The Effect of Information Security Incidents on Corporate Values in the Japanese Stock Market

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Abstract

We investigated the economic effects of newspaper reports of information security incidents on corporate values in the Japanese stock market. We found a different trend of effects in terms of reaction speed in the Japanese stock market compared with the US market. The reaction to news reports of the incidents is slower in the Japanese stock market than in the US market. We found statistically significant reactions in around 10 days after the news reports.

We also found a new factor, i.e. PBR (Price Book-value Ratio), has more impact to the corporate market values than incident type, firm type or firm size. Corporate investments on information security are highly evaluated as intangible assets in the stock market especially for IT-oriented firms. PBR represents a kind of a measure how much intangible assets are evaluated in the market compared with net (tangible) assets. Our result suggests that firms whose intangible assets are highly evaluated suffer from the security incidents more severely than those whose intangible assets are evaluated smaller.

Keywords: Information Security Investment, Intangible Assets, Event-Study, Capital Market Valuation, Empirical Analysis

1 Introduction

While information technologies have increased corporate productivity and corporate market values[5], they in turn posed great threats for corporations of being attacked via networks or suffered from failures of business operations. It is said that costs to establish the right security measures at the outset is far less than the costs to recover from a security incident[9]. In order to assess the benefit of information security investments, it is strongly demanded to estimate the costs caused by information security incidents. Although it is difficult to directly quantify the costs associated with security incidents, it is possible to indirectly estimate the costs based on the capital market valuations of corporations. There are several researches investigated the effects of information security incidents in terms of firm types or incident types on the basis of stock market valuations[10, 3, 7, 8, 1] as described in Section 2

We investigated trends of market response to news reports of information security incidents in the Japanese stock market. We found a different trend of response in terms of speed in the Japanese stock market compared with the US market. The response to news reports of the security incidents is slower in the Japanese stock market than US market. We found significant reactions in around 10 days after the news reports.

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We also found new factors such as PBR (Price Book-value Ratio) and article size (i.e. the number of characters in a newspaper article) have large impact to the firms' market values. Information security investment is highly evaluated as intangible assets in the stock market especially for IT-oriented firms[6, 15, 20]. PBR represents a kind of a measure how much intangible assets are validated in the market compared to net assets. Our result suggests that firms whose intangible assets are highly evaluated are much affected by the security incidents than those whose intangible assets are evaluated smaller. Article size of the security incidents may be considered to indicate criticality of incidents, because the more critical the incident is, the larger the article size tends to be. Our result indicates an article size is another important factor to estimate the cumulative abnormal stock returns.

The reminder of this paper is as follows: In Section 2, we review the related researches. In Section 3, we present the methodology for impact analysis based on event-study method in consistent with previous research. In Section 4, we describe the sample selection and present analysis results. In Section 5, we provide implications of our analysis result. Finally we conclude our study in Section 6.

2 Related Research

We review the related researches from the following viewpoints: 1) Effect of information security incidents on the basis of stock market valuation, 2) Effect of information security investments on intangible assets.

2.1 Effect of Information Security Incidents on Corporate Values

Effects of information security incidents in terms of incident types, firm types, date of announcements have been investigated and the support for statistically significant impacts to the corporate values in the US market were provided. Ettredge et al. investigated the stock market reaction to the February 2000 DoS attacks and found Internet firms suffered market reactions more severely than traditional firms[10]. Bharadwaj et al. studied the impact of announcements of IT failures and found a significant drop in the market value of firms[3]. Campbell et al examined the stock market reactions to newspaper reports of information security breaches and found significant negative market reactions for information security breaches involving unauthorized access to confidential data[7]. Cavusoglu et al. conducted a large-scale examination of the effects of security breaches on capital markets. They investigated the effect of firm type, firm size and year the breach occurred to the market reaction and found that breach cost is higher for Internet firms than conventional firms, and that breach cost increased during the study period, and that security breaches are costlier for smaller firms than larger firms[8]. Acquisti investigated the impact of company's privacy incidents on its stock market. They showed negative and significant impact of data breach on company's market value on the announcement day for the breach[1].

Comparative analyses between the effects in the US market and in other countries markets still remained to be investigated.

2.2 Effect of IT Investments on Intangible Assets

The effect of information technology investments on corporate productivity and corporate values has been investigated. Bharadwaj et al. examined the association between IT investments and firm performance by using Tobin's q, a financial market-based measure of firm performance. They showed that the IT expenditure has a significantly positive association with Tobin's q and discussed the relationship between Tobin's q and intangible capital values.[4]. Brynjolfsson et al. explored the effect of computerization on productivity and output growth and found the computerization makes a contribution to measured productivity and output growth in the short term. They also showed the financial markets put a higher value on intangible assets related to IT investments[5, 6]. Tanaka showed information security investments to intangible assets such as process managements and security training significantly improve the level of corporate information security[20].

