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A fuzzy real option approach for investment project valuation

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ABSTRACT

The main purpose of this paper is to propose a fuzzy approach for investment project valuation in uncertain environments from the aspect of real options. The traditional approaches to project valuation are based on discounted cash flows (DCF) analysis which provides measures like net present value (NPV) and internal rate of return (IRR). However, DCF-based approaches exhibit two major pitfalls. One is that DCF parameters such as cash flows cannot be estimated precisely in the uncertain decision making environments. The other one is that the values of managerial flexibilities in investment projects cannot be exactly revealed through DCF analysis. Both of them would entail improper results on strategic investment projects valuation. Therefore, this paper proposes a fuzzy binomial approach that can be used in project valuation under uncertainty. The proposed approach also reveals the value of flexibilities embedded in the project. Furthermore, this paper provides a method to compute the mean value of a project's fuzzy expanded NPV that represents the entire value of project. Finally, we use the approach to practically evaluate a project.

1. Introduction

DCF-based approaches to project valuation implicitly assume that a project will be undertaken immediately and operated continuously until the end of its expected useful life, even though the future is uncertain. By treating projects as independent investment opportunities, decisions are made to accept projects with positive computed NPVs. Traditional NPV techniques only focus on current predictable cash flows and ignore future managerial flexibilities, therefore, may undervalue the projects and mislead the decision makers. Furthermore, for high-risk investment projects, the traditional NPV method may adopt higher discount rates to discount project cash flows for trade-off or compensation. However, higher discount rates may result in the underestimation of project value and the rejection of a potential project. For instance, investments such as new drug development or crude oil exploitation may carry high risk, but may also bring higher returns.

Since DCF-based approaches ignore the upside potentials of added value that could be brought to projects through managerial flexibilities and innovations, they usually underestimate the upside value of projects (Bowman & Moskowitz, 2001; Dixit & Pindyck, 1995; Luehrman, 1998; Trigeorgis, 1993; Yeo & Qiu, 2003). In particular, as market conditions change in the future, investment project may include flexibilities by which project value can be raised. Such flexibilities are called real options or strategic options. The real options approach to projects valuation seeks to correct the deficiencies of the traditional valuation methods through recognizing that managerial flexibilities can bring significant values to projects. According to real options theory, an investment is of higher value in a more uncertain or volatile market because of investment decision flexibilities.

Real options approach, as a strategic decision making tool, borrows ideas from financial options because it explicitly accounts for future flexibility value. Real options analysis is based on the assumption that there is an underlying source of uncertainty, such as the price of a commodity or the outcome of a research project. Over time, the outcome of the underlying uncertainty is revealed, and managers can adjust their strategy accordingly.

The objectives of this paper are to develop a fuzzy binomial approach to evaluate a project embedded with real options, to propose a method suitable for computing the mean value of fuzzy NPV, and to explore the value of multiple options existing in projects. The paper is organized as follows. Section 2 provides a survey of real options analysis. We especially focus on pricing, applications and recent developments of real options analysis. Section 3 presents a fuzzy binomial approach to evaluate a project under vague situations. This section also proposes a method to compute the mean value of fuzzy NPV. Section 4 illustrates a project valuation based on our approach. In the example, the values of the real options are also assessed. Section 5 discusses the results and findings in the example. Finally, conclusions are drawn in Section 6.

2. Related works

Based on real options theory, Chen, Zhang, and Lai (2009) presented an approach to evaluate IT investments subject to multiple

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risks. By modeling public risks and private risks into a unified framework, they utilized the binomial model to evaluate an ERP development project. Wu, Ong, and Hsu (2008) argued that ERP may be best represented by a non-analytical, compound option model. However, most IT studies that employ the options theory only consider a single option, use an analytical model such as the Black–Scholes model (1973), and cannot deal with multi-option situations. Therefore, Wu et al. employed the binomial tree approach to implement an active ERP management which involves uncertainties over time. Hahn and Dyer (2008) proposed a recombining binomial lattice approach for modeling real options and valuing managerial flexibility to address a common issue in many practical applications—underlying stochastic processes that are mean-reverting. The models were tested by implementing the lattice in binomial decision tree format and applying to a real application by solving for the value of an oil and gas switching option. Reyck, Degraeve, and Vandenborre (2008) proposed an alternative approach for valuing real options based on the certainty-equivalent version of the NPV formula, which eliminates the need to identify market-priced twin securities. Moreover, Bowe and Lee (2004) also utilized the log-transformed binomial lattice approach to evaluate the Taiwan High-Speed Rail (THSR) project.

In DCF, parameters such as cash flows and discount rates are difficult to estimate (Carlsson & Fuller, 2003). In particular, innovative investment projects may count on the subjective judgments of decision makers due to lack of past data for reference. These parameters are essentially estimated under uncertainty. With respect to uncertainty, probability is one way to depict whereas possibility is another. Fuzzy set theory provides a basis for the theory of possibility (Zadeh, 1999). Fuzzy logic may be viewed as an attempt at formalization of two remarkable human capabilities. One is the capability to converse, reason and make rational decisions in an environment of imprecision, uncertainty and incompleteness of information and the other one is to perform a wide variety of physical and mental tasks without any measurements and computations (Zadeh, 2008). The outstanding feature of fuzzy logic is that in fuzzy logic everything is—or is allowed to be—a matter of degree. In the generalized theory of uncertainty, uncertainty is linked to information through the concept of granular structure—a concept that plays a key role in human interaction with the real world (Zadeh, 2005). Thus, these parameters can be characterized with possibilistic distributions instead of probabilistic distributions, and can be estimated by making use of fuzzy numbers.

