reaction. This study included 18 chemical and petrochemical companies with 26 different accidents between 2001 and 2013.

Abnormal returns are triggered by 'event' and the abnormal returns are derived from the deals in the stock market by individuals and companies. If the event date is to be the first day of abnormal negative return, there can be unobserved variable affected by normal return. However, we can use the event date as the first day of abnormal negative return and check how the results change with using Instrumental Variable (IV) in Two-Stage Least Squares (2SLS).

The major topic in this study is to confirm the relationships between the accident and the company’s abnormal returns. I did not check the mutual relationships among the companies but it is worth to see that with the interaction terms in OLS.

All of the results did not match my expectations. Four cases (DL^{1st}, SK, HS^{2nd}, SKE) in ARs and three cases (LG^{3rd}, HS^{1st}, KG) in CARs revealed different results; and only presented statistically significant positive ARs and CARs since the event windows. The companies that showed significant positive ARs and CARs are HS (Feb 24, 2004) on day 2 and day 8, SKE (Oct 26, 2010 and Dec 20, 2010) on day 5 and day 8, SK (Oct 20, 2003) on day 3, and DL (Oct 15, 2001) on day 1 and day 2 in ARs results. The LG (Nov 12, 2005) in four post-event windows (5, 10, 20, and 30 days), KG (Apr 28, 2004) in CAR 30 days, and HS (Sep 21, 2004) in CAR 20 days showed significant positive CARs after the event day.

I initially thought that the effects on stock market reactions were different due to the type, extent, and number of casualties in the accident. When I performed the event study with the topic, I got the results from 15 cases of the relationship between the ARs or CARs and the extent, type, and the number of casualties. However, all of the cases did not show the same results. The 16 cases revealed that the degree of severity of the chemical accidents was not really related to the market reaction. The reason why the unmatched results arose was because of the exposure of the event information. Hamilton (1995) mentioned that the market is influenced by the leak of information.

I have concluded that the relationship between the ARs/CARs and the extent, type of accidents, and the number of casualties are not seriously related to each other. However, there is a limitation to this conclusion because of the leak of information to the market (Hamilton, 1995).

This makes it possible that the market and investors will not to think of selling the shares. The other possible reason why the result occurred relates to the media exposure. The bigger the size of the accident, the less the target company reveals. Such information control is common in Korea and companies located in industrial complexes often conceal news about their accidents.

What factors influencing the share price of companies are: 1) Is the company making money? 2) People running the company 3) Taking over other companies and 4) Technological innovation. As we know, the market reacts what the company shows to the public. Besides these four factors, there might be a lot of factors can be existed. Korajczyk, Lucas, and McDonald (1990) showed the asymmetry should be of greatest concern to potential buyers of common stock. That means there should be a factor(s) affect(s) the market and its behavior.

According to the Center for Occupational Environmental Health (COEH) in Korea, there was a briefing session in June 2013 about the current state of concealment of fires, explosions and chemical spills in industrial complexes at the congress. The statistical data investigation about the accident has a couple of problems. First, there is no report of the accident to local authority if the petrochemical plant doesn't have death casualties. That means they handle the problem internally. Second, there are statistical differences in the accident investigations between the central and the local government. Lastly, the classification of industrial accidents is not established precisely. In other words, the company creating employments and local economic growths can have more power to the local and control over local media.

For example, One of firm I tested in the study, Daelim industry (Mar 14, 2013), was charged in the manipulating and concealment of information about the accident. The Ministry of Employment and Labor in Korea inspected working environment and safety procedures. The prosecution opened the investigation report to the public that Daelim industry's accident report was falsified to shift the liability for the incident. Plant manager and offices of Daelim industry were charged in professional negligence resulting in death and injured.

This study has a few limitations. First, the company that has experienced the accident is likely to control the information. It results in a lack of information regarding incidents. When I tried to collect the data of the events related to chemical disasters, I found hundreds of cases in my target industrial complexes from the casebook of toxic chemicals of the Ministry of Environment (ME) and National Institute of Environmental Research (NIER). However, there are only random initials on the event in the government's accidents casebook. I then made an effort to look for information about the accidents within the media sources such as newspapers and online websites. Nothing else showed up.

