

The impact of Personal Information Breaches on the Firm's value in the South Korean Stock Market – A Comparative Study of IT and Non-IT Industries

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Abstract — As the collection of customers' personal information is becoming economically feasible, security breaches are also increasing. Therefore, it is important to estimate the direct and indirect costs of personal information security breaches. In this study, we examined the effects of personal information security breaches on the market values of breached firms and analyzed the difference between IT and non-IT industries. This study was formulated and conducted by using the event study methodology. We investigated the effects of personal information breaches on the firm's value in Korea stock market. The study result shows that information security breaches have an effect on firm's value from the day before breaches occurred. We also found that the magnitude of effect is different between IT and Non-IT Industries

We aim to provide an investment standard of information security to corporate decision makers and help to calculate the costs of personal information breaches in the stock market.

Keywords—event study, security breaches, information security, privacy, personal information, customer information, security incidents

I. INTRODUCTION

Generally, through business transactions conducted on the Internet, companies' collection of their customers' personal information is steadily increasing. Personal information accumulated by firms has become a powerful business tool.

However, personal information does not only constitute a

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firm's asset but is also an individual's private information. If personal information breaches occur, both individuals and firms are directly and indirectly affected. So many researchers in the world studied method or model to support decision making in information security investment [11], [13].

Nonetheless, Korean firms' information security investment is low. According to a survey conducted by the Korea Communications Commission in 2012, Korean firms that invested in information security comprised 26.1 %, and 73.3% did not do so. Moreover, companies' prevention activities for breaches decreased from the previous year. This survey shows that Korean firms have overlooked the importance of information security [15].

Studies have been conducted to measure the effects of security issues (such as security investments or information security breaches, etc.) on firms' stock market values. However, related research in Korea has been done mostly in the early to mid-2000s. Korea has a more recent history of the stock market compared to those of other countries. Also most studies about this topic focused on all types of security incident, even though each type of security incidents has different characteristics. Therefore, a study which can gather and analyze the most current event data is needed.

Consequently, we studied on information security breaches. Based on relevant research, we collected the latest data. Next, we quantitatively measured the effects of personal information breaches on firms' market values by using the event study methodology. Also we analyzed whether there is a significant difference between IT and non-IT industries.

We expect that our study help to calculate the costs of personal information security breaches in Korea stock market and to provide an investment standard of information security to decision makers of firms.

This paper is organized as follows: In Section 2, we provide the related reaches and surveys. Our study model and methodology are discussed in section 3. In section 4, we discuss our study results. The section 5 is conclusion.

II. RELATED RESEARCH

A. Definition of IT Industry

The Framework Act on Informatization Promotion	Information and communications are activities and measures to promote information collection, processing, storage, retrieval, transmission, reception, application, related equipment, related technology, related services, and other informatization.
Special Purpose Category of the National Statistical Office (Information Industry)	<ul style="list-style-type: none"> • Information and communication technology (ICT) industry: <ul style="list-style-type: none"> ○ Manufacturing industry: Produces products by using electronic processing for the functions of processing, delivering, or revealing information to control a physical process or to detect, measure, and record a physical phenomenon ○ Service industry: Processes, transmits, or reveals information by using electronic means ○ Information content industry: Produces and distributes information content to the general public <p>Information content is stored and sent in electronic media format.</p>
OECD (Organization for Economic Cooperation and Development)	<ul style="list-style-type: none"> • Information sector <p>:Industries that support the electronic display, processing, storage, and transmission of information</p> • Content sector: <p>:The term "communication product" is used to describe content that is displayed, processed, stored, and transmitted electronically by the goods and services of the ICT sector</p>

Table. 1 Definitions of IT industry and related industries [3]

This study analyzes the effects of personal information security breaches on firms' market values, and determines whether there is any significant difference between IT and non-IT companies in this regard. We begin by reviewing definitions of the IT industry and related industries in Table 1.

As shown in Table 1, the IT and related industries have been defined in various ways. But actually we could find out all most of definition of Information Technology similar.

B. Occurrence of Personal Information Breaches

The rapid development and extensive use of digital technologies, Internet and mobile device and electronic commerce lead to the collection and processing of huge amounts of personal information data. Personal information collected by a firm is a firm's asset, as well as the private information of individuals. Losses from information security breaches can be caused by a poor organization of security activities, human failures or swindles, technical failures or impact on external incidents. Besides Losses from information security breaches are classified as financial, technical, ecological, social, psychological or other[2].

What is certain is that they result in direct costs to companies and negative effects on the reliability of companies when personal information breaches happen. Consequently, the issue may cause problems for future business activities.

