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A three-stage real options model on fire risk management decision-making under the fire loss frequency uncertainty

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This paper aims to adopt the real options approach to the fire risk management decision-making of alternative fire insurance and fire security services in the context of the fire loss frequency uncertainty. This paper constructs a three-stage model to analyze the frequency of fire loss with a dynamic viewpoint and examines the ten years fire loss data of an international city to propose the optimal timing to buy fire insurance or install a fire security system. The research findings can serve as a reference to the fire insurance companies and fire security service providers in the design of new products and service offerings. The results, supported with many cases in real life, can offer insight to decision makers.

1. Introduction

How do metropolitan citizens manage fire risks? When do they decide to purchase fire risk management products/services? Based on the real options approach (ROA), this paper proposes a different decision-making framework and conducts a comparison analysis to construct a three-stage model for the analysis of the frequency of fire loss with a dynamic perspective and the optimal timing for buying fire insurance or installing a fire security system. The ROA approach is different from the traditional cost benefit analysis (CBA) method with net present value (NPV) for consumers' decision-making.

Lee (1988) articulates the difference between the insurance and security service industries about risk management functions. Insurance is about risk financing, while fire security is about risk control. Chilton et al. (2002) report the results of two studies aiming at estimating the preference-based value of safety, namely (1) domestic rail fires, (2) fires in public places relative to the corresponding value for roads by using 'matching' (or 'equivalence') questions. The study includes a variety of questions intending to shed light on respondents' perceptions of risk and attitudes to safety in the various perspectives. Boyer and Gobert (2008) look at the dynamic properties of insurance contracts for which insurers have a better technology at preventing catastrophic losses than the insured. Lee (2011) shares the concept of a technically integrated service to encourage industries to engage in product innovations. Lian and Schlesinger (2012) examine the optimal indemnity contract in the insurance market where the insurer has private information about the size of an insurable loss. Their study proposes that the optimal contract should be compared with the contracts where only the insurer can observe the loss size. Hoyt and Liebenberg (2011) measure the extent to which specific firms have implemented ERM (enterprise resource management) programs and then assess the value implications of these programs. Meyer and Meyer (2011) assume that the loss variable follows a Bernoulli distribution and the changes in the level of self-protection are mean reverting. Shafran (2011) reports the results of experiments designed to test the effect of experience on preferences for self-protection against low and high probability of losses. Subjects gained experiences by repeatedly making choices about whether to invest in a protective activity and then observing the results of their choices.

Quiggin (2002) briefly outlines the implications of state-contingent production of the self-insurance problem. A general state-contingent approach to choice and production under uncertainty is presented. The upper and lower bounds for willingness-to-pay for reductions in ambient risk are derived. Loomes, Orr, and Sugden (2009) use the reference-dependent expected utility

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theory to develop a model of status quo effects on consumers' choices. The study explains why status quo effects may vary substantially from one decision context to another and why some of such effects may decay as individuals gain market experience. Christian and Nicolas (2003) examine the link among irreversibility, the prospect of increasing information over time, and risk management by elaborating on the notion of option values closer to that of precaution (expiration). Lin (2010) provides a mathematical model to assess the entry and exit thresholds in respect of the most optimum technology innovation for maximizing the firm value based on the real options approach. Henseler and Roemer (2013) use a real options model to calculate option values and suggest that a customer's option between switching suppliers and wait-and-see first adds to customer value in uncertain markets and affects the customer's switching behavior. Driouchi and Bannett (2012) analyze and criticize the decision-making and performance implications of real options in the context of management theories. Their study explores both the strategic and operating perspectives of decision-making in organizations and conducts a literature review on the empirical evidence of real options decision-making and performance. Tapen (2004) shows that there are many examples of options to expand and abandon in the insurance industry. Insurance companies cannot afford to ignore such options. Hey and Panaccione (2011) implements a new and simple experimental design in which subjects are asked to take two sequential decisions interspersed by a random move (natural variable) concerning the allocation of a given sum of money based on dynamic decision-making. Moreover, this paper presents the concept in practice.