Second, the number of sample companies was quite low. This study included only 18 companies with 26 different cases. I collected 42 accidents related to chemical disasters from the casebook from ME and NIER. There were only firms' initials with the exact information about the accidents. The 25 cases were excluded from the list of the casebook, and nine cases from the various sources were then added to the sample list. The sources consisted of the online local newspapers of Yeosu and Ulsan, press releases from the Ministry of Employment and Labor (MOEL), statistics of National Emergency Management Agency (NEMA), and so on.

The papers and other studies using the same event study methodology over environmental accidents and chemical disasters showed abnormal and cumulative abnormal returns and other meaningful results. For example, Capelle-Blancard and Laguna (2010) investigated each firm's financial losses and showed the difference before and after the event.

They also tried to collect a large number of events from around the world. Herbst, Marshall, and Wingender (1996) showed the same movement of the stock market as the one that I analyzed with regard to the accident.

The 15 accidents related to chemical disasters showed statistically significant negative ARs and four cases showed significant negative CARs after the event (Table 12.~13.). The three firms (KP, LT^{2nd}, SE) showed statistically significant negative ARs on the event day, and the LT^{2nd} accident showed three significant negative ARs after the event day. The companies that showed significant negative ARs have more reliable safety standards in their chemical plants because they have experienced financial losses through the accidents.

Table 12. Companies showing significant negative/positive AR after the event day

	Companies showing Significant Negative AR after the Event Day	Companies showing Significant Positive AR after the Event Day
Day 0 (The Event Day)	KP, LT(10/03/03), SE	
Day +1	HD	DL (10/15/01), SFC, SO
Day +2	HD, LG (11/12/05), SFC	CH, DL(10/15/01), HS (09/21/04), HS (02/24/08)
Day +3	DSR	LG (11/12/15), SK, SY (04/22/04)
Day +4	LG (03/17/02), LT (10/03/03), SO, KP	
Day +5	CH, KY , LT (10/03/03)	KH, KP, LG (03/17/02), LG (11/12/05), SKE
Day +6	KH, KY	LG (03/17/02)

Day +7		CH, KY, LT (10/03/03)
Day +8	LG (08/25/04), LG (11/12/05)	CH, HS (09/21/04), HS (02/24/08), SKE
Day +9	HS (09/21/04), SY (04/22/04)	
Day +10		LG (11/12/05)
Total	15 / 26 cases	16 / 26 cases

The number in parenthesis is the different event dates of the same company. (Month/Date/Year)

Table 13. Companies showing significant negative/positive CAR after the event day

	Companies showing Significant Negative CAR after the Event Day	Companies showing Significant Positive CAR after the Event Day
Day +5	LT (10/03/03), KY	LG (11/12/05)
Day +10	KH, KP	LG (11/12/05)
Day +20	KP, KY	HS (09/21/04), LG (11/12/05), KH
Day +30	KP, KY	LG (11/12/05), KH, KG
Total	4 cases / 26 cases	4 cases / 26 cases

The number in parenthesis is the different event dates of the same company. (Month/Date/Year)

The 16 accidents showed a statistically significant positive AR and the four cases (LG^{3rd}, HS^{1st}, KH, KG) showed significant positive CARs after the accidents, because information about the accident was not leaked to the public. The companies which showed significant positive ARs have been careful to avoid accidents. Moreover, they are not likely to improve their safety requirements. In concluding this study, the companies that experienced the chemical disasters tend to improve or neglect their safety requirements due to the market's reaction and the market reaction is heavily influenced by the leaks of the accident information (Hamilton, 1995).

Objectives of the study are initially to see the relationship between the chemical accidents and the companies' stock response to the market reaction but there are not a few factors affecting the market but the accident itself. Besides, there are a couple of different methodologies available to use to seeing the relationships such as 2SLS and Tobit Model. These can be also limitations. Lastly, I hope the Korean government sets up the more detailed safety standards.

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