Touch on Valuing Investment with Uncertainty focusing on R&D

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1. Introduction

The objective of the study is to briefly mention how to estimate economic value of R&D investment under uncertainty by employing the basic concept of Real Option Analysis. Most investment decisions have three basic characteristics: irreversibility, uncertainty, and postponement[1]. Investment tends to be irreversible. The investments, once they are made, they are hard to be changed back to the way they were before. The benefits from the investments are uncertain over the future. And the investment can be postponed choosing the right time to invest getting more information about the future.

R&D is understood as an investment in a strategy(option). In other words, R&D creates an option purchasing the right but not the obligation to undertake business initiatives. A strategy can be unfolded in the future when it is considered favorable.

This study touches on the essential part of Real Option Analysis providing two case studies. One is on valuing the preliminary design of a super-jumbo jet at Boeing, and the other one is on preliminarily valuing R&D investment of a Fast Reactor focusing on fuel cycle cost in Korea.

2. Introduction of Option Analysis

The economic valuation of an option has been developed in the financial sectors, where there are a lot of uncertainties including the behavior of prices of stocks. Financial assets are primarily stocks and bonds that are traded in financial markets. As the methodology for real option analysis is based on that of financial option analysis, it would be helpful to be familiar with financial option analysis.

A call option in financial market is a contract between parties, the buyer and the seller of the option. The option purchaser has a right but not an obligation to buy shares of stock at a specified time in the future for a specified price, that is, an exercise price. Call option is traded in the financial market, and the buyer can purchase it by paying option price. With a call option, if the underlying asset (for example, stock) value is less than the exercise price at the time of option expiration, the option will not be exercised. Thus your net payoff in this case is negative and equal to the option price. If the asset value exceeds the exercise price, the option will be exercised and your gross payoff will be positive. Your net payoff, however, may be positive or negative depending on the option price. So, the option does not always guarantee positive payoff. However, we observe option is traded in a financial market, where buyers purchase an option with paying price for it. This means that option has a value.

Call option is divided between an European and American one, depending on the dates it can be exercised; A European option has a fixed maturity date, whereas an American option can be exercised any time before the option's maturity or expiration date.

Black-Scholes formula is very famous one for estimating the value of an European call option.

Black-Sholes formula is as follows:

$$C_0 = S_0 N(d_1) - Xe^{-r_f T} N(d_2)$$

Where,
S_0 = The price of the underlying asset(Stock)
X = The exercise price
T = The time to maturity
r_f = The risk-free rate
e = The vase of natural logarithms
$N(d_1)$ = The cumulative normal probability of unit normal variable d_1
$N(d_2)$ = The cumulative normal probability of unit normal variable d_2

$$d_1 = \frac{\ln(S/X) + r_f T + 0.5\sigma^2 T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

$\sigma =$ Volatility factor

There are other methods to estimate economic value of an option. They include a binomial model and a Monte Carlo simulation method, which are widely used.

If the underlying asset is not a financial asset but a real asset, the option is classified into real option. Real assets may include real estate, project, and intellectual property, most of which are not usually traded.

1 Investment under uncertainty, Avinash K.Dixit and Robert S. Pindyck, Princeton University Press, 1994

3. Case study on valuing R&D investment

3.1 The preliminary design of a super-jumbo jet at Boeing[2]

In the mid-1990s, Boeing expected a great market of a super-jumbo jet in airline business would come in 21st century. In order to produce a super-jumbo jet, a preliminary design of the plane should be made.

In 1996, Boeing evaluated the worth of launching a preliminary design of a super-jumbo jet. The preliminary design would cost $0.5B taking 5 years with completing it in 2001. In 2001, the company would invest $20B to build the plane. In 1996, the company estimated the financial market value of the business to be $18.5B in 2001[3].

NPV of the R&D investment given commitment to invest in 2001 is -$1.314B[= ($18.5B - $20B)/$1.13^5$ - $0.5B]. NPV analysis shows us the R&D investment is not economically viable.