It still remained to be investigated that the relationship between the amount of intangible assets in the corporate market values and the effect of information security incidents.

3 Methodology

The event-study methodology is used to assess the impact of news reports of information security incidents on capital markets. This method seeks to determine the effect of events based on the stock prices of firms on the market. It has been employed extensively in the finance literature to investigate the impacts of various kinds of events[8].

To estimate the effect of the news reports of information security incidents, we first estimate what the return of the stock would have been if the event had not occurred, which is called the normal return. In the event-study method, the normal returns are usually estimated by using the following liner model in consistent with the capital asset pricing model (CAPM)[16, 17]:

$$R_{i,t} = \alpha_i + \beta_i R_{m,t} + \epsilon_{i,t}, \tag{1}$$

where $R_{i,t}$ is the return of firm i on day t; $R_{m,t}$ is the return of the market portfolio on day t; α_i and β_i are the model parameter representing intercept and slope respectively for firm i; $\epsilon_{i,t}$ is a disturbance term of the firm i on day t.

We use 120-day stock market data of each firm i and the market return data corresponding to the industry that the firm i belongs. We use the Tokyo Stock Price Index of each industry for $R_{m,t}$ in Equation (1) to improve the estimation accuracy than using the market index of all industries.

The coefficient estimates, $\hat{\alpha}_i, \hat{\beta}_i$, from regression of Equation (1) are used to predict the expected return. We are then able to calculate the abnormal returns as follows which represent the deviations of realized return from normal returns.

$$AR_{i,t} = R_{i,t} - \left(\hat{\alpha}_i + \hat{\beta}_i R_{m,t}\right). \tag{2}$$

Assuming that abnormal returns are independent of time, for firm i, the cumulative abnormal return (CAR) is calculated as the sum of individual abnormal returns over the event window $[t_1, t_2]$ as follows:

$$CAR_{i,t_1} = \sum_{t=-1}^{t_1} AR_{i,t} \tag{3}$$

In order to capture the market reaction due to information leakage, we include the day before the newspaper report i.e. summation starts from $t = -1$. In the Japanese stock market, we often observe reaction to incident news reports emerge gradually in a few weeks as is reported in the several research[14, 13], we analyzed longer windows ranging from $t_1 = 0 \cdots 38$ in stock market operation days.

We conduct following two kinds of analyses using CAR_i as an impact measure of incidents: tests of population means, and tests of regression.

Test of Population Mean

We conduct t-test on population mean by sample CAR_{i,t_1}'s to assess the statistical significance of the abnormal returns for several subsets of incident samples classified by incident types or firm types. A null hypothesis for our test is defined as follows:

H_0 There is no stock market reaction to news reports of corporate information security incidents for the target class of samples.

In order to assess the difference between the effect of incident types and firm types, we select subsets of samples specified by these types and carry out t-test on these subset samples. For example, we extract samples of incidents involving leakage of confidential information to assess significance of this type of incidents. We use this test of population mean in the analyses in Section 4.2 and Section 4.3.

Test of Regression

In order to assess the linear relationship between CAR_{i,t_1} and several factors such as PBR, size of articles in the newspapers (we call this “article size”) or firm size, we conduct multiple linear regression with the following model:

$$CAR_i = \beta_0 + \beta_1(PBR)_i + \beta_2(ArticleSize)_i + \beta_3(FirmSize)_i + \beta_4(OtherFactor)_i + \cdots + \epsilon_i, \quad (4)$$

where $\beta_0, \beta_1, \beta_2, \cdots$ are regression coefficients; ϵ_i is disturbance term. Statistical significance of explanatory variables can be assessed by p-value of the regression coefficients. We use the test of regression in the analyses in Section 4.5.

4 Analyses

4.1 Sample Selection

We extracted incidents from articles in the Japanese four major economy and financial newspapers Nippon Keizai Shinbun, Nikkei Sangyo Shinbun, Nikkei Ryutsu Shinbun, Nikkei Kinyu Shinbun, which are the most influential newspapers for investors in Japan. In order to avoid bias of sample selection, we adopted all the incidents in the articles obtained by online searching with the Japanese keywords corresponding to the following English words in the period from September 2002 to August 2005:

information, incident, damage, trouble, leak, intrusion, virus.

This search resulted in 923 articles. 70 incidents were identified from this search results by eliminating articles which are not incident reports such as announcement of IT security systems installation in organizations or those of new security technologies. An announcement that contains news about incidents of multiple corporations is counted as announcements of multiple events.

Table 1 presents descriptive statistics for reported 70 incidents[1]. "Std. dev." means a standard deviation. "Num. Employees" is the number of employees, "Sales" is the annual sales, "Capital" is the corporate capital, "PBR" is Price Book-value Ratio.

