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Toshihiko Takemura
Makoto Osajima
Masatoshi Kawano

RCSS

文部科学大臣認定　共同利用・共同研究拠点
関西大学ソシオネットワーク戦略研究機構
関西大学ソシオネットワーク戦略研究センター
（文部科学省私立大学学術フロンティア推進拠点）

Research Center of Socionetwork Strategies,
The Research Institute for Socionetwork Strategies,
Kansai University
Suita, Osaka, 564-8680 Japan
URL: http://www.rcss.kansai-u.ac.jp
http://www.socionetwork.jp
e-mail: rcss@jm.kansai-u.ac.jp
tel: 06-6368-1228
fax. 06-6330-3304

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Toshihiko Takemura* ,
The Research Institute for Socionetwork Strategies,
Kansai University,
Makoto Osajima† ,
The Global Information and Telecommunication Studies,
Waseda University,
Masatoshi Kawano‡
The Ministry of Internal Affairs and Communications

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Abstract

This paper discusses a statistical analysis to quantitatively grasp the relationship among information security incidents, vulnerability, and information security countermeasures by using data based on a 2007 questionnaire survey for Japanese ISPs (Internet Service Providers). To grasp the relationships, we use logistic regression analysis. Our results clarify that there are relationships between information security incidents and information security countermeasures. There is a positive relationship between information security incidents and the number of information security systems introduced as well as a negative relationship between information security incidents and information security education. We also point out that (especially, local) ISPs do not execute efficient information security countermeasures/investment concerned with systems, and we suggest that they should positively execute information security education. In addition, to further heighten the information security level of Japanese telecommunication infrastructure, we insist on the necessity of the government to implement policy to support the countermeasures of ISPs.

KEYWORDS: information security countermeasures, information security incidents, internet service providers, positive analysis

JEL CLASSIFICATION: C35, D21, L86

*Corresponding author. e-mail:takemura@rcss.kansai-u.ac.jp. Assistant professor of the Research Institute for Socionetwork Strategies and research fellow, Research Center of Socionetwork Strategies, Kansai University

†e-mail: osajima@aoni.waseda.jp. Visiting associate professor of Graduate School of International Telecommunications Studies, Waseda University

‡e-mail: m-kawano@soumu.go.jp. The Ministry of Internal Affairs and Communications

1 Introduction

Information and Communication Technology (Abbreviation, ICT) including the Internet, improves the productivity of firms, and creates new businesses. ICT provides a positive impact to society and the economy [1], [2]. On the other hand, according to an information security white paper 2008 [3], serious problems have also occurred at the same time. These problems are caused by Internet threats such as illegal access, malware, Spam mails, and system troubles. Many accidents caused by these incidents are reported all over the world. These threats evolve hour by hour every day and increase rapidly. Moreover, vulnerability (chiefly, in Web application) has increased every year. Therefore, firms and individuals are exposed to those threats. Although secured networks, or NGNs (Next Generation Networks or New Generation Networks) have appeared recently, information security countermeasures against these threats must be executed because the Internet has no security of its own.

As academic research in the field of natural science, much research on information security as technology (cryptographic technology and secured networking) exists. This accumulated information achieves a constant result. However, Internet threats evolve minute by minute every day. Management tries to support workers against these threats, but more research is needed. Unfortunately, research in the social sciences about how management can avoid these threats is still limited, and still exploratory. The majority of research is theoretical and uses the framework of game theory, and empirical research is limited. We believe that many scholars are not interested in empirical research because of scant data on information security countermeasures/investment[1].

In this paper, we focus on telecommunication infrastructure, especially in Internet Service Providers (Abbreviation, ISPs) that provide an Internet environment for users[2]. Considering the ISPs influence on society and the economy, the level of information security countermeasures is not necessarily uniform. In other words, we believe that the level of information security countermeasures in critical infrastructures should be set higher than in general firms [4], [6][3]. We quantitatively explain the relation among information security incidents, vulnerability, and the information security countermeasures of ISPs, and we suggest effective countermeasures. To achieve this purpose, we use the results (micro data) of the questionnaire survey we conducted in 2007, and logistic regression analysis as the statistical method.