At this point, it is noted that the NPV analysis implies that you should invest to build the plane once you launched R&D investment maintaining a now-or-never decision (no flexibility).

In addition, we know that the financial market value of the business is subject to uncertainty. The company estimated the annual volatility to be 38%. The underlying (here, the financial market value of the business) is our current understanding of its future values, and the volatility of the underlying represents how much our understanding can change.[4] The current (in 1996) value of the underlying is $10B (= $18.5B/$1.13^5$).

The option created by the R&D is analogous to a European call option in financial market. The value of the option can be estimated through the Black-Scholes formula in section 2 in this paper.

In this case, S_0= $10B, X= $20B, r_f= 7%, T= 5(years), and σ = 38%

Plugging these input data into the Black-Scholes formula gives us the option value of $2.214B. As a result, the true NPV of investment in the R&D is $1.714B(= $2.214B - $0.5B). This means that R&D investment is profitable as long as it costs less than $2.214B.

It is noted that the R&D investment does not secure its profitability in the future. The analysis informs us that the option is estimated to be valuable enough for launching its R&D investment.

The same result can be achieved through Monte Carlo simulation method[5]. Let me introduce how to apply Monte Carlo simulation to this problem.

As the Black-Sholes model assumes that the value of the underlying(S) follows Geometric Brownian Motion, we need to generate the value of the underlying following GBM in 2001, when the option is matured.

If S follows GBM, it is known that change in the logarithm of S follows normal distribution with mean of (r – $0.5\sigma^2 T$) and with variance of $\sigma^2 T$ over any finite time interval T(here, r is a rate of return, risk free rate, of 7%/year, T is 5 years and σ is 38%).

The distribution of the present value of the underlying is shown in figure 1.[6]

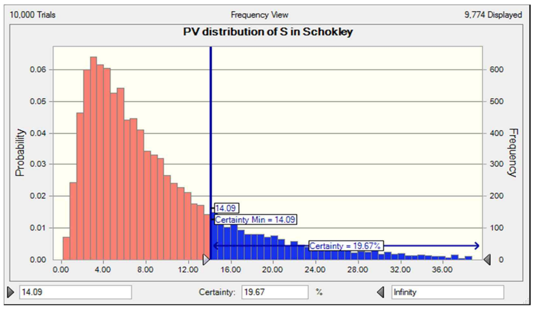

Fig. 1. Distribution of the present value of the underlying

Figure 1 includes exercise price of $14.09B, which is computed by bringing exercise price of $20B back to the current year of 1996.[7] Figure 1 shows that probability of being profitable is 19.67%, and the discounted mean value of the profitable outcomes is $25.13B. From these values, real option value is computed as follows:

Real option value = 19.67% × ($25.13B − $14.09B) = $2.17B

This value is almost similar to that(2.214B) from the Blalck-Scholes formula. The same value can also be calculated by using the Excel spreadsheet formula:

Real option value=

Average[MAX(Present value of the underlying – Present value of exercise value($14.09B), 0)]

[2] This part is extracted from Chapter 5 of “real options valuation”, Shockley(2007)
[3] As of 1996, the number is expected to be $18.5B when 2001 actually arrives.
[4] Low volatility implies great confidence in our current estimate, whereas high volatility admits that our current estimate could be quite wrong(Shockley(200&).

[5] Monte Carlo simulation method was not employed in the Shockley(2007)
[6] The number of sample drawn from distribution in the Monte Carlo simulation is 10,000.
[7] $14.09B = $20B × EXP(-0.07 × 5)

Calculating the maximum value for 10,000 simulated trials creates the payoff distribution in Figure 2.