Table 1: Descriptive Statistics for Reported Incidents (N=70)

	Mean	Median	Std.dev.	Min	Max
Num. Employees	3488.2	1800.0	4946.7	80.0	27832.0
Sales	551705.3	118226.0	1087556.0	4897.0	5645615.0
Capital	168180.4	35565.0	539479.0	500.0	4284376.0
PBR	3.42	1.90	4.66	0.648	29.5
$CAR_{i,1}$	-0.0023	0.00014	0.036	-0.173	0.127
$CAR_{i,10}$	-0.0173	-0.00144	0.111	-0.656	0.154

4.2 Effect of Incident Types

In order to assess the effect of incident reports associated with some type of incident, we set up the following null hypothesis:

H_0^I: There is no stock market reaction to news reports of corporate information security incidents associated with some specific type of incident I in t_1 days after incident reports.

We examined three types of incidents described in Table 2 to test the hypothesis H_0^I. The test is conducted on CAR_{i,t_1} of subsamples classified as in Table 2.

Table 2: Types of Incidents and Sample Classification

Type	Category	Description
Confidential	1	Incidents which caused leakage of confidential information
	0	Otherwise
Availability	1	Incidents which caused information system availability problems
	0	Otherwise
Intrusion	1	Incidents which was caused by system intrusion
	0	Otherwise

[1] There were several firms which suffered two different incidents at different date. Different incident reports of the same firm are counted as different incidents. Table 1 shows statistics on incident basis and not on firm basis.

Table 3: Test Results on Samples by Incident Type ($t_1 = 10$)

Incident type	Num. samples	Mean CAR	p-value	t-value	Test's power	Std. dev.
All incidents	70	-0.0189	0.0801	-1.419	0.0011	0.1116
Confidential=1	28	-0.0225	0.0175	-2.219	0.0001	0.0536
Confidential=0	42	-0.0166	0.2206	-0.778	0.0080	0.1380
Availability=1	6	-0.1092	0.0939	-1.525	0.0014	0.1754
Availability=0	64	-0.0105	0.2067	-0.823	0.0070	0.1017
Intrusion=1	27	-0.0318	0.0486	-1.720	0.0004	0.0961
Intrusion=0	43	-0.0108	0.2796	-0.589	0.0130	0.1206

Table 3 shows the results of the tests for each of subset of samples defined in Table 2 for elapsed days $t_1 = 10$ after incident reports[2]. We carried out tests on CAR_{i,t_1} for every elapsed days $t_1 = 1 \cdots 38$ after news reports, but the results are not significant for fewer elapsed days like $t_1 \leq 6$. The mean CAR_{i,t_1} are significantly negative for some categories in elapsed days around $t_1 = 10$. This result is very different from the previous research carried out for incidents in the US market[8, 7]. They showed significant reaction to incident reports in 1 day after news reports. The slow reaction in the Japanese stock market are also reported in some other research[14, 13]. We examined the relationship between CAR_{i,t_1} and the elapsed days t_1 after news reports in Section 4.4.

In this section, we examine the difference of statistical significance among incident types with respect to the elapsed days $t_1 = 10$. The mean CAR of confidential leakage incidents(Confidential=1) is -0.0225 and statistically significant (p-value= 0.0175). The mean CAR of intrusion incident (Intrusion=1) is -0.0318 and statistically significant (p-value=0.0486). The mean CAR of availability incidents (Availability=1) is not significant[3].

4.3 Effect of Industry Type

In order to assess the effect of news reports classified by the type of industry, we set up the following null hypothesis:

H_0^B: There is no stock market reaction to news reports of corporate information security incidents for some specific type of industry B.

We obtained only few types of industries which have enough number of samples from the total samples. We carried out tests on CAR_{i,t_1} of subsamples of each industry types for elapsed days $t_1 = 1 \cdots 38$.

[2]Although longer time span of CAR (i.e. t_1) after incident reports may include noise factors to abnormal return which are not associated with the incident, this does not affect in favor of statistical significance. Because the larger the noise factor is, the less significant the test would be.

[3]Since the number of availability incidents (Availability=1) is 6 and its test's power is very small (power=0.0014), it might be the case that we could not find the support for significant negative effects because the sample size is too small.

Table 4 shows the results of the tests for elapsed days $t_1 = 10$ for every industry categories[4] which have more than 3 samples. In this case, we also observed that CAR_{i,t_1} is not statistically significant for fewer days after news reports. We examine the relationship between CAR_{i,t_1} and elapsed days in Section 4.4.

