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EVPI and Real Option Valuation

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Real Options Analysis

Traditional discounted cash flow techniques have been criticized because they to not capture the value of management flexibility. Real options analysis has been promoted as a means to more accurately capture the value of management flexibility, which exists in many real engineering projects. The analysis of real options is based on financial option pricing theory that has been developed and discussed over the past two decades by many engineering economists and financial professionals. The real options approach also has become one of several ways to analyze capital budgeting projects under uncertainty.

Case Study: A Dementia Drug

A drug company is seeking approval for a new drug product. The company is hoping for approval from the Food and Drug Administration (FDA) two years from now. The drug will have patent protection for 10 years after FDA approval. Once on the market, year-one net cash flow from sales is expected to be $8M (million), year two net revenues are expected to be $15M, and years three through ten are expected to be $22M.

The facility to produce the new drug will take two years to build at a cost of $38M with a $5M salvage value at the project horizon. There is a 90% chance that the FDA will approve the new drug. The project's hurdle rate is 25%, and the risk-free interest rate is 5%.

If facility construction begins after FDA approval, initial sales will be delayed two years. Because the patent limits the horizon for sales, two years of revenues are lost. If facility construction begins now, it will be available to produce the drug upon FDA approval. However, if the FDA does not approve the drug, the unused $38M facility will have a salvage value of only $9M at the end of year 2. The cash flows are shown in Table 1. The decision tree is shown in Figure 1.

The question facing the firm is whether the facility should be built now or delayed until after FDA approval? Delays in approval can lead to shorter periods of product exclusivity. While there may be value in delaying, there is a cost of waiting. The NPV of the "Build Now" option is −$0.90 million, and the NPV of the "Build Later" option is −$0.36 million. Traditional tools would indicate that the project should not be funded now or two years from now.

Cash Flows			
Year	Build Now FDA Approves	Build Now FDA Rejects	Build Later FDA Approves
1	0	0	0
2	0	0	−38
3	8	9	0
4	15		0
5	22		8
6	22		15
7	22		22
8	22		22
9	22		22
10	22		22
11	22		22
12	27		27

