Chapter 11

Optimal Timing of Information Security Investment: A Real Options Approach

Ken-ichi Tatsumi and Makoto Goto

Abstract This chapter applies real options analytic framework to firms’ investment activity in information security technology and then a dynamic analysis of information security investment is explored by extending Gordon–Loeb (2002). The current research provides how firms have to respond to immediate or remote threat numerically. It shows that although positive drift of threat causes both larger and later investment expenditure, negative drift causes immediate investment and lower investment expenditure. The efficiency of vulnerability reduction technology encourages firms to invest earlier and induces cost reduction. To know the form of vulnerability is important because the effect of high vulnerability on timing and amount of the investment expenditure is mixed.

11.1 Introduction

Importance of information security has emerged very rapidly as information society has developed great deal. The information security investment has accordingly been considered by Gordon and Loeb in 2002. The highlight of their analysis is an introduction of vulnerability concept to formal optimization problem. Although Gordon–Loeb (2002) mentioned aspects of dynamics such as a first-mover advantage or the time value of money, their analysis is static and they did not consider any aspect of dynamic theory of information security at all. A dynamic analysis of information security investment is therefore explored in the following of this chapter, in terms of real options theory often used for the analytic tools of investment timing.

Ken-ichi Tatsumi
Faculty of Economics, Gakushuin University, Mejiro 1-5-1, Toshima-ku, Tokyo 171-8588, Japan; e-mail: Kenichi.Tatsumi@gakushuin.ac.jp

Makoto Goto
Graduate School of Economics and Business Administration, Hokkaido University, Kita 9, Nishi 7, Kita-ku, Sapporo 060-0809, Japan; e-mail: goto@econ.hokudai.ac.jp
The chapter is organized as follows. First, Sect. 15.2 presents an outline of Gordon–Loeb model. Next in Sect. 15.3 we introduce real options theory that achieves the optimal timing of the investment level. In Sect. 15.4, we numerically calculate the optimal investment timing and level, and additionally some comparative statics. Then finally, Sect. 15.5 draws some conclusions and mentions directions for future works. We point out necessary extension of the model which captures an equilibrium nature of information security investments and needs to estimate the parameters of the dynamics.

11.2 Optimum Investment Size: The Model of Gordon and Loeb

In order to estimate the optimal level of information security investment for protecting some information system within a firm or an organization, Gordon–Loeb (2002) considers several variables and parameters of the system. We will utilize similar notation with a little change only for expositional purpose.

First, let $L$ denote the potential loss associated with the threat against the information system, i.e. $L = T\lambda$, where $T$ is a random variable of the threat occurring and $\lambda$ is the (monetary) loss suffered on conditioned on the breach occurring. Further, let $v$ denote vulnerability, i.e. the success probability of the attack once launched; $vL$ is then the total expected loss associated with the threat against the information system.

If a firm invests $z$ dollars in security, the remaining vulnerability will be denoted by $S(z, v)$. The expected benefit from the investment which is the reduction in the expected loss attributable to the investment can then be computed as $(v - S(z, v))L$, where $(v - S(z, v))$ is the reduction in the vulnerability of the information system. The expected net benefit can therefore be computed as $(v - S(z, v))L - z$. Under suitable differentiability assumptions (see the conditions A1–A3 below), we can see that the optimal level of investment can be found by computing the local optimum $z^*$ of the expected net benefit, i.e. by solving the first order equation:

$$\frac{\partial [(v - S(z, v))L - z]}{\partial z} = 0,$$

(11.1)

and obtaining the following condition for $z^* = z^*(v)$:

$$- \frac{\partial S(z^*, v)L}{\partial z} = 1.$$

(11.2)

Of course, the remaining vulnerability function can not be arbitrary. Since $S(z, v)$ could be interpreted to be a probability, we must clearly have $0 \leq S(z, v) \leq 1$. Its first argument is an investment and the second one another probability, so that $0 \leq z$ and $0 \leq v \leq 1$. Besides that, the following restrictions are defined in Gordon–Loeb (2002):