The mean CAR of credit card industry is negative (-0.0291) and significant (p-value=0.0426). Though the mean CAR of service industry is negative and significant (p-value=0.0385), the number of samples for service industry is very small i.e. 4. Therefore, the result for service industry is not so confident. We found no statistically significant support for the other industries. P-value for bank is not good in this analysis. The reason for this is that, most of the incident reports are related to accidental discards of the customer informations such as account numbers and customer addresses and it is not likely to be misused by others.

Table 4: Test Results on Samples by Industry Type ($t_1 = 10$)

Industry type	Num. Samples	Mean CAR	p-value	t-value	power	Std. dev.
All industries	70	-0.0189	0.0801	-1.419	0.0011	0.1116
Credit Card	17	-0.0291	0.0426	-1.835	0.0003	0.0654
Services	4	-0.0489	0.0385	-2.650	0.0001	0.0369
Banks	26	-0.0115	0.3400	-0.418	0.0201	0.1395
ICT	7	-0.0882	0.1273	-1.259	0.0027	0.1852
Retail	4	0.0261	0.8617	1.326	0.2726	0.0394

4.4 Relationship between Market Response and Elapsed Days

In order to examine how the speed of the stock market response in the Japanese market is, we investigated the relationship between mean CAR and elapsed days after incident reports.

Figure 1 shows trend of p-values of statistical test on subsamples by incident types and industry type over elapsed days after incident reports ranging from -1 to 38 days. Meanings of the data series labels in the legend in Figure 1 are described in Table 5 and in Section 4.3.

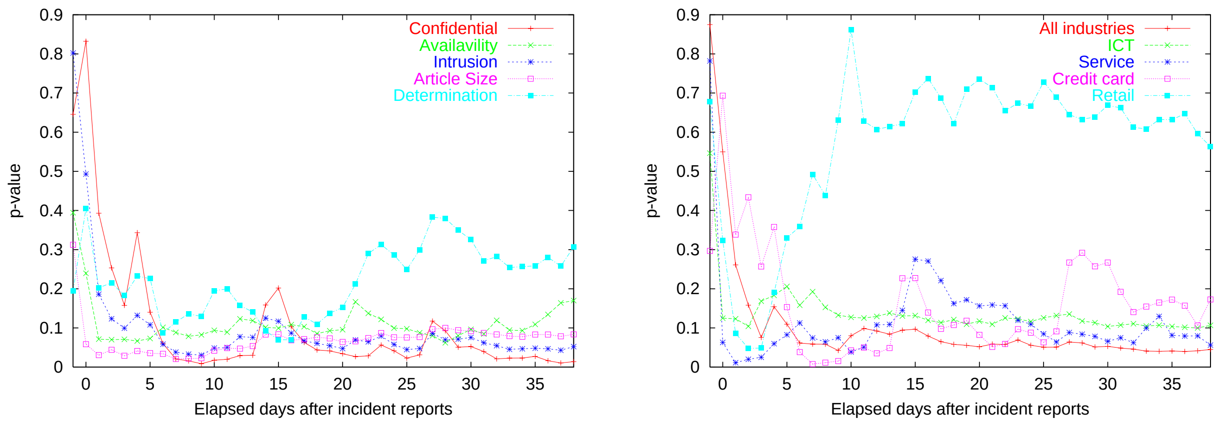
The graph (A) shows the response in the stock market emerges significantly during 6 to 10 days after incident reports. In the analysis conducted on incidents in the US stock markets[8, 7], they evaluated the impact of CAR in three-day window, which correspond to one day after incident reports. Our result suggests the response in the Japanese stock market emerges slower than we expected. The graph (B) shows the responses are significant during 2 to 7 days after incident reports depending on industry. We find service industry including B-to-C e-commerce companies and retail business including convenience stores shows quick response i.e. 1 day or 2 days after incident reports accordingly. These responses resemble to the research in the US market[8, 7].

Figure 2 shows mean CAR by incident types and industry type over elapsed days after incident reports ranging from $t_1 = -1 \cdots 38$. The graph (C) shows variance of mean CAR becomes larger along with the elapsed days after incident reports. This is because various kinds of effects other than incident reports increase along with number of days after events. Since

[4] Industry type is based on the classification specified by Securities Identification Code Committee in Japan. Service industry includes B2C Internet companies, leisure companies etc and excludes credit card companies, banks etc. ICT is the information communication technology companies.

Table 5: Description for subsample classification

Label	Samples	Description
Confidential	28	Incidents which caused leakage of confidential information
Availability	6	Incident which caused information system availability
Intrusion	27	Incidents which was caused by system intrusion
Article Size	32	Incidents whose number of characters in the news article exceeds 400
Determination	27	Correlation coefficients of regression for normal stock estimation model exceeds 0.4



(A) Samples by Incident Type

(B) Samples by Industry Type

Figure 1: Trend of p-values of the test over elapsed days after incident reports.