By modeling the stock price in each state as a fuzzy number, Muzzioli and Torricelli (2004) obtained a possibility distribution of the risk-neutral probability in a multi-period binomial model, then computed the option price with a weighted expected value interval, and thus determined a "most likely" option value within the interval. Muzzioli and Reynaerts (2008) also addressed that the key input of the multi-period binomial model is the volatility of the underlying asset, but it is an unobservable parameter. The volatility parameter can be estimated either from historical data (historical volatility) or implied from the price of European options (implied volatility). Providing a precise volatility estimate is difficult; therefore, they used a possibility distribution to model volatility uncertainty and to price an American option in a multi-period binomial model. Carlsson and Fuller (2003) mentioned that the imprecision in judging or estimating future cash flows is not stochastic in nature, and that the use of the probability theory leads to a misleading level of precision. Their study introduced a real option rule in a fuzzy setting in which the present values of expected cash flows and expected costs are estimated by trapezoidal fuzzy numbers. They determined the optimal exercise time with the help of possibilistic mean value and variance of fuzzy numbers. The proposed model that incorporates subjective judgments and statistical uncertainties may give investors a better understanding of the problem when making investment decisions. Carlsson, Fuller, Heikkila, and Majlender (2007) also developed a methodology for valuing options on R&D projects, in which future cash flows were estimated by trapezoidal fuzzy numbers. In particular, they presented a fuzzy mixed integer programming model for the R&D optimal portfolio selection problem.

In addition to the binomial model, the Black–Scholes model is another way to evaluate the option's value. Owing to fluctuations in the financial market from time to time, some input parameters in the Black–Scholes formula cannot be expected to always be precise. Wu (2004) applied the fuzzy set theory to the Black–Scholes formula. Under the assumptions of fuzzy interest rate, fuzzy volatility and fuzzy stock price, the European option price turns into a fuzzy number. This allows the financial analyst to pick a European option price with an acceptable degree of belief. Lee, Tzeng, and Wang (2005) adopted the fuzzy decision theory and Bayes' rule as a basis for measuring fuzziness in the practice of option analysis. Their study also employed "Fuzzy Decision Space" that consisted of four dimensions—fuzzy state, fuzzy sample information, fuzzy action and evaluation function—to describe the decisions of investors. These dimensions were used to derive a fuzzy Black–Scholes option pricing model under fuzzy environments. Thiagarajah, Appadoo, and Thavaneswaran (2007) also addressed that most stochastic models involve uncertainty arising mainly from lack of knowledge or from inherent vagueness. Traditionally, these stochastic models are solved using probability theory and fuzzy set theory. In their study, using adaptive fuzzy numbers, they modeled the uncertainty of characteristics such as interest rate, volatility, and stock price. They also replaced fuzzy interest rate, fuzzy stock price and fuzzy volatility with possibilistic mean values in the fuzzy Black–Scholes formula.

Making a R&D portfolio decision is difficult, because the long lead times of R&D and the market and technology dynamics lead to unavailable or unreliable collected data for portfolio management. Wang and Hwang (2007) developed a fuzzy R&D portfolio selection model to hedge against the R&D uncertainty. Since traditional project valuation methods often underestimated the risky project, a fuzzy compound-options model was used to evaluate the value of each R&D project. The R&D portfolio selection problem was formulated as a fuzzy zero-one integer programming model that could handle both uncertain and flexible parameters to determine the optimal project portfolio.

From the viewpoint of fuzzy random variables, Yoshida, Yasuda, Nakagami, and Kurano (2006) discussed, under uncertainty in financial engineering, an American put option model that was based on the Black–Scholes stochastic model. In their study, probability is applied as the uncertainty such that something occurs or not with probability, and fuzziness is applied as the uncertainty such that the exact values cannot be specified because of a lack of knowledge regarding the present stock market. By introducing fuzzy logic to the log-normal stochastic processes for the financial market, they presented a model with uncertainty of both randomness and fuzziness in output.

The Garman–Kohlhagen (G–K) model is a closed-form solution of the European currency options pricing model based on the Black–Scholes model, but the input variables of the G–K model are usually regarded as real numbers. However, it is more suitable and realistic to price currency options with fuzzy numbers because these variables are only available with imprecise data or data related in a vague way. Therefore, Liu (2009) started from the fuzzy environments of currency options markets, introduced fuzzy techniques, and created a fuzzy currency options pricing model. By turning exchange rate, interest rates and volatility into triangular fuzzy numbers, the currency option price turns into a fuzzy number. This allows financial investors to pick any currency option price with an acceptable degree of belief.