



Decisions on optimal adoption time for new technology



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ABSTRACT

The rapid development of science and technology has brought a lot of convenience to the industry, and allowed companies to enhance their competitive advantages in the market. However, at some point in the growth stage, companies often reach a bottle neck of efficiency and effectiveness in production due to a saturated scale of economy, leading managers to face a decision of adopting more advanced technologies with consideration of market requirements and related costs. In this study, the adoption of a new technology is modeled as a decision problem in which related uncertain factors are considered to determine the optimal adoption time for the new technology. Bayesian decision analysis is used to integrate the subjective judgment of the decision maker and the objective information of the market. A practical case from a food and beverage company is illustrated to demonstrate the effectiveness of the proposed approach.

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1. Introduction

Technology improves and progresses over time. Managers must be conscious of market trends and requirements, and able to evaluate available technologies and make proper decisions to enhance competitive advantages and earn profits for their companies. However, there are often numerous uncontrollable uncertainties in the evaluation process which may result in the judgment errors for adopting new technologies, thus leading to operation difficulties or even profit loss. Therefore, it is essential to make correct assessments and appropriate decisions for adopting proper technologies which grant companies an advantage in the competitive market. Discussion on the optimality of technology adoption has focused on the analyses with either strategic or experiential consideration which, though having some managerial implications, are not capable of providing decision makers with relative quantitative decision criteria to solve significant decision problems in the ever changing business environment. In this study, uncertainties about market share and possible competition from rival companies are considered to develop a Bayesian decision analysis approach in which, with consideration of both subjective judgments of decision maker and objective information of market surveys, the profit of the company is maximized to determine the optimal adoption time for a new technology.

The definition and content of technology management has been discussed for decades (Ayles, 1969; Drejer, 1997; Ellil, 1964; Khalil,

2000; Schumpeter, 1934). The adoption of more new technologies has great impacts on the operations of a company which is the key concern for the company to grow. However, adopting new technologies can bring both profits and risks to companies, especially in a complete market (Bhattacharjee, 1998; Christensen, 1992; Drejer, 2002; Hahn & Yu, 1999). Therefore, it is of special importance to effectively implement technology management to manage the inevitable risk and gain the competitive advantage (Bhattacharjee, 1998; Kline, 1995; McDermott, Kang, & Walsh, 2001; Premkumar & Roberts, 1999; Claxton et al., 2002; Kumar & Jain, 2003). Recent years have seen increased attention to the evaluation of new technologies aimed at establishing criteria to assess the optimality of adopting a new technology (Brown, 2001; Mateos-Planas, 2004; Premkumar & Roberts, 1999; Singh & Sohal, 1995; Thong & Yap, 1995). In addition, various factors must be considered internally and externally, e.g. related cost, marketing status, production capacity, technology difficulty, etc., while assessing a new technology (Anderson & Newell, 2004; Batz, Janssen, & Peters, 1999; Batz, Janssen, & Peters, 2003; Huggett & Ospina, 2001; Miyazaki & Kijima, 2000; Morgan & Daniels, 2001; Reppelin-Hill, 1999; Swamidass, 2003).

With regard to the approach of evaluating the adoption of a new technology, most research has been aimed at resolving the problem in a qualitative way with perspectives from either strategic or experiential concern. Research based on field survey by questionnaire or interview is common (Huggett & Ospina, 2001; Malhotra, 1999; Morgan & Daniels, 2001; Pretorius & Wet, 2000; Reppelin-Hill, 1999; Thong & Yap, 1995), and statistical analysis in predicting the effects of adopting advanced technology has also been used in the literature (Anderson & Newell, 2004; Batz et al., 2003; Chambers, 2004; Lynne, Casey, Hodges, & Rahmani, 1995).

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However, the decision of adopting new technologies is complex to an extent that it faces an uncertain business environment and must be determined based on the decision maker's subjective judgment. The use of decision analysis approach to quantitatively deal with the technology adoption decision problem has not often been seen in the literature. Ilori and Irefin (1997) considered the decision process related to organizational technology innovation and technology adoption procedure based on the analytical steps of decision theory. Farzin, Huisman, and Kort (1998) developed a dynamic framework of decision process with consideration of the degree of technology innovation to predict the opportune moment of adopting an advanced technology.

Based on the aforementioned discussion, this study probes into the determination of the optimal adoption time of a new technology upon understanding the competitors' response's under different market requirements. This paper is organized as follows: Section 2 states the research problem of new technology adoption; Section 3 depicts the development of the proposed approach; Section 4 demonstrates the effectiveness of the proposed approach by performing numerical investigation; and finally, Section 5 draws the concluding remarks.