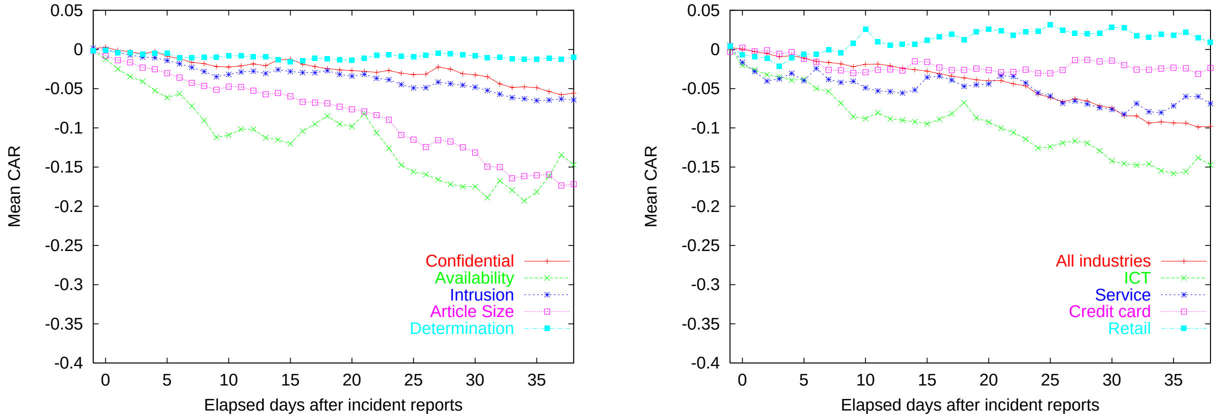
CAR is a estimate of cumulative abnormal return and the effect of market trends is eliminated, mean CAR shows response specific to the samples. However, we should notice that each incident type's p-value of mean CAR in larger elapsed days (i.e. $t_1 = 13 \cdots 38$) is not significant. The graph (D) shows mean CAR classified by industry over the number of days after events ranging from $t_1 = -1 \cdots 38$ days. It also shows variance of mean CAR becomes large along the number of days after incident reports in a similar way as in Figure 2. In this case, mean CAR of retail business recovers soon after decrease in few days.

The graph (C) and (D) show that mean CAR does not recover some time after the impact caused by the incident reports. This presents different phenomenon shown by the analysis[1] in the US stock market.

Though incident type of availability shows the largest decrease in mean CAR, p-value of its test is not significant as is shown in Figure 1.

4.5 Effects of PBR and Article Size

We employ a multiple linear regression model to assess the linear relationship between cumulative abnormal return and some variables associated with firm and news article. We selected explanatory variables from a large set of candidate variables. Table 6 shows the correlation between CAR_{i,t_1} and individual candidate variable.



(C) Samples by Incident Type

(D) Samples by Industry Type

Figure 2: Trends of means CAR over elapsed days after incident reports.

Table 6: Correlations between CAR_{i,t_1} and candidate explanatory variables (N=68)

Classification	Explanatory variables	Samples[1]	Cor.($t_1 = 1$)	Cor.($t_1 = 10$)
Industry (dummy)	Bank	25	0.07	0.05
	Service	4	-0.18	-0.07
	ICT	7	-0.22	-0.21
	Credit Card	16	0.03	-0.04
	Retail	4	-0.05	0.10
Firm	Num. Employees	-	0.05	0.05
	Sales	-	-0.23	-0.31
	Capital	-	-0.10	-0.06
	PBR	-	-0.35	-0.45
Incident (dummy)	Confidential information	27	0.06	-0.01
	Personal information[2]	47	0.18	0.16
	Availability	6	-0.19	-0.26
	Intrusion	27	-0.03	-0.10
Reports	Article Size[3]	-	-0.26	-0.19
	Circulation[4]	-	0.22	0.14
	Article Influence[5]	-	0.02	-0.00
	Date[6]	-	-0.08	-0.08

1 The number of samples whose dummy variable equal to 1.
2 Personal information: An incident type involving leakage of personal information.
3 Article Size: The number of characters of an article in the newspaper.
4 Circulation: Circulation of the newspapers.
5 Article Influence = (Article Size) × (Circulation)/(the page number of the article in newspaper)
6 Date: News report date in the Julius calendar from the first event.

Figure 3 shows the relationship between the number of days t_1 after incident reports and the correlation coefficients between CAR_{i,t_1} and the candidate explanatory variables. It shows the most of the correlations approach to zero after 15 days.