Myers (1977) predicts that corporate borrowing is inversely correlated to the proportion of market value accounted for by real options. He first proposes the real options concept and points out the similarities between real options and financial options. Real options incorporate the opportunities to expand or abandon projects if certain conditions arise amongst other options. Lander and Pinches (1998) summarize the applications of real options for 16 purposes such as natural resources, competition and business strategy, production, real estate, R&D, public good, mergers and acquisitions, corporate governance, interest rates, inventory, labor, venture capital, advertising, legal, hysteretic effect and corporate behavior, and environmental development and protection. Meanwhile, this paper delves into competition and business strategy, hysteretic effect and corporate behavior, and environmental development and protection. Yeo and Qiu (2003) review investment strategies as a series of options and explain the fundamental differences in assumptions between the traditionally passive approach and the real options model. They study the application of real options in the expansion of opportunity sets, technology investments, and business acquisitions. Olsson (2006) introduces a structured consequence approach to project flexibility management and analyze the dynamics related to project flexibility from both the theoretical and the empirical perspectives to ensure the efficiency of the project organizations. Kayali (2006) proposes the use of real options as a valuable tool for strategic investment decisions and the management's scope of flexibility.

This paper attempts to explore the following issues. Firstly, this paper analyzes risk considerations and uncertainties with a dynamic viewpoint and provides a better decision-making framework centered on consumers' perspectives. Secondly, this paper helps consumers make the optimal decision concerning the purchase of fire insurance or fire security services, and provides the analysis of the potential value of the subject with a numerical example. This approach enhances the creditability of the argument. Thirdly, this paper offers insight and innovation in business operations and the integration of products and services to the insurance and fire security companies.

2. The proposed model

2.1. Three-stage entry mode

This proposed model attempts to apply the real options to the fire risk management of alternative fire insurance and security services under fire loss frequency uncertainty. According to the studies on real options in investment under uncertainty (Dixit & Pindyck, 1994, pp. 6–7) and the concept of a paradigm for primary asset valuation in Shimko (1995, pp. 1–31), finance in continuous time under fire loss frequency uncertainty follows the geometric Brownian motion (GBM), which can be modelled positively and increase (on average) a variation trend at a constant exponential rate.

This paper makes certain assumptions based on a three-stage model of the fire insurance and security services. The x axis expresses the time (t) with the function of expected fire loss frequency f_t, and the y axis expresses the value of subject-matter, $V(f_t)$. From the viewpoint of cash flows, under no insurance and protection of fire and security systems, the value of the subject-matter shows a decreasing straight line (downward slope) over time (no insurance and protection of fire and security system in the Stage 0). When f_t reaches the expected threshold $E[f_1(t_1^*)]$ with full fire insurance coverage but without fire and security systems in place, the value of the subject-matter will show a *slowly decreasing curve* over time (full fire insurance except fire and security system in the Stage 1). When f_t reaches the expected threshold $E[f_2(t_2^*)]$ with full fire insurance coverage and fire & security systems deployed, the value of the subject-matter will show a *more slowly decreasing curve* a less steep downward slope over time (full fire insurance and fire and security systems in the Stage 2).

The higher the fire risk, the better the fire and security systems are required to control losses. This paper considers the expected value of the alternative on the three-stage entry mode with the real options model and argues that the *potential value* will rise along with the fire insurance coverage and security services in place.

Fig. 1 shows the NPVs. NPV_0 indicates the present value for the strategy in Stage 0, NPV_1 the present value for the strategy in Stage 1, NPV_2 the present value for the strategy in Stage 2. The traditional optimal solution is Max〔NPV_0, NPV_1, NPV_2〕. If decision makers do not take any risk management measures, the value of the subject-matter (such as buildings) will gradually decrease over time as a result of the depreciation. Even if the expectations of fire loss frequency are not high (such as $E[f_1(t_1^*)]$), a total loss will wipe out the value of the subject-matter asset in order to be able to save the value of the subject-matter. Consumers generally buy the fire insurance so the value of the subject-matter can be recovered based on insurance companies' on-site inspections and loss prevention services so as to slow down the decline of the value of the subject-matter.

In the event of fire occurrence, insurance companies will be able to timely recover the actual value of the insured asset because of the indemnity function of insurance. In addition to buying fire insurance, consumers should pay more attention to the strengthening of risk control functions and install fire security systems as the higher fire loss frequency the higher expectations (such as $E[f_2(t_2^*)]$). This does not only reduce the actual loss of fire, but also recover the salvage value of the asset with the insurance coverage. The decline in the value of the asset slows down given the double protection. In fact, the preservation of the value of the subject-matter becomes possible. This three-stage real options model with cash flows concept is illustrated as Fig. 1.

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