Recently, however, many countries, including Japan, have begun to gather data and analyze them on information security incidents because they recognize that this kind of research is important. In Japan, the Information Security Measures Promotion Office was established in the IT strategy headquarters of the Cabinet Secretariat in 2001, and the office has worked on security policy. This policy was promoted further by the reestablishment of the NISC (National Information Security Center) in 2005. Every year, the NISC implements a new national information security policy package called "Secure Japan". In [9], "accident assumption society" are keywords, which stand for accidents that happen in the Internet society, and what information

[1]It seems that the majority of firms might not disclose the information security countermeasure and the investment even if the data exists.

[2]Refer to [4], [5] for investigation and research on Japanese ISPs.

[3]Some research exists on the layer of the infrastructure and its interdependent relationship [7],[8]. In particular, the telecommunication infrastructure discussed in this paper is a critical infrastructure following the electric power infrastructure. Critical infrastructure includes the following fields; telecommunications, finance, airlines, railways, electric power, gas, government and administrative service (including the local public entity), medical treatment, water service, and distribution.

security policy the government should implement is discussed.

In addition, since 2007, there is a project of the Cyber Clean Center (Abbreviation, CCC), which MIC (the Ministry of Internal Affairs and Communications) and METI (the Ministry of Economy, Trade and Industry) in Japan has been set up to coordinate measures against bot threats. The project gathers information on bots, and suggests countermeasures. Nippon Information Communications Association gathers the information on Spam mails, and suggests the countermeasures as correspondence to Spam mails. These organizations have achieved constant effects. The Information-technology Promotion Agency also provides various information analyses and enlightening activities on security as well as Japan (Abbreviation, IPA), the Japan Vulnerability Notes (Abbreviation, JVN), the Japan Network Security Association (Abbreviation, JNSA), and the Japan Computer Emergency Response Team Coordination Center (Abbreviation, JPCERT/CC). Thus, in Japan, academic investigation is still rare although the accumulation of surveillance study data has advanced.

This paper consists of the following sections. Section 2 introduces related literatures. Section 3 explains logistic regression analysis and the data sets used in this paper. In Section 4, we show the estimation results. Finally, we present a summary and future work in Section 5.

2 Related Literatures

In this section, we briefly introduce related works on information security in the fields of social science. We classify three types of the related works and discuss Tanaka and Matsuura's work [10].

The first type of related work models the relations among information security incidents, information security countermeasures/investment from the viewpoint of economics and management science. Theoretical representative research includes models of Gordon and Loeb, and Varian [11], [12]. In the former, the economic effect of information security investment is theoretically analyzed, and the latter discusses the free rider problem by analyzing the information security system as public goods[4]. Under these frameworks, there are some positive analyses [6], [15], [16].

The second type of related work models the relations between the value of the firm (market value) and information security investment/countermeasures from the viewpoint of economics and management science. The representative model is the market value model of Brynjolfsson, Hitt and Yang [1] applied to information security investment instead of ICT investment. For example, Tanaka [17] carry out positive analysis using their framework, and Nagaoka and Takemura [18] discuss a new type of model from the viewpoint of BCP (a Business Continuity Plan). Moreover, in recent years many firms have paid pay attention to the information security report based on this model.

The third type of related work calculates the amount of damage and influence to economy using the frameworks of economics, business administration, and law. For instance, JNSA calculates the amount of compensation when information leakage was caused [19]. References [20]-[24] calculate the amount of GDP loss caused by Spam mails in Japan.

[4]References [13] and [14] enhance the model in Gordon and Loeb [11].

3 Framework

3.1 Model

The purpose of this paper is to clarify quantitatively the relationships among information security incidents, information security countermeasures, and vulnerability. By clarifying the relationships, we can discuss which factors reduce the risk that ISP s will encounter information security incidents. In other words, we provide suggestions about what efficient countermeasures are available.

For a long time, logistic regression (or multiple logistic regression) has been widely used as a statistical method for grasping the relationships among explanatory variables and explained variables in various fields such as psychology, sociology, economics, and business administration. In logistic regression, an explained variable is a probability that a certain event happens p, and explanatory variables are co-variables that influence p. Note that p follows logit distribution, $\mathrm{logit}(p) = \log(p/1-p)$.

In this paper, we use a logistic regression and build our model. We build the model showing which factors such as vulnerabilities and information security countermeasures influence the risk that ISPs encounter in information security incidents. The relationship is described by using equation (1).

$$\log(p_j/1-p_j) = a + b_V X_V + b_C X_C + cZ_C, \tag{1}$$

where p_j represents the probability that ISPs encounter information security incident j, and X_V, X_C and Z_C represent vulnerability, information security countermeasure, and characteristics of ISPs, respectively.