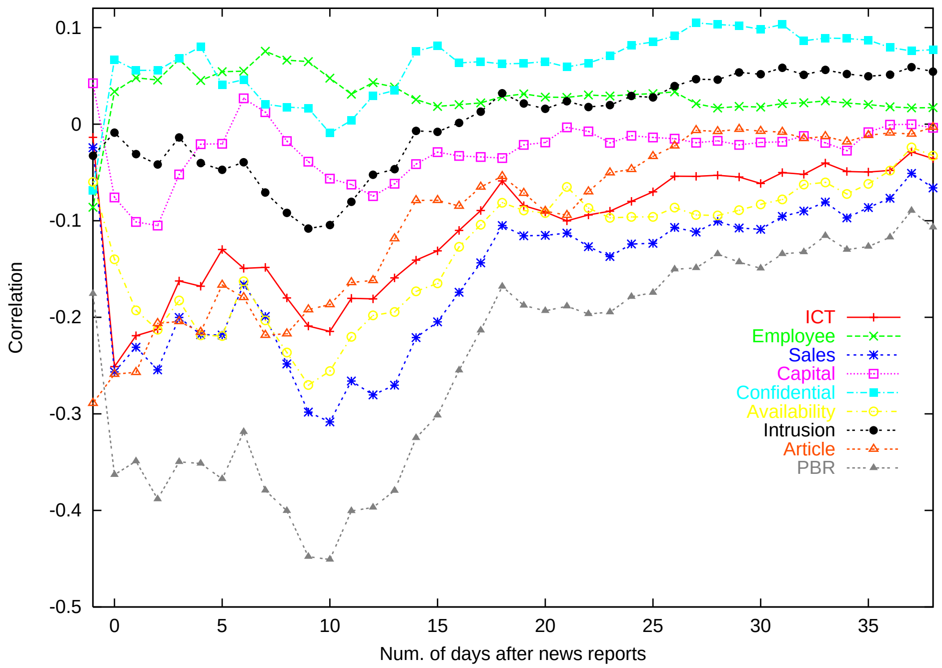


Figure 3: Relationship between the elapsed days and correlation coefficients of CAR and several variables

Based on Figure 3 and Table 6, we assume candidates of major variables which may have much impact to CAR are as follows:

- PBR
- Sales (Firm Size)
- Availability (Incident Type)
- ICT (Industry Type)
- Article Size

Table 7 shows a summary statistics[5] for the qualitative variables from these major variables of the sample data[6].

PBR is considered to be a measure representing the ratio of intangible assets to net (tangible) assets. A firm with large PBR is considered to be highly evaluated of its intangible assets in the market. We presume a firm whose intangible assets are highly evaluated has more impact from news report of information security incident than others. We also presume an article size has much effect on CAR, because the larger the article is, the more serious the incident would be.

[5] In this analysis, we eliminated 2 samples; we eliminated one because we could not obtained PBR and sales data due to its merger into another firm; we eliminated the other one based on the outlier condition that $\sigma \geq 4$. CAR of the latter indicates the largest drop in the samples.

[6] All the coefficients of determination r^2 (i.e. the square of the correlation coefficient) among the variables in Table 7 satisfy the condition that $r^2 < 0.7$ and therefore the effect of multiple colinearlity is considered to be limited. However we should be aware that the correlation coefficient between PBR and Sales is rather large. Therefore we use PBR and Sales separately in our analyses.

Table 7: Summary Statistics for Sample Data (N=68)

				Correlation (p-value)		
Variables	Mean	Median	S.D.	PBR	Article Size	Sales
PBR	3.46	1.93	4.59	1	-	-
Article Size	517.9	369.5	400.0	0.04 (0.14)	1	-
Sales	557650	117506	1094512	0.67 (0.09)	-0.04 (0.10)	1

In order to assess the impact of PBR, we assume the following (alternative) hypothesis:

H_1^P: The cumulative abnormal return due to information security incidents is larger for firms with larger PBR than firms with smaller PBR.

Since the correlation between PBR and Sales is rather large ($r = 0.67$) as in Table 7, we set up the multiple linear regression model defined in Equation (5) and (6) using PBR and Sales respectively[7]

$$CAR_{i,t_1} = \beta_0 + \beta_1(PBR)_i + \beta_2(ArticleSize)_i + \beta_3(IndustryType)_i + \epsilon_i \tag{5}$$

$$CAR_{i,t_1} = \beta'_0 + \beta'_1(Sales)_i + \beta'_2(ArticleSize)_i + \beta'_3(IndustryType)_i + \epsilon_i \tag{6}$$

The null hypothesis corresponding to the hypothesis H_1^P for test on coefficients of regression analysis is as follows:

H_0^P: The coefficient of PBR in the regression equation 5 is no less than zero.

Table 8 presents the results of regression analyses for the equation (5) for elapsed days $t_1 = 1$ and 10 respectively. The overall model is significant for both results ($F = 10.3, p = 0.000$ and $F = 24.7, p = 0.000$, respectively).