Nevertheless, the scale of personal information breaches is becoming larger. According to the Korea Communications Commission, the number of breaches in personal information from 2011 to 2012 caused by hacking reached more than 60 million. Given 49 million population of Korea, Koreans experience leaks of personal information more than once per person [19]. Moreover after enforcement Act on the Protection of Personal Information, about 30million people reported personal information leakage during 9 months a year[20],[21].

Worldwide trends of personal information breaches scale also tend to larger. According to the Symantec Intelligence Report (August 2012 issue), the average incidence of data breaches in the world from January to August 2012 was 14 per month, which was lower than that from May to December 2011. Moreover, the number of disclosures of per-data breaches of personal information decreased by more than half; however, the median value of the same increased by 41 % [18].

These statistical data showed that the physical number of data breaches decreased, but the number of disclosures of per-data breaches of personal information increased. This finding suggests that attackers capture specific information by employing targeted attacks.

C. Korean Studies on Effects of Information Security Issues on Firms' Market Values

Many researchers have tried to prove that information security incident has impact on firms' value or assets.

Name (2006) studied the impacts of security event announcement on firms' market values by using the event study methodology. In this study, security events were separated into information security breaches and malfunctioning.

His study shows that stock prices of a company which has information security breach drops from the 1day after(-0.52%) to 6 days after(-5.25%) and get no effect from 7 days later. And stock prices of a company which has malfunctioning drops from 1 day after(-2.41%) to 3days(-4.45%) and get normal condition after 4 days. In conclusiton, breach gets 3.82% loss and malfunctioning gets 6.44% loss(from 3 days before the events to 3 days later the evnet)..

Kim (2013) investigated the stock market reactions to newspaper reports of personal information security breaches in order to confirm the impact of the enforcement of the Privacy Act which protects personal information.

She showed that personal information security breaches affected firms' market values. But there were no changes in the stock market in comparison with previous studies that conducted before enforcement of the Privacy Act. This Study could not verify that investigation results were resulted in the Privacy Act. And sample size is only 6. Because this study is based on the personal information breaches which occurred from 2010 -2012.

Kwon and Kim (2007) examined the association between information security investments (such as introduction of an information security solution) and firms' market values. At the same time, they studied the effects of information security breaches on firms' market values.

They showed that breached firms lost, on average, 0.86 % of their respective market values. In other words, the firms lost 54 billion won in market values. They couldn't verify the difference between industry and type of incident. However, the authors could not verified information on the security investments' effects.

D. International Studies on Effects of Information Security Issues on Firms' Market Values

Ettredge and Richardson (2001) examined the stock market reactions to the February 2000 denial-of-service attacks, and they analyzed the difference between the non - Internet and Internet firms.

They found that the attacks had negative effects on Internet firms more than they did on non-Internet firms.

Cavusglu, Mishara and Rahunathan (2004) investigated the effects of security breaches on capital markets by using the event study methodology. They analyzed the effects of firm

type, firm size and year of the breach on the market reactions. They showed that breach cost was higher for Internet firms than those for conventional firms.

Their study indicated that breached firms on the sample list lost, on average, 2.1 % of their respective market values within two days of the announcement. The average loss of breached firms was \$1.65 billion in per breach in the capital market. However, the market value of the security developers was different. The security developers on the sample list gained an average abnormal return of 1.36 % during the two-day period after the announcement. An average gain amounts to \$1.06 billion in two days.

Acquisti, Friedman and Telang (2006) studied the effect of a company's privacy breaches (which occurred in 2000–June 2006) on its market value.

Their study showed a negative and statistically significant impact on the announcement day about the breach. And a number of outlying firms were driving a significant portion of the negative results.

Masaki, Hideyuki, Kanta and Ichiro(2006) examined the economic effects of newspaper reports of information security incidents on firms' values in the Japanese stock market. The sample comprised 70 companies over the 2002–August 2005 period.

Their study showed that the response to newspaper reports of security incidents was slower in the Japanese stock market than in the US counterpart. There were significant reactions approximately 10 days after the newspaper reports. They also found that the price book-value ratio (PBR) and article size had substantial impacts on the firms' market values.

III. METHODOLOGY

We investigated the effects of personal information security breaches on firms' market values by using the event study methodology.

This method is used to assess the effect of a public announcement or a special event on the capital market. Fama, Fisher, Jensen, and Roll (1969) first used event study methodology to prove the efficient market hypothesis which is about an effect of public announcement of stock split in New York Stock Exchange [4]. After they used this methodology, it has become a standard methodology to estimate stock returns about specific events.