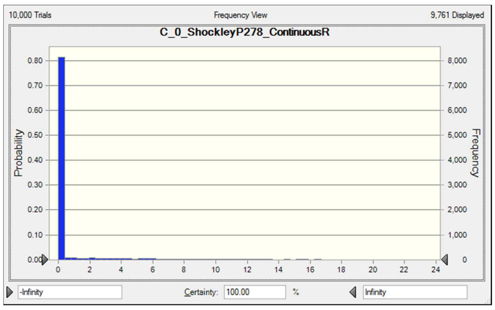

Fig. 2. Distribution of the payoff

The mean value of this distribution is estimated to be \$2.17B.

3.2 Preliminarily valuing R&D investment of Fast Reactor focusing on fuel cycle cost in Korea.

Nuclear fuel cycle costs include uncertainties. Korea will be faced to choose once through cycle or recycling cycle in the future. Korea has launched R&D on fast reactor combined with pyroprocessing spent fuel.

Optional way of thinking can be applied to the R&D investment. The R&D investment can be considered as purchase of an option, which provides ability to exercise it by introducing FR combined with pyroprocessing facility.

Material balance of equilibrium fuel cycles producing 1TWh are considered for both once through cycle and SFR-pyro recycling as shown in figure 3[8]. It is assumed that burn up be 55GWd/MTHM and fuel stay in reactor for 4.5 years producing electricity.

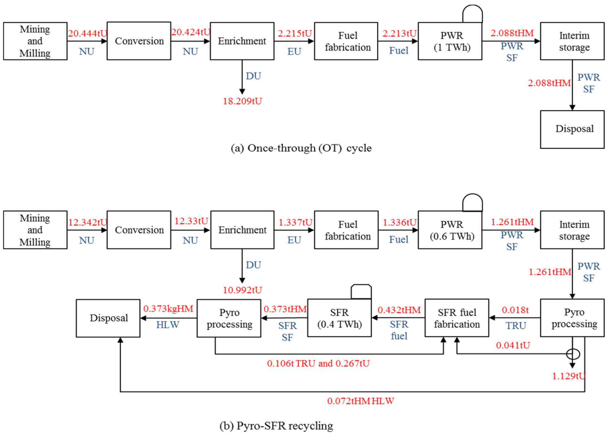

Fig. 3. Material balance for the fuel cycles

Unit costs of fuel cycle steps are listed in table1.

Table1. Unit costs of nuclear fuel cycle

Cost items	Units	Ref.
Uranium Purchase	\$/kgHM	158
Yellow Cake Conversion	\$/kgHM	17
Enrichment	\$/kgSWU	143
Fabrication of UOX fuel	\$/kgHM	355.79
Interim Storage	\$/kgHM	442.5
Geologic Disposal	\$/kgHM	637.5
Pyroprocessing of SF_PWR	\$/kgHM	781
SFR fuel fabrication from PWR SF	\$/kgHM	5511
Pyroprocessing of SF_SFR including fuel Fabrication	\$/kgHM	5511

Note: Unit costs for once through is based on Korean data and that for recycling is on the literature surveys

It is assumed that choice should be exclusively made between once through and recycling in 2035. As of 2017, we estimate the optional value of introducing SFR combined with pyroprocess. As nuclear fuel cycle is very complicated, it is hard to define the underlying. Instead of defining the underlying, payoff is defined assuming no difference in construction and O&M cost between PWR and SFR system, as follows:

$$\text{Payoff} = \text{Max}(NFC_{once\ thru} - NFC_{recycle}, 0)$$

Fuel cycle costs represent present value of each fuel cycle over the whole operating years(60 years). Discount rate of 2% per year is used to get present value at the year of 2017. Each unit cost in fuel cycle step is assumed to follow GBM process, where annual growth rate is assumed to be 0, and annual uncertainty is assumed to be 15.7%[9].

Present value distribution of each fuel cycle is shown in figure 4.