The coefficient of PBR is negative and significant ($\beta_1 = -0.0258, p = 0.0004$ for $t_1 = 1$ and $\beta_1 = -0.01084, p = 0.0000$ for $t_1 = 10$), indicating null hypothesis H_0^P is rejected.

Table 9 shows the results of regression analyses for the model (6). For the case of $t_1 = 10$, Adjusted R^2 drops dramatically from 0.515 to 0.315 suggesting PBR has much impact than Sales. These regression analyses and preliminary correlation analyses in Figure 3 and Table 6 suggest that PBR has much impact to CAR than Firm Size (Sales), Industry Type (ICT), Incident Type (Availability) etc.

The coefficient of Article Size is also negative and significant in all the regression results in Table 8 and Table 9. We could not find evidence for linear relationship between Industry type (i.e. ICT industry) and CAR in this analysis.

[7] We carried out multiple regression analyses several times using the aforementioned major variables and we found that Availability (Incident Type) variable does not have better impact to CAR when it used with other variables together. Therefore we eliminated Availability variables in the models.

Table 8: Results of Regression using PBR Variable

(1) Elapsed days ($t_1 = 1$)

Coefficients	Estimate	Std. Error	t value	p value
PBR	-0.00258	0.000688	-3.76	0.0004
ArticleSize	-0.00002	0.000008	-2.85	0.0058
Industry=ICT	-0.01444	0.010557	-1.37	0.1761
(Intercept)	0.02192	0.005430	4.04	0.0001

$N = 68$, $R^2 = 0.326$, Adjusted $R^2 = 0.294$
F-statistic= 10.3, p-value=0.0000137

(2) Elapsed days ($t_1 = 10$)

Coefficients	Estimate	Std. Error	t value	p value
PBR	-0.01084	0.001535	-7.06	0.0000
ArticleSize	-0.00005	0.000017	-2.77	0.0074
Industry=ICT	-0.03307	0.023565	-1.40	0.1654
(Intercept)	0.05748	0.012120	4.74	0.0000

$N = 68$, $R^2 = 0.536$, Adjusted $R^2 = 0.515$
F-statistic= 24.7, p-value=0.000000

Table 9: Results of Regression using Sales Variable

(1) Elapsed days ($t_1 = 1$)

Coefficients	Estimate	Std. Error	t value	p value
Sales	-0.00000	0.000000	-2.40	0.0192
ArticleSize	-0.00002	0.000008	-2.88	0.0053
Industry=ICT	-0.01920	0.011100	-1.74	0.0873
(Intercept)	0.01840	0.005600	3.29	0.0016

$N = 68$, $R^2 = 0.245$, Adjusted $R^2 = 0.21$
F-statistic= 6.92, p-value=0.000415

(2) Elapsed days ($t_1 = 10$)

Coefficients	Estimate	Std. Error	t value	p value
Sales	-0.00000	0.00000	-4.09	0.0001
ArticleSize	-0.00005	0.00002	-2.65	0.0100
Industry=ICT	-0.05260	0.02770	-1.90	0.0624
(Intercept)	0.04310	0.01400	3.08	0.0031

$N = 68$, $R^2 = 0.346$, Adjusted $R^2 = 0.315$
F-statistic= 11.3, p-value=0.000005

5 Discussion

Response to the incident reports in the Japanese stock market is slower compared with the US market. While the analyses results on the US market[8, 7] show the significant negative impact in one day after incident reports, our results in Figure 1 and 3 suggest the response in the

Japanese market is the most significant in around 10 days after incident reports. One possible explanation for this time lag in the Japanese market is that investors in the Japanese market were uncertain about the amount of economic loss caused by the incidents in the period of the incidents and they gradually realized the effect of the incidents as they repeatedly read and listen the news in the following days after first announcements[8]. However if we pay attention to the coefficient of Article Size in the regression analyses in Table 8 and Table 9, it is suggested that incidents have impact to CAR also in the Japanese market soon after the incident reports, if the level of information disclosure of the incidents is relatively high.

We found new explanatory variables PBR and article size that have much impact on CAR. Though PBR is associated with stock price, it does not bind the amount of change of the stock price before and after the incident report. The PBR is some sort of a measure of a firm at certain time (date), whereas CAR represents a ratio of difference of stock prices before and after the incident. Therefore there is no essential constraints between PBR and CAR. PBR is neither associated with firms' aggregated market values nor firm size, because PBR is generally independent of scale of firms' business, but rather PBR is associated with performance of capital. We obtained PBR data at certain date after incident reports, but the best option is to use PBR just before the date of incident reports. Still we obtained the good support which indicates PBR is much better factor to explain the effect of the information security incidents.

Article size is considered to be associated with criticality of the incidents. The more critical the incident is, the more area in the newspaper is used to announce the incidents. Therefore article size would be considered as a proxy variable for criticality of incidents.