The explained variable on the left side of equation (1) represents a logarithm odds ratio. This can be interpreted as one of the risk indices[5]. Also, the coefficient parameter of each explanatory variable on the right side represents a logarithm odds ratio when the explanatory variable increases one unit. For example, this increase implies that the risk that ISPs encounter information security incident j becomes $\exp[b_V]$ times when X_V increases one unit.

By using this model, we can discuss which countermeasures ISPs can use to reduce the risks that they encounter from an information security incident. At the same time, we can evaluate the risk that each ISP faces.

Combining vulnerability with various threats such as artificial mistakes creates the risk that a user may encounter as an information security incident. Vulnerability is one of the factors that raise risk. This implies that the coefficient parameter of X_V in equation (1) is positive; $b_V > 0$.

Generally, information security countermeasures are executed to reduce the risk that a user encounters an information security incident. Therefore, the coefficient parameter of X_C in equation (1) is negative; $b_C < 0$. We assume that information security countermeasures are roughly divided into technical information security countermeasures and non-technical information security countermeasures. The former introduces and operates various information security systems, and the latter manages countermeasures such as information security education and reminder of information security incident to users. In this paper, we focus on two kinds of information

[5]An odds ratio is a statistical measurement showing the odds of an event occurring in one group to the odds of it occurring in another group.

security countermeasures, and we see the effects of both. We are particularly interested in countermeasures concerned with management.

We use the difference of areas providing service as characteristics of ISPs. The reason for different areas is the differences in the financial health between local ISPs and nationwide ISPs, as discussed in Section 2. We assume that the possibility of differences causes the difference of the risks encountered by information security incidents[6].

Finally, we introduce methods and processes to estimate coefficient parameters in equation (1), and to evaluate the fitness of our model.

To estimate each coefficient parameter in equation (1), we use the general maximum likelihood estimation method based on a binominal distribution. Because calculating the estimation is too complex, we use SPSS as a statistical computer software in this paper[7]. SPSS has a) a method by compulsion inserting explanatory variables, b) a variable increase (decrease) method by likelihood ratio, c) a variable increase (decrease) method by Wald, and d) a conditional variable increase (decrease) method as a method of variable selection. From these methods, we apply the variable increase (decrease) method by likelihood ratio as a method of variable selection in this paper. This method is often used as one of the most preferable indices.

Next, we run the Hosmer-Lemeshow test to evaluate the fitness of our model. Note that the null hypothesis of this test H_0 is that the model is well suited[8]. In addition, we evaluate the validity of the model by using a positive distinction rate, which forecasts this model correctly[9].

3.2 Dataset

We conducted the mailing questionnaire survey for ISPs in Japan from February to March 2007[10]. As a result, we received answers from 63 ISPs (the recovery percentage was about 10.3%). The purpose of this questionnaire was to clarify the realities regarding information security countermeasures of Japanese ISPs. Overall, the contents included the general business conditions of ISPs, the situation of the information security countermeasure, the situation of the information security incidents, and opinions toward government. We use a part of the results and analyze them below[11].

3.2.1 Information Security Incidents

As information security incidents, we used the following: illegal access, computer viruses and worms, and system trouble. Although we set four outcomes on information security incidents in the questionnaire survey, we replaced them with binary outcomes (whether or not ISPs encounter

[6]Reference [25] points out that because the financial health of local ISPs have deteriorated, they might not execute enough information security countermeasures.

[7]We use SPSS version 16.0J for Windows, SPSS, Inc..

[8]Refer to [26] about details of this test.

[9]The higher the positive distinction rate, the more correctly the model is forecasted. Therefore, this model is said to be preferable.

[10]Strictly speaking, we conducted this questionnaire survey to ISPs in the Internet Service Provider Association, Japan. You can refer to this mailing questionnaire survey by accessing http://www.kansai-u.ac.jp/riss/shareduse /data/07.pdf.

[11]This questionnaire survey has other data including the data used in this paper. Refer to [6] about these results in the questionnaire survey.

information security incidents) as follows[12]:

For $j = IA, CV$, and ST,

$$p_j = \begin{cases} 1 & \text{if ISP encounters information security incident } j, \\ 0 & \text{Otherwise,} \end{cases}$$

where IA, CV, and ST are illegal access, computer viruses and worms, and system trouble, respectively.