2. Decision of the adoption time of a new technology

Suppose that a company originally uses an old technology to operate its business, and is currently considering the adoption of a more advanced technology to improve its profitability. The new technology is recognized as a mature one and has reputation in the market for its superiority, and the company has positive experiences in operating it by utilizing a few trials for a quit while (Christensen, 1992). Therefore, the new technology cannot only effectively improve the operation process, but is also able to achieve a lower defective rate for the product it produces or the service it provides. However, along with the advantages that the new technology can bring to the business, it would also require a huge capital investment. In addition, since the rival companies may also adopt the new technology at some point of time which would cause the company to have less advantage, the determination of the right time to adopt the new technology is thus critical for the company. Suppose that the time horizon for adopting the new technology is T , and the crucial decision occurs during the period of T , which is the best moment to adopt the new technology with the aim to maximize the company's profit. Since the managers decide to maintain the market price unchanged due to marketing concerns, the adoption of the new technology is profitable as long as the production cost can be significantly reduced and the market share can be substantially elevated. Moreover, with regard to the external competition environment, the actions or reactions of rival companies to the new technology adoption must be considered when making any marketing decision accordingly. Therefore, three critical aspects are considered to construct the decision problem in this study: (1) the adoption time of the new technology; (2) the market share; and (3) the strategy of the major rival company. Suppose that among the companies that adopt the new technology, only one is considered to be the major rival which will actually harm the company.

This study discusses two cases. The first case considers the condition in which the company does not have any information about the technology adoption status of the rival company. Having estimated the market demand rate the product, D , the company has to "guess" the rival company's adoption time of the new technology, t_2 , in order to determine his own ideal adoption time, t_1 . The other case considers the condition in which the company can utilize an effective information system to thoroughly collect and analyze the information about the rival company, and upon knowing

the rival company's adoption time in advance, the new technology's optimal adoption time can thus be determined for the company accordingly. Note that in such a case, an information asymmetry situation is assumed in which the rival company can only collect little information about the company. Weyant and Zhu (2003) stated that the dynamics of interactive strategies among competitors would impact profits, and thus affect production decisions. Therefore, in considering the role that asymmetric information plays in the competitive market, the reaction of the rival competitor is one of the important uncertainty events that the company must seriously consider. Suppose that the rival company would take the initiative in attempting to know the adoption time of the new technology of the company. For a defensive consideration, the company can use the strategy of legitimate discourses and disseminations of information (e.g., stockholder reports, press releases of intentions) to make the rival company believe that the company will adopt the new technology at time t'_1 . Upon obtaining this information, the rival company will thus react by adopting the new technology at time t_2 . Since that the company is able to thoroughly collect and analyze the information to accurately predict the possible reaction of the rival company (i.e., possible distribution of t_2), the company can thus determine its optimal adoption time of the new technology accordingly.

Suppose that the market price of the product is fairly stable at p , and the related costs that the company considers are from three aspects: technology development, production and marketing, and product quality. The cost for technology development, C_D , may include the training cost, the purchasing cost for new facilities, and the research and testing cost. The related costs regarding production and marketing are the labor wage per unit time, m , and the variable cost, ω_0 , and the factors affecting the product quality are the defective rates before and after the adoption of the new technology, i.e., r_0 and r_1 , and the cost results from a defective product, C_R . It is assumed that the wage varies with the adoption time of the new technology, and the wage varying rate, γ , decreases as the adoption time defers. Suppose that the wage varying rate is of the form $\gamma(t_1) = a - \frac{a}{b}t_1$ ($0 \leq \gamma \leq 1$, $b \geq t$), where a denotes the condition that the new technology is adopted immediately, that is, the wage varying rate if $t_1 = 0$, and b denotes the adoption time as the wage varying rate equals to zero. A greater a indicates that the wage varying rate would be high if the new technology is adopted early, and vice versa. Note that the values of a and b can be obtained by the managers' experiences and field investigations. Moreover, it is also assumed that, once the new technology is adopted, the variable cost, λ , would vary with the adoption time; in particular, it increases as the adoption time defers. Suppose that the variable cost is of the form $\lambda(t_1) = \frac{d-c}{T}t_1 + c$ ($0 \leq c \leq d$, $v \geq d$), where c denotes the variable cost that the new technology is adopted immediately, that is, the variable cost varying rate if $t_1 = 0$, and d denotes the variable cost that the new technology is adopted at T . A greater c indicates that the variable cost would be high if the new technology is adopted early, and vice versa. Note also that the values of d and c can be obtained by the managers' experiences and field investigations. Following are the notations used throughout this paper:

a, b : The parameters of the wage varying rate (a is unitless and b is based on time).

c, d : The parameters of the variable cost varying rate (c and d are based on common currency).

C_D : The development cost of the new technology.

C_R : The cost resulting from a defective product.

D : The market demand of the product per unit time.

V : The variable cost per unit before adopting the new technology, $v \geq d$.

w : The wage per unit time.

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