We carefully treated the effects of correlation among explanatory variables in the regression analyses, but any variables associated with a firm inevitably have correlations each other. We investigated several combinations of explanatory variables which have significant effect on CAR. Exploration of new factors which have impact on CAR and optimization of explanatory variable set of the regression model would be beneficial to improve the accuracy of analyses and estimation.

6 Conclusion

We investigated economic effect of newspaper reports of information security incidents on corporate value in the Japanese stock market. We found a different trend of response in terms of speed in the Japanese stock market compared with the US market. We found significant reactions in around 10 days after the news reports.

We also investigated new factors such as PBR and article size that may have impact to CAR and found that PBR has more impact to the firms' market values than firm type or firm size. Corporate investments on information security are highly evaluated as intangible assets in the stock market especially for IT-oriented firms. Our result suggests that firms whose intangible assets are valuated larger are much affected by the security incidents than those whose intangible assets are valuated small. Article size of security incidents may be considered to indicate criticality of incidents, because the more critical the incident is, the larger the article size tends to be. Our result indicates article size is an important factor to estimate cumulative abnormal stock return.

[8] We should also notice that since the most of the incidents in the samples in this research were reported in the newspaper on weekend or after stock market close time, it made the effect in the stock market to appear at least in one-day later.

References

[1] Alessandro Acquisti, Allan Friedman, and Rahul Telang. Is there cost privacy breaches? an event study. In *The 5th Workshop on the Economics of Information Security*, 6 2006.

[2] R. Anderson. Why information security is hard: An economic perspective. In *Proceeding of 17th Annual Computer Security Applications Conference (ACSAC)*, New Orleans, Louisiana, 2001.

[3] A. Bharadwaj and M. Keil. The effect of information technology failures on the market value of firms: An empirical examination. In *INFOMS*, 2001.

[4] AS Bharadwaj, S.G. Bharadwaj, and B.R. Konsynski. Information technology effects on firm performance as measured by tobins's q. *Management Sceience*, 45(7):1008–1024, 1999.

[5] Erik Brynjolfsson and Lorin M. Hitt. Computing productivity: Firm-level evidence. *The Review of Economics and Statistics*, 85(4):793–808, November 2003.

[6] Erik Brynjolfsson, Lorin M. Hitt, and Shinkyu Yang. *Intangible Assets: Computers and Organizational Capital*. Brookings Papers on Economics Activity, 2002. 137–181.

[7] Katherine Campbell, Lawrence A. Gordon, Martin P. Loeb, and Lei Zhou. The economic cost of publicly announced information security breaches: Empirical evidence from the stock market. *Journal of Computer Security*, 11:431–448, 2003.

[8] Huseyin Cavusoglu, Birendra Mishra, and Srinivasan Raghunathan. The effect of internet security breach announcements on market value: Capital market reactions for breached firms and internet security developers. *International Journal of Electronic Commerce*, 9(1):69–104, 2004.

[9] CSC(Computer Science Corporation. Csc survey reveals inadequate information security practices among companies worldwide (november 19,2001).

[10] M. Ettredge and V.J. Richardson. Assessing the risk in e-commerce. In Jr. R.H. Sprague, editor, *Proceeding of the Thirty-fifth Hawaii International Conference on System Science*, Los Alamitos, CA, 2002. IEEE Computer Society Press.

[11] L.A. Gordon and M.P. Loeb. The economics of information security investment. *ACM Transactions on Information and System Security*, 5(4):438–457, 2002.

[12] Computer Security Institute. 2004 csi/fbi computer crime and security survey. http://www.gocsi.com/, 2004.

[13] InterRisk Research Institute & Consulting, Inc. Analysis of risk events appeared in the fiscal year 2004. Working report.

[14] Japan Network Security Association (JNSA). A Report on Information Security Incidents in the Fiscal Year 2004 (In Japanese). http://www.jnsa.org/active/2004/active2004_1a.html.

[15] Baruch Lev. *Intangibles: Management, Measurement, and Reporting*, chapter 1. Brookings Inst Pr, 2001.

[16] Willam F. Sharpe. Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance*, 19:425–442, 1964.

[17] Willam F. Sharpe. Factor models, capms, and the apt. *Journal of Portfolio Management*, pages 21–25, 1984.

[18] Willam F. Sharpe. Capital asset prices with or without negative holdings. *Journal of Finance*, 1991.

[19] Mani Subramani and Eric Walden. The impact of e-commerce announcements on the market value of firms. *Information Systems Research*, 12(2):135–154, June 2001.

[20] Hideyuki Tanaka. Information security as intangible assets: A firm level empirical analysis on information security investment. *Bulletin of The Graduate School of Interdisciplinary Information Studies, The University of Tokyo*, 69:123–136, 2005.