In Fig. 1, conditions on each information security incident are shown.

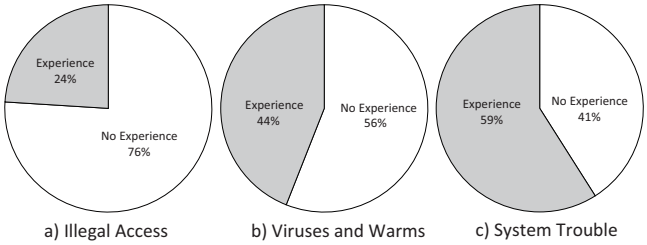

Figure 1: Conditions on Information Security Incidents

From Fig. 1, we see that the rate of ISPs that encounter system trouble is about 59%, and at least one or more system troubles occurred in more than half of the ISPs. According to [6], the rate of crashes in all ISPs systems was about 6%.

For reference, we calculate the odds ratio between risks (probability) that ISPs encounter at each information security incident. The results are shown in Table 1. We see that the risk is not mutually independent. From these results, it is clear that we need to discuss efficient countermeasures against information security incidents.

Table 1: Odds Ratio between Information Security Incidents

	Illegal Access	Computer Virus and Warms	System Trouble
Illegal Access	—	9	19
Computer Virus and Warms	—	—	3

3.2.2 Vulnerability

In this paper, we use the following two vulnerability indices; one is the number of users as a proxy variable of the vulnerability caused by the users, and the other is the number of servers as a proxy variable of the vulnerability caused by vulnerabilities of Web application and/or computer

[12]The four outcomes are the following; 1) nothing, 2) there is a network fault, but servers are not downed, 3) some servers are downed, and 4) the entire system crashes.

software and programs[13].

The number of users and servers vary greatly in scale among ISPs; that is, these distributions are too large. Therefore, we control the model by taking their logarithm[14]. Therefore, vulnerability $X_{V,m}$ is the following:

For $m = U$ and S,

$$X_{V,m} = \log(m)$$

where U and S represent the number of users and the number of servers, respectively.

Table 2 shows a descriptive statistics on the number of users and servers.

Table 2: Descriptive Statistics on the Number of Users and Servers

	Mean	Standard Deviation	Skewness	Kurtosis
$X_{V,U}$	8.121	1.917	-1.019	2.134
$X_{V,S}$	2.814	1.314	0.056	-0.435

3.2.3 Information Security Countermeasures

We use the number of introduced information security systems as a technical information security countermeasure index. The kinds of systems we assume are six: 1) a firewall (FW), 2) an Intrusion Detection System (IDS), 3) an Intrusion Prevention System (IPS), 4) a virus check on the Web, 5) setting a DMZ segment, and 6) the others. On the other hand, we use the following four indices as a non-technical information security countermeasure index: 1) information security education, 2) reminder of information security incident to users, 3) a penetration test, and 4), a system audit. The non-technical information security countermeasure indices are given by binary choices (whether or not the ISP executes the information security countermeasure) as follows:

For $k = EDU, RU, PT$, and SA,

$$X_{C,k} = \begin{cases} 1 & \text{if ISP executes the countermeasures } k, \\ 0 & \text{otherwise,} \end{cases}$$

where EDU, RU, PT, and SA represent information security education, reminder of information security incident to users, the penetration test, and the system audit, respectively.

Table 3 shows descriptive statistics on the number of introduced security systems, and Fig. 2 shows conditions on each information security countermeasure.

[13]We have data on the number of individuals and firms, separately. First, we tried to estimate coefficient parameters in equation (1). Unfortunately, we could not find a significant result. Therefore, in this paper we use data on the sum of the number of individual users and firm users. The number of users can be considered as not only a proxy variable of the vulnerability, but also the scale of the ISP.

[14]Reference [16] use mail accounts as a proxy variable of the vulnerability.