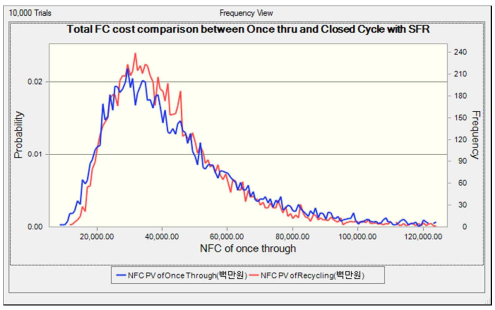

Fig. 4. Distribution of present value of each fuel cycle

[8] Referring "Economic analysis of different nuclear fuel cycle options", Science and Technology of Nuclear Installations, Won Il Ko and Fanxing Gao, 2012

[9] To keep analysis simple, the same level of annual uncertainty is applied to each unit cost in fuel cycle. Uncertainty is calibrated for each unit step cost to increase to two times as high as the reference value over 10 years from the current year falling within 95% confidence level.

The distribution patterns look similar between the two fuel cycles. Mean values are 46,609 and 43,922 million Won for once through cycle and recycling respectively. Mean value is 5.8% less in recycling than in once through cycle. And standard deviations are a little less in recycling than in once through.

Payoff is defined as follows:

Payoff = MAX(Present value of Once through – Present value of recycling, 0)

Frequency distribution from Monte Carlo simulation of the payoff is shown in figure 5.

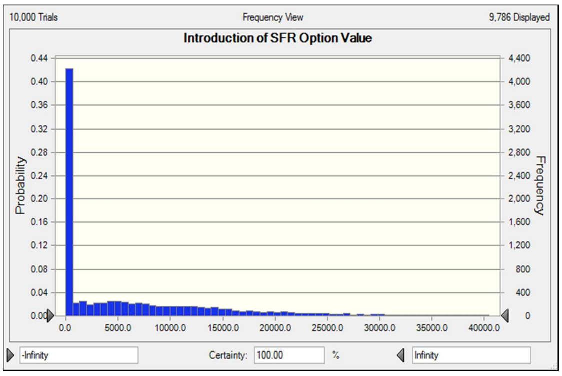

Fig. 5. Pay off distribution for introduction of recycling

The mean value of the payoff distribution is 7.5 billion Won, accounting for the annual power generation of 0.0888 TWh[= (1/4.5) × 0.4] from SFR. Consequently, contribution to the optional payoff of introducing 1400MW SFR is estimated to be around 875 billion Won in terms of fuel cycle[10]. It is evident that the economics of R&D entirely depends on the payoff of the introduction of SFR. The analysis indicates that 10 units of SFR deployment in the future with construction and O&M cost the same as in conventional PWR would make R&D investment secured as long as it costs less than 8,750 billion Won.

4. Conclusions

The payoff of R&D investment is uncertain. It is especially true of nuclear sector including fuel cycle. For this reason, the conventional Net Present Value method is not relevant for the economic assessment of R&D. This paper introduces optional way of thinking for the economic assessment of R&D. We believe optional way of thinking is better than the conventional NPV method in addressing investment under uncertainty. It is noted that the numerical results are significantly subject to the assumptions taken for the analysis. It is admitted that the same value of uncertainty of each unit cost of fuel cycle step in the Geometric Brownian Motion is too much crude assumption. Therefore, in-depth study on that is especially required in the further studies.

[10] As SFR with 1400MW class at 85% capacity factor produces 10.424 TWh annually, the payoff of 7.5 billion Won is converted to 875 billion Won as follows: 875 billion Won = 7.5 billion Won ×(10.424/0.0888)

References

[1] Investment under uncertainty, Avinash K.Dixit and Robert S. Pindyck, Princeton University Press, 1994
[2] This part is extracted from Chapter 5 of "real options valuation", Shockley(2007)
[3] Economic analysis of different nuclear fuel cycle options", Science and Technology of Nuclear Installations, Won Il Ko and Fanxing Gao, 2012
[4] Economic Valuation of the Design Certificate of SMART by using Real Option, Transactions of the Korean Nuclear Society Spring Meeting, PyeongChang, Korea, Man-ki Lee, et al, May 27-28, 2010