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Simulation–optimization mechanism for expansion strategy using real option theory

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Abstract

A right expansion strategy can bring a company more market shares and profits, and hence increase shareholders' equities. However, limited financial resources and various uncertainties require business practitioners to achieve their goals while controlling the risks incurred at an acceptable level. Therefore, justification of expansion investments is an important and complex topic in industry. The traditional investment analysis tools such as net present value (NPV) often tend to undervalue investment decisions. We formulate the expansion investments using real options, and develop a financial model to assess the option value. Monte Carlo simulation is considered a good way to estimate the value of the option. This valuation gives decision makers a way to choose the appropriate expansion strategy based on an integrated view of the market dynamics, but optimization is still a difficult problem to resolve. This paper presents a model of optimization under uncertainty combining system simulation with GA-based optimization to resolve the expansion problem. An industry case is used to demonstrate the application of real options to value expansion investment by using simulation–optimization. This approach also provides some new insights for the real options theory.

Keywords: Expansion strategy; Net present value (NPV); Real options; Monte Carlo simulation; Simulation–optimization

1. Introduction

Capital budgeting often involves large expenditures with long-term implications such as expansion decisions, equipment selection or replacement decisions, and lease/buy decisions, etc. An organization's long-term health can be affected significantly by its capital-budgeting decisions. Hence, managers must carefully select those projects that promise the greatest future return. How well managers make these capital budgeting decisions is a critical factor for the long-term profitability of a company (Garrison & Noreen, 2003; Hilton, 2004).

The valuation of long-term investments is challenging because it is characterized by long payback periods, uncertainty, and changing business conditions. A few approaches are used for making capital budgeting decisions, such as the net present value method, the internal rate of return method, payback method, and simple rate of return. The net present value and internal rate of return methods, both using discounted cash flows (DCF), have gained widespread acceptance as decision-making tools. DCF estimates inflow and outflow cashes from an investment, and cash flows are discounted to their present value at a discount rate commensurate with the project risk. This approach has assumed that an investment cannot be postponed and that, once started, nothing can be done to alter the course of the project. In reality, investments can often be postponed. Therefore, this approach does not properly account for the flexibility inherent in most long-term expansion investment decisions.

Real options analysis presents an attractive alternative because it explicitly accounts for the value of future flexibility in management decision-making (Amram & Kulatilaka, 1999; Smith & McCardle, 1998; Trigeorgis, 1996). More

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recently, managerial operating flexibility has been likened to financial options. The goal of our research is to view the flexibility surrounding corporations' operations in expansion strategy using financial options.

In this paper, we specifically consider the manufacturing decision to increase flexibility through expansion strategy. We use the options approach to find the value of expansion decision during a specified length of time, considering future uncertain variables. The uncertainty is included through a Monte Carlo simulation. Then, genetic algorithms (GAs) are used to optimize a Monte Carlo simulation of real options expansion problems and to find the best investment timing and portfolio. In Nembhard, Shi, and Aktan (2002, 2003), they have investigated the use of Monte Carlo simulation to value the real options associated with applying statistical process control (SPC) charts to monitor quality and product outsourcing. The use of computational intelligence techniques in real options applications is very rare. In the research, a case example from the TFT manufacturing industry is used to illustrate the application of simulation–optimization method. The case example includes numerical results and a sensitivity analysis for key parameters to supplement our results.

2. Option models and valuation methods

Fundamentally, an option is the right, but not the obligation, to take an action in the future (Amram & Kulatilaka, 1999). Some options are associated with investment opportunities that are not financial instruments. These operational options are often termed *real options* to emphasize that they involve real activities or real commodities, as opposed to purely financial commodities, such as stock options (Luenberger, 1998). A European option gives a holder the right to exercise the option on the expiration date. An American option gives the right to exercise the option on or before the expiration date.

In our model, we formulate the expansion strategy as a series of n European options, where all options start at time zero, and each option expires at one of the n equally spaced time intervals. In our context, this means that expansion can be applied or not applied (that is the option) in any time period until expiration date of the option. One might consider that modeling the problem as an American option is an easier alternative, but this would give only one chance to make a decision at a single time point. Because manufacturing processes often require sequential decisions, the model used must permit multiple decisions. Therefore, we model the problem as a bundle of n European options instead of using a single American option, in such a way expansion exercised or not are possible options at each time slot.

We use the European options approach to find the value of expansion strategy during a specified length of time, considering several future uncertain market variables. As discussed in Nembhard's article (2002), the value of European options with more than two state variables can be evaluated by using multinomial lattices as developed by Boyle, Evnine, and Gibbs (1989) and Kamrad and Ritchken (1991), or Monte Carlo simulation as illustrated by Hull (2003). Although in principle, multinomial lattice approaches can be used for multiple state variables, they are not really practical for option valuation involving three or more variables because they generate a large amount of nodes and result in complex calculations. In these cases, Monte Carlo simulation is a viable alternative. As mentioned above, Monte Carlo has the difficulty to optimize. Therefore, we will combine Monte Carlo and genetic algorithm to find the best solution for our financial model of expansion strategy. The model is provided in the next section.

3. A financial model for expansion strategy

Total sales revenue of a product is determined by two main sources: the number of sales and the price of the product. The number of sales of a product is affected by the following sources of uncertainty: quantity demanded and quantity produced, and the market demand is affected by the market growth rate, market size, and market share. Let $g(t)$ be the market growth rate and $M1(t)$ be the market share for the product during time interval beginning at time t, both with a uniform probability distribution with the entered *minimum* and *maximum* values. Every value across the range of the uniform distribution has an equal likelihood of occurrence. We assume that the market size M_2 is deterministic. Then, the quantity demanded $D(t)$ of the product per time interval that begins at time t is

$$D(t) = g(t) * M_2 * M_1(t)$$

The quantity produced $Q(t)$ is determined by the number of units produced of each factory N, production perfect rate PR, and the number of factories F. Genetic algorithm technology (Goldberg, 1989) is used to find the "best" values for facility investment portfolio. The net profit can be maximized by adjusting the type and number of factories, and the best timing for investment. Then, the quantity produced $Q(t)$ can be defined as

$$Q(t) = N * \mathrm{PR} * F$$

If the quantity demanded $D(t)$ is larger than quantity produced $Q(t)$, the number of sales $S(t)$ for the product during the time interval that begins at time t is

$$S(t) = Q(t)$$

Otherwise,

$$S(t) = D(t)$$

Let $P(t)$ be the price of the product, for the sake of simplicity, assume that the product prices follow the popular Geometric Brownian Motion (Hull, 2003), in the format of a risk-neutralized stochastic process:

$$P(t) = P(t-1) * \mathrm{Exp}((r - 0.5 * \sigma \wedge 2) + \sigma * \mathrm{Normal}(0, 1))$$