Table 3: Descriptive Statistics on the number of Introduced Security Systems

	Mean	Standard Deviation	Skewness	Kurtosis
$X_{C,NS}$	2.480	1.424	−0.072	−0.811

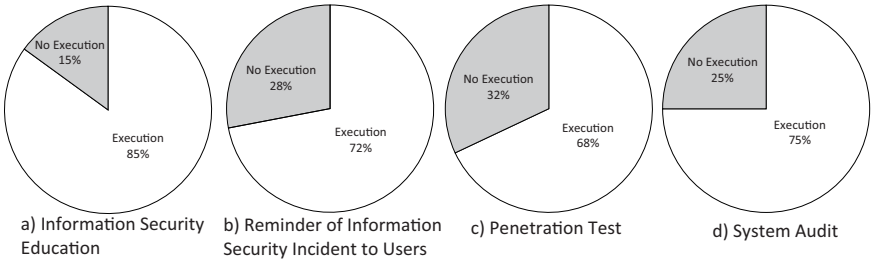

Figure 2: Conditions on Information Security Countermeasures

3.2.4 Characteristics of ISPs

We use the differences of the areas providing service as characteristics of the ISPs. In other words, this index shows whether the ISP is local or nationwide. Concretely,

$$Z_C = \begin{cases} 1 & \text{if ISP is nationwide,} \\ 0 & \text{if ISP is local.} \end{cases}$$

Fig. 3 shows the rates of local ISPs and nationwide ISPs.

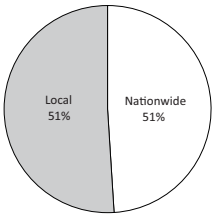

Figure 3: Local ISPs and Nationwide ISPs

4 Estimation Results

Before logistic regression, we examine (rank) the correlations among explanatory variable correlations. Unless the variables are mutually independent, we cannot run logistic regression. Table 4 shows the rank correlation coefficient of explanatory variables because many explanatory variables are discrete.

We can easily see that each rank correlation coefficient is far less than 1. Therefore, we can use these data for our analysis as explanatory variables.

Table 4: Correlation Coefficient of Explanatory Variables

	$X_{V,U}$	$X_{V,S}$	$X_{C,NS}$	$X_{C,EDU}$	$X_{C,RU}$	$X_{C,SA}$	$X_{C,PT}$	Z_C
$X_{V,U}$	—	0.216	-0.076	0.211	0.177	-0.035	0.168	-0.092
$X_{V,S}$	0.216	—	0.223	0.123	0.268	0.189	0.173	0.281
$X_{C,NS}$	-0.076	0.223	—	0.313	0.333	0.323	0.139	-0.042
$X_{C,EDU}$	0.211	0.123	0.313	—	0.338	0.093	0.209	0.080
$X_{C,RU}$	0.177	0.268	0.333	0.338	—	0.196	0.090	0.090
$X_{C,SA}$	-0.035	0.189	0.323	0.093	0.196	—	0.365	0.093
$X_{C,PT}$	0.168	0.173	0.139	0.209	0.090	0.365	—	0.145
Z_C	-0.092	0.281	-0.042	0.080	0.090	0.093	0.145	—

Next, we divide estimation results in some cases and estimate the coefficient parameters in equation (1). Hereafter, the results are sequentially shown. Unfortunately, we cannot attain significant results using the risks that ISPs encounter with virus and worm accidents as an explained variable. Therefore, we omit these cases in this paper.

4.1 Illegal Access

In Tables 5-7, we show the explained variables, which are the estimation results using the risk that ISPs encounter with illegal access accidents. Note that in Table 5 both the numbers of users and servers are used as the vulnerability index. In Table 6, we use only the logarithm of the number of users as the vulnerability index and we use only the logarithm of the number of servers as the index in Table 7. Chi-square in each Table is used to run the Hosmer-Lemeshow test.

In Tables 5-7, we find that it is common to the results that the estimated coefficient parameter of the number of countermeasures, $b_{C,NS}$, is positive, and the estimated coefficient parameter of the information security education, $b_{C,EDU}$, is negative. Both parameters are statistically significant. Oppositely, variables such as the logarithm of the number of users, reminder of information security incident to users, the system audit, the penetration test, and the area providing service were not selected as inappropriate variables during the process of the logistic regression.

In addition, the coefficient parameter of the logarithm of the number of users, $b_{V,S}$, in Table 7 becomes positive at a 10% significance level.

From the results of the Hosmer-Lemeshow test, we can evaluate how these models are fit to some degree because each model has a 5% or more significance level. In addition to these results, because the positive distinction rate is at a level between 76.3 and 82.9%, we can insist that our models are valid.