Table 1: Dementia drug investment options and cash flows

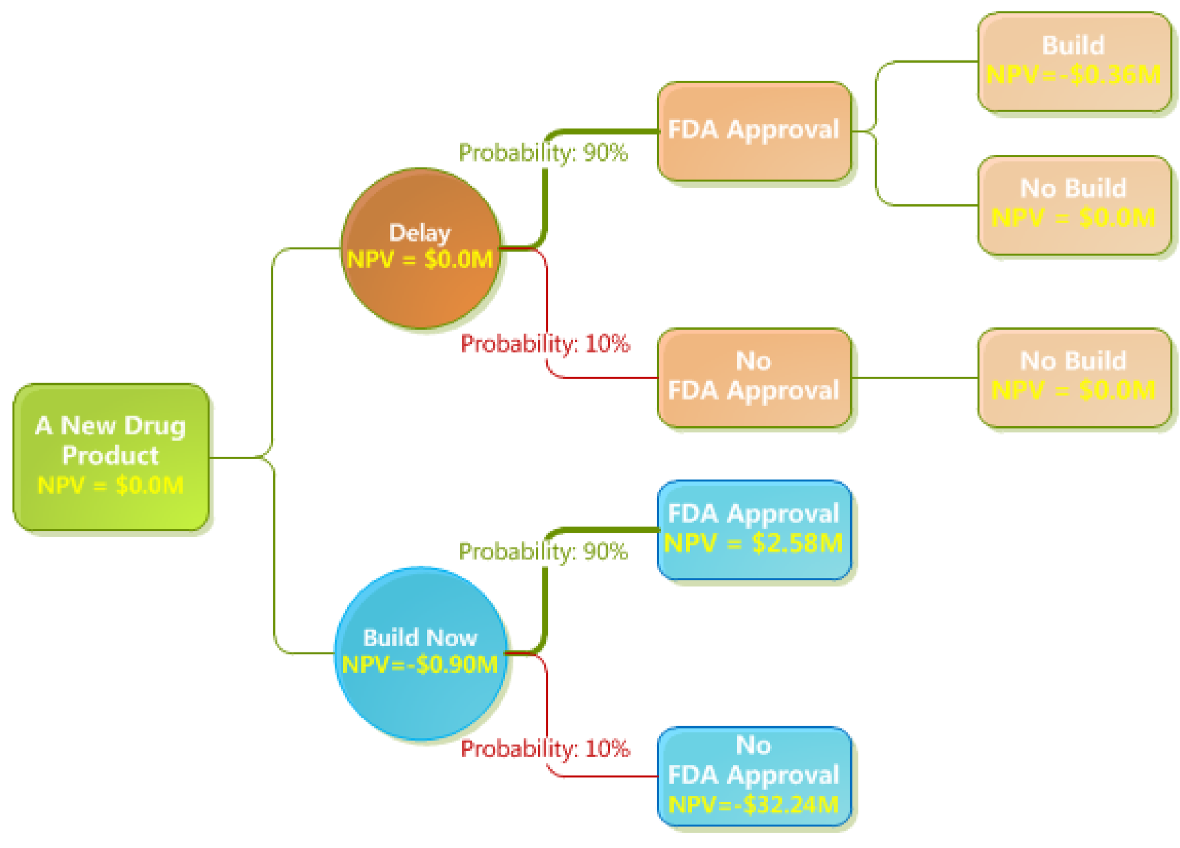

Figure 1: Decision tree, dementia drug problem

1. Black, F., and Scholes, M., 1973, "The Pricing of Options and Corporate Liabilities," *Journal of Political Economy*, 81(3), 637-654.
2. Copeland, T., and Antikarov, V., 2001, *Real Options; A Practitioners Guide*, Texere LLC.
3. Borissiouk, O., and Peli, J., 2001, "Real Option Approach to R&D Project Valuation: Case Study at Serono International S.A.," *The Financier*, 8(1-4), 7-71.
4. Lewis, N.A., Eschenbach,T.G., and Hartman, J.C., 2008, "Can We Capture the Value of Option Volatility," *The Engineering Economist*, 53(3), 230-258.
5. Nichols, N., 1994, "Scientific Management at Merck: An Interview with CFO Judy Lewent," *Harvard Business Review*, 89-99.

Black-Scholes Pricing Model

The Black-Scholes pricing model [1] can be used to determine the value of a financial call option (an option to buy), but it is also the basis for several types of real options. The value of the option, C, may be determined as follows:

S: the present value of future net revenues
X: investment costs
t: the time horizon
r: interest rate
σ: volatility of the project's rate of return

$$C = S_0\phi(d_1) - Xe^{-rt}\phi(d_2)$$

$$d_1 = \frac{\ln\left(\frac{S_0}{X}\right) + \left(r + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

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

Where $\phi(d_x)$ is the cumulative standard normal distribution of d_x

Option values are very sensitive to changes in the forecasted net revenues. Many authors have pointed out that there is often value in delaying a decision, hence the value of a deferral option. What few authors point out is that there is always a cost involved in the delay of a real engineering project. If nothing else, projected revenues will be delayed, causing a decrease in their present value due to discounting. Of course, the value of delaying may outweigh the cost of waiting, but deferral costs must not be ignored as they are in much of the literature. The traditional view of a delay cost is to model it after dividends. However, the dividend model is rarely the correct model because it fails to accurately describe the nature of lost cash flows. Delay models must be matched to the details of the case being analyzed. Including waiting costs is virtually a requirement for realistic industrial projects.

Considering the cost of waiting, the Black-Scholes equation can be modified for this adjustment. The modified equations become:

W: cost of waiting

$$C = (S_0 - W)\phi(d_1) - Xe^{-rt}\phi(d_2)$$

$$d_1 = \frac{\ln\left(\frac{(S_0 - W)}{X}\right) + \left(r + \frac{\sigma^2}{2}\right)t}{\sigma\sqrt{t}}$$

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

Volatility

The volatility recognizes that we are dealing with uncertainty. Volatility is defined as the standard deviation of the rate of return of the project. The project volatility must be estimated, and this is the most difficult variable to forecast.