That is, an event study assumes that returns on a stock are significantly impacted by an event[1]. By using stock market returns as the basis of our proxy for economic effect, we will be able to capture both direct and indirect costs of the information security breaches [8], [10].

A. Sample Selection

We have collected news about breach events that occurred from January 2005 to August 2013 by conducting a keyword search in the Naver news online database. The reason why we chose Naver as the news database is that Naver is the Korean

largest portal site. Therefore the information which is reported by Naver has an impact on Korean.

We set up the first news day as the day of an event. The search keywords we have used are as follows:

Search Keywords for collecting personal information breaches

: Personal information breaches, customer information leak, information disclosure, leak, private information, security incident, privacy information

We have not considered some of the search results which did not mention the breached firm's name. Moreover, the news articles that reported events of multiple firms have been counted as multiple events.

We chose events that reported at least 3 times from different news sources. A few event data were abandoned when unrelated major announcements.

We excluded the cases that didn't have enough stock price data. After the cleaning process, we were left 26 events.

We gathered the stock price and stock price indexes by industry data in homepage of Korea Exchange. Also we confirmed the financial information in Data Analysis, Retrieval and Transfer System.

In order to assess the difference in effect between firm types, we have classified our samples into IT and non-IT firms.

The classification standard of our sample data is Korean standard industrial classification. Because Korea Composite Stock Price Index(KOSPI) by industry and Korea Securities Dealers Automated Quotations(KOSDAQ) Index by industry are classified on the Korean standard industrial classification. As follows:

- **IT companies**

: computer companies, game companies, cell phone producers, portal sites, wired and wireless network equipment manufacturers, software companies, semiconductor manufacturers, display manufacturers, telecom/network equipment and mobile communications sector, broadcast services. Etc.

- **Non - IT companies**

: All other businesses except for IT firms.

Table 2 and table 3 which are in down below provide information of our data which we have collected and analyze.

Our samples is limited to personal information breaches. Therefore our sample size is a relatively small than other studies which was conducted on all type information incident.

Breached firm's industry type	Number of samples
IT company	17
Non-IT company	9
Total	26

Table. 2 Distribution of personal information breaches in publicly traded firms(KOSPI and KOSDAQ) by Industry type.

Year	Number of samples
2005	2
2006	3
2007	4
2008	5
2009	3
2010	2
2011	2
2012	3
2013 (Until August 1st)	3

Table. 3 Distributions of personal information breaches in publicly traded firms (KOSPI and KOSDAQ) by year.

Actually, we had collected more personal information breaches data. However some of them were not statistically significant or can't gather enough stock data. According to our final data set, IT firms are breached more than Non-IT firms in Korea.

B. Hypotheses

The previous literature has shown that information security incidents negatively affect the company's stock market valuation.

But few studies have been conducted to find out personal information breaches effect on the stock market because most studies focused on all types of security incident.

We have formulated the hypotheses based on previous studies. Our study aims to find out personal information breaches effect on the stock market in South Korea. The hypotheses for this study are the following:

H1: There is negative abnormal return when a personal information breach is announced.

Security incidents are divided into many types. In this study, we try to find out the effect of personal information breach in the South Korean stock market.

H2: The magnitude of the negative cumulative abnormal return will be different between IT and Non-IT Industries.

Several international studies proved that IT industries are more sensitive than Non - IT industries about information security incidents in foreign stock markets. Therefore we tried to analyze the difference between IT industries and Non - IT industries.

IV. RESULT

C. Model

In this study, we use the market model which assumes a stable linear relation between the market return and the return on the stock. There are three models for estimating abnormal performance in event study methodology : mean adjusted returns model, market adjusted returns model, and market model.

The reason why we chose market model is that this model has good test power in Korean stock market[20]. To measure the effect of the news of personal information security breaches, we estimated the normal returns.

The normal return is the return of the sock if the event had not occurred. In the market model, the normal returns are usually estimated by using the following linear model:

$$R_{it} = \alpha_i + \beta_i * R_{mt} + E_{it}.$$

Where R_{it} is the return of stock I on day t; R_{mt} is the return of the market portfolio on day t; α_i and β_i are the intercept and slope parameters, respectively for firm i; E_{it} symbolizes a disturbance term of the firms i on day t. We use Korea Composite Stock Price Index(KOSPI) by industry and Korea Securities Dealers Automated Quotations(KOSDAQ) Index by industry as R_{mt} in this linear model. The estimation accuracy can improve by using Stock Price Index of each industry than the market index of all industries.