Table 5: Estimation Result I

	Estimated Coefficient Parameter (B)	Standard Error	Wald	Significance probability	exp[B]
$b_{C,NS}$	1.755	0.789	4.956	0.026	5.686
$b_{C,EDU}$	-4.515	1.966	5.272	0.022	0.011
Constant term	-2.108	1.436	2.155	0.142	0.121
	Chi-square(5)=2.556 [0.768], 7 Steps Positive distinction rate: 80.6%				

Table 6: Estimation Result II

	Estimated Coefficient Parameter (B)	Standard Error	Wald	Significance probability	exp[B]
$b_{C,NS}$	1.373	0.533	6.641	0.010	3.947
$b_{C,EDU}$	-3.659	1.555	5.539	0.019	0.026
Constant term	-1.971	1.148	2.947	0.086	0.139
	Chi-square (5)=2.059 [0.841] ,6 Steps Positive distinction rate: 76.3%				

Table 7: Estimation Result III

	Estimated Coefficient Parameter (B)	Standard Error	Wald	Significance probability	exp[B]
$b_{V,S}$	0.732	0.423	2.996	0.083	2.079
$b_{C,NS}$	0.893	0.459	3.791	0.052	2.443
$b_{C,EDU}$	-2.833	1.254	5.101	0.024	0.059
Constant term	-3.428	1.609	4.538	0.033	0.032
	Chi-square (8)=2.990 [0.935], 5 Steps Positive distinction rate:82.9%				

4.2 System Trouble

In Tables 8 and 9, the estimation results using the risk that ISPs encounter system trouble as explained variables are shown. Note that in Table 8 we use both the numbers of users and servers as the vulnerability index and we use only the logarithm of the number of users as the vulnerability index in Table 9. In the case using the logarithm of the number of servers as the vulnerability index, we cannot gain significant results. Thus, we omit the results.

Table 8: Estimation Result IV

	Estimated Coefficient Parameter (B)	Standard Error	Wald	Significance probability	exp[B]
$b_{V,U}$	0.534	0.290	3.397	0.065	1.706
$b_{C,NS}$	1.085	0.587	3.420	0.064	2.959
$b_{C,EDU}$	-3.562	1.719	4.295	0.038	0.028
$b_{C,PT}$	-1.915	1.201	2.543	0.111	0.147
c	2.886	1.303	4.906	0.027	17.918
Constant term	-5.110	3.091	2.733	0.098	0.006
	Chi-square (7)=3.730 [0.881], 3 Steps Positive distinction rate: 80.6%				

Table 9: Estimation Result V

	Estimated Coefficient Parameter (B)	Standard Error	Wald	Significance probability	exp[B]
$b_{C,NS}$	0.522	0.292	3.192	0.074	1.685
$b_{C,EDU}$	-1.968	1.220	2.604	0.100	0.140
Constant term	0.877	1.169	0.563	0.453	2.403
	Chi-square (5)=7.659 [0.176], 6 Steps Positive distinction rate:73.7%				

In Tables 8 and 9, we find that it is common to the results that the estimated coefficient parameter of the number of countermeasures, $b_{C,NS}$, is positive, and the estimated coefficient parameter of the information security education, $b_{C,EDU}$, is negative. Both parameters are statistically significant. Oppositely, variables such as the logarithm of the number of servers, reminder of information security incident to users, and the system audit were not selected as inappropriate variables during the process of the logistic regression.

In addition, the coefficient parameters of the logarithm of the number of users, $b_{V,S}$, the penetration test, $b_{C,PT}$, and the area providing service, c, in Table 8 become positive (at a 10% significance level) and negative (but statistically significant), respectively.

From the results of Hosmer-Lemeshow test, we can evaluate how these models are fit to some degree because each model has a 5% or more significance level. In addition to these results, because the positive distinction rate is at a level between 73.7 and 80.6%, we can insist that our models are valid.

4.3 Personal Opinions of Estimated Results

The estimated results in the previous subsection are interesting. First, the number of introduced information security systems and information security education show that the estimated coefficient parameters are statistically significant and the same sign through all models. The former is positive and the latter is negative. The former means that the more ISPs introduce information security systems, the higher the risk will be that they will encounter information security incidents[15]. On the other hand, the latter means that the more positively ISPs execute information security education, the lower the risk will be. If the education is executed more positively, the risk can be reduced.