A method of identifying the volatility for real options using the logarithmic present value returns approach was presented by Copeland and Antikarov [2]. In this method, the estimated future cash flows are discounted (using the hurdle rate) to two present values: one for time 0 and another for time 1. The time 0 value is treated as a static value, while the time 1 value is varied through Monte Carlo simulation. The present value at the present time (t = 0) is calculated as:

$$\sum_{t=0}^{N} PVCF_i = \frac{CF_0}{(1+i)^0} + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \ldots + \frac{CF_N}{(1+i)^N}$$

The present value at year 1 omits CF_0 and discounts later cash flows by one less period, and it is calculated as:

$$\sum_{t=1}^{N} PVCF_i = \frac{CF_1}{(1+i)^0} + \frac{CF_2}{(1+i)^1} + \frac{CF_3}{(1+i)^2} + \ldots + \frac{CF_N}{(1+i)^{N-1}}$$

A logarithmic ratio of the present values of the cash flows is calculated as:

$$X = \ln\left(\frac{\sum_{t=1}^{N} PVCF_i}{\sum_{t=0}^{N} PVCF_i}\right)$$

A limitation of the method is its exclusive focus on future cash flows. While the volatility of a project is not equal to the volatility of its firm's stock, neither is it equal to the volatility of just one of its input parameters [3]. The technique is an improvement from previous methods, but is still limited in its scope.

Using the information and equations above, the volatility is first determined, using Monte Carlo analysis, to be 0.637 or 63.7%. The Black-Scholes pricing model was then used to determine the option value of $5.27 million. Use of binomial lattices provides a very similar option value estimate.

We previously [4] determined the volatility and option value using two additional methods. Using the logarithmic cash flow method, often used in financial options, the volatility was 0.231, resulting in an option value of $0.45 million. We also proposed a method based on IRR, where the volatility was 1.15 with the resulting option value of $11.3 million.

EVPI

If perfect information were available on which chance branches would occur, then optimal decision choices could be made. These optimum choices present the case where there is no loss of opportunity, and no loss of optimum payoff. This optimum represents the expected project value with perfect information (EVwPI). The difference between the expected NPV and the expected value with perfect information (EVwPI) is the expected value *of* perfect information (EVPI).

The project has many variables, but to simplify the problem, we will assume that we know all of the values with certainty except for the decision of FDA approval. This question is the primary source of risk in the project. With this simplified problem all uncertainty is shown in the decision tree in Figure 1.

With perfect information, we will build if the FDA will approve the project, and we will not build if the FDA will not approve.

With perfect information, we cannot change the 90% and 10% probabilities of FDA approval, but we do get correct predictions of what will happen. So 90% of the time FDA approves and we build, and 10% of the time FDA does not approve and we don't. Thus, the EVwPI equals 90% of the NPV of the 'build now' option ($2.58 million) plus 10% of $0, or $2.32 million. EVPI is calculated according to the following equation. In this case the best decision without the perfect information has a present value of $0 since the decision is *not* to proceed.

EVPI = EVwPI – EVwithoutPI
= $2.32M – $0 = $2.32M

The EVPI of the dementia drug project is $2.32 million

Implied Volatility

We have four different estimates for the option value and EVPI, yet they all are supposed to be the same. The numbers used for the techniques are the same, except for the volatility estimation. We can assume that the option value equals the EVPI, and calculate the implied volatility using Goal Seek. This finds the volatility where the Black-Scholes equation provides an option value of 2.32 million. This results in an implied volatility of 0.41, or 41%, which is a very reasonable number. In fact, many pharmaceutical projects tend to run about 40%; this is a number that has been used by Merck to approximate small-molecule drug projects (based on stock proxies) [5]. The implied volatility of 41% is certainly more conservative, and probably more realistic, than the initial estimate of 63.7%.

Two additional example problems were solved, providing a total of four different volatility techniques that are used in the literature. These included 1) management estimates with scenarios of given probabilities, 2) logarithmic cash flow method, similar to that used for financial options, and 3) logarithmic present value method as recommended by Copeland and Antikarov [2], and the internal rate of return method [4]. It was interesting to note that the EVPI provided a smaller option value estimate (and therefore smaller implied volatility) in five out of six analyses. While this does not prove EVPI to be a more accurate method, it infers that it may be a more conservative method.

Method	σ	Option value
EVPI	0.41	$2.32M
Logarithmic cash flow	0.231	$0.45M
Logarithmic PV	0.699	$5.85
IRR	1.15	$11.30

Implications

1. EVPI is far less math intensive
2. EVPI has fewer constraints
3. Real options criticized for too high an option value
4. EVPI provides a more conservative estimate
5. Implication is that all volatility methods (including ours) are wrong

Future Work

1. Conclusion is that EVPI = Option Value
2. Need to test on additional problems
3. Work on mathematical proof of the equality
4. Demonstrate major impact on real option valuation techniques