The size of estimation window and the event window were based on previous studies. The estimation period ranges typically from 120 days to 250 days. So this study used an estimation window of 150 days and event window of 7 days. Day 0 means the event day which has reported the news of personal information breaches.

We predict the expected return over the event window by using linear model. Than we calculate the abnormal return for firm i on day t, which represent the deviations of realized returns from normal returns, as follows:

$$AR_{it} = R_{it} - \alpha_i - \beta_i * R_{mt}$$

Assuming that abnormal returns are independent of time, for firm i, we calculate cumulative abnormal returns. The cumulative abnormal return(CAR) is the sum of the individual abnormal returns over the event window. Equation as follows:

$$CAR_{i,t} = \sum_{t=-1}^{t=1} AR_{i,t}$$

We include the day before the event (day -1) because stock market can get the information quickly. We conduct analyses using $CAR_{i,t}$ and abnormal returns.

These are the results of our event study of 26 events. We used an estimation window from day -156 to day -6. We used a forecast window from day -1 to day +5.

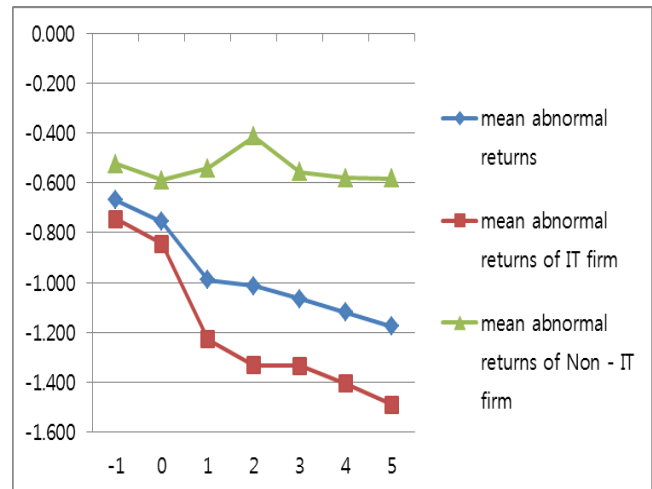


Fig. 1: Trend of Means abnormal returns over elapsed days

The figure 1 shows the mean abnormal return values of whole samples, IT firm’s samples and non-IT firm’s sample over the day -1 to day +5. The trend of mean abnormal returns of whole sample is a significant decline.

We conducted t-test on Abnormal Return classified by day to find out the statistical significance of the each day. A null hypothesis for our t test is as follow:

H_0 : The abnormal returns are not significantly different from zero.

Day	Mean abnormal returns	T	P-value	Cumulative mean abnormal returns
day-1	-0.669	-2.130	0.043**	-2.008
day0 (event day)	-0.756	-2.217	0.036**	-2.764
day1	-0.990	-2.607	0.015**	-3.754
day2	-1.014	-2.586	0.016**	-4.768
day3	-1.065	-2.760	0.011**	-5.833
day4	-1.120	-2.413	0.023**	-6.953
day5	-1.176	-2.360	0.026**	-8.128

Table. 4 Abnormal Returns with One Sample T-test
 **: this represents significance at the 0.05 level

T-TEST RESULT									
	IT firm			Non IT firm			All samples		
Day	Mean CAR	p-value	t-value	Mean CAR	p-value	t-value	Mean CAR	p-value	t-value
-1	-0.746	0.122	-1.633	-0.276	0.362	-0.967	-0.583	0.044**	-2.363
0 (event day)	-1.590	0.114	-1.673	-0.866	0.176	-1.485	-1.339	0.010**	-3.069
1	-2.816	0.067**	-1.968	-1.406	0.163	-1.536	-2.328	0.007**	-3.918
2	-4.148	0.053**	-2.086	-1.820	0.171	-1.505	-3.342	0.001**	-3.747
3	-5.482	0.045**	-2.170	-2.377	0.169	-1.512	-4.407	0.008**	-3.487
4	-6.888	0.043**	-2.204	-2.957	0.168	-1.515	-5.527	0.009**	-3.027
5	-8.377	0.042**	-2.216	-3.540	0.170	-1.513	-6.703	0.011**	-2.860

Table. 5 One Sample Test result on CAR

** : this represents significance at the 0.05 level

Table 4 contains the test result. Table 4 shows that personal information breaches have negative impacts on firms' values in the Korean stock market, and make an impact on the day before an event day.

This mean that the stock market reacts to information breaches beforehand. This mean that the stock market reacts to information breaches before they occur. Negative values also appeared up to day 5.