Generally, many people think that the risk would be reduced if ISPs introduce various information security systems. Of course, when we discuss network security (countermeasures) against Internet threats, systems such as FW and IDS play an important role and they are needed. However, the former result throws doubt on this thinking. We interpreted this result as follows. First, ISPs may tend to hesitate on investment on information security countermeasures and use old information security systems because the amount of investment is vast. This fact is pointed out in [25]. Therefore, there is a possibility that the old systems will not be able to correspond to present threats. Next, even if ISPs introduce the recent systems, the various systems may be not efficiently operated because ISPs have few employees of a high technical level, such as system administrators[16]. Third, including ISPs that had encountered an information security incident, the causal relation might be reversed. In other words, the higher the risk becomes that ISPs encounter information security incidents, the more ISPs introduce information security systems. If these possibilities exist, coefficient parameters of the number of introduction systems can be considered intentionally positive.

Moreover, it seems that the result that executing information security education reduces the risk has the great meaning. Though costs are necessary to execute information security education, the cost-benefit is higher than introducing information security systems in the long term. The reason is that executing information security education is effective (reduces the risk that ISPs encounter information security incidents), and is covered by management only to some degree.

Reference [6] reported that in information security education, etiquette on the Internet, knowledge about not only viruses and worms, but also the knowledge about security laws, and correspondence in emergencies were discussed[17]. The information security education is executed with not only prior countermeasures, but also posterior countermeasures in mind. Moreover,

[15]This result might represent an opposite causal relation. That is, the higher the risk, the more ISPs will introduce information security systems. We want to discuss this relation further in the future.

[16]We believe that enough effects cannot be demonstrated unless the system is introduced to employees such as the SE (System Engineer) who has enough knowledge.

[17]Reference [6] asks the question about two types who receive the information security education; 1) all employers and employees, and 2) only engineers.

according to [6], the ratio of ISPs planning to execute information security education in the future is over 95%. In other words, many ISPs intend to execute information security education. We expect that the risk of ISPs encountering information security incidents will be reduced in the future.

As part of the results, the estimated coefficient parameters of the logarithm of the number of servers and users are positive. These results imply that these vulnerabilities heighten the risk that ISPs encounter information security incidents, and these results are consistent with the theoretical consideration in Section 3.1[18]. In addition, we confirm that some countermeasures are not effective now because their coefficient parameters are not statistically significant. In Table 8, the estimated coefficient parameter of the area providing service is positive. That is, nationwide ISPs have a higher risk than local ISPs that they will encounter system trouble. The reason may be that the systems and networks they handle are too complex and widespread. At first we assumed that local ISPs have a higher risk rather than nationwide ISPs. However, our results overrule our initial intuition.

5 Concluding Remarks and Future Work

Our purpose has been to quantitatively clarify the relation among information security incidents, information security measures, and vulnerability. We have used positive analysis to do this by using data on a 2007 questionnaire survey for Japanese ISPs and logistic regression analysis as our statistical method. As a result, we found that there are statistically significant relations between information security incidents and some information security countermeasures. Concretely, the relation between information security incidents and the number of introduced information security systems (resp. information security education) is positive (resp. negative). The results mean that the risk would rise if the number of introduced information security systems increases, and the risk would decrease if information security education were executed. Our results are valid and provide important information when considering the financial health of ISPs. That is, the timing of countermeasures and investments that correspond to their financial health is key, and information security education that is a non-technological countermeasure is also efficient. Therefore, we believe that information security education should be enhanced to maintain a higher security level. This higher information security level cannot be achieved by the IPSs alone, because these ISPs need to cooperate with the government. Particularly efficient policy recommendations discussed at the seminar on information security showed that IPA, JNSA, and/or JPCERT/CC should cooperate with governmental offices such as the Ministry of Economy, Trade, and Industry as well as the Ministry of Internal Affairs and Communications. In addition, the government should put out united guidelines on information security, instead of many different kinds of the guidelines from different ministries. Moreover, seminars concerning policy recommendations should be held regularly. This idea of holding seminars on security countermeasures also applies to general firms, of course. In the future, we expect that NISC will play an important role in coordinating information security policies among ministries, and should implement such policies with unions [27].

[18]The estimated coefficient parameter of penetration test, $b_{C,PT}$, in Table 8 is negative, but the parameter is not statistically significant at a10% level.

To discuss deeply the effect of a number of information security systems introduced in this paper, we need to check the causal relation with information security incidents. This will be one of our future endeavors. In addition, we will continue to research the social and economic effects of information security countermeasures and investment, and help to accumulate research on the economics of information security.

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