Also we conducted t-test on cumulative abnormal return (CAR) classified by day. A null hypothesis for our t test is as follow:

H_0 : The cumulative abnormal returns $_{i,t}$ are not significantly different from zero.

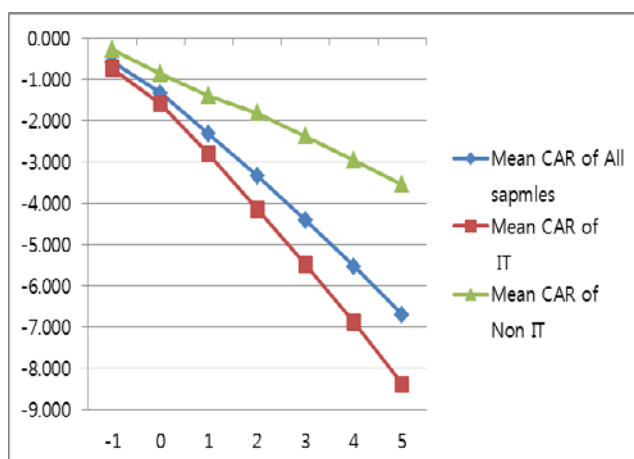


Fig. 2: Trend of Means CAR over elapsed days

Test result is in the table 5. Table 5 presents that personal information breaches seem to have a negative impact on a firm's market value in Korean stock market during window days (day -1 – day 5). Also figure 2 shows the mean cumulative abnormal return (CAR) by industry type over elapsed days after reports of personal information breaches (t_1 : -1.. 5).

We could confirm that Mean CARs IT firms, Non IT firms and all samples show a significant decline in figure 2. Especially IT firm's sample has most significant decrease trend.

However p-value of Non IT firm samples' CAR are not significant in all elapsed days (t_1 = -1.. 5). We are guessing that the reason is a small sample size (sample size is 9). IT firm samples are significant from days 1 to day 5.

Through these results we could verify hypothesis H1, that there is a negative abnormal return when a personal information breach is announced.

To address our second hypothesis, H2, that the magnitude of the negative cumulative abnormal return will be different between IT and Non-IT Industries, we carried out independent sample t-test on CAR of sample of IT and Non IT industries because sample size of IT and Non IT firms are different.

A null hypothesis for our independent sample t test is that there is no difference in mean values of CAR between IT firms and Non IT firms.

The result of test is in the table 6 down below.

Independent Sample T Test Result		
Day	p-value	t-value
-1	0.008**	1.062
0	0.159	-.022
1	0.105	-1.706
2	0.000**	-2.692
3	0.000**	-3.319
4	0.000**	-3.832
5	0.000**	-3.950

Table. 6 Result of cumulative mean abnormal returns with independent sample t test on IT and Non IT firms' sample.

** : this represents significance at the 0.05 level

We found statistically significant support for difference between IT and Non IT industries. Table 6 is the result of the independent sample t test. Table 6 shows that the mean CAR of IT and Non IT samples are different during the period from day 2 to day 5. Moreover p-values are very good in this analysis. Also day before the breaches occurred is significant too.

As the result we verify that the magnitude of the negative CAR is different between IT and Non-IT Industries during the period from day 2 to day 5. Also we expect that IT industries are more sensitive of personal information breaches in South Korean stock market than Non – IT industries.

V. CONCLUSION

Relationship between firms' market values and security issues has been studied to estimate the costs of security incidents and the benefits of security investments. Previous studies in South Korea have shown that information security breaches affect the firms' values in the stock market. Most related studies focused on all types of security incident. However each type of security incidents has different characteristics. Especially, personal information breaches which occurred in firms are directly related to customers.

Therefore, we investigate the effects of personal information security breaches on firm's market value and the difference between the IT and non-IT industries by using the event study methodology. We collected the data about personal information breach events which occurred from 2004 to August 2013.

As the result of study, we found that information security breaches have an effect on the firm's value from the day before breaches occurred to day after five days. This effect is statistically significant and negative. We also found that the magnitude of mean CAR(cumulative abnormal return) is

statistically different between IT and Non-IT Industries during the period from days 2 to day 5. However it is true that our sample size of Non IT is somewhat small. We are

Our study result suggests that IT firms seem to be more affected by personal information breaches than Non IT firms. Consequently stock investors probably think that personal information security is more critical situation for the IT firms than Non IT firms.

Therefore we plan to gather more sample data about information security events. We will try to analyze in various ways by using large sample sizes. After finding more significant results, we will compare with other previous studies conducted in other countries.

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