Using Real Options for Policy Analysis

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Executive Summary

Real options are a way of calculating the value of a future option in an uncertain world. So why are real options of interest to us? Because they provide a way of valuing research and energy projects in terms of future benefits. Options provide a way of estimating benefits for projects that may or may not become economically viable in the future, but are nevertheless valuable in much the same way that an insurance policy protects its owner, whether or not an actual claim is filed. They can also be used as a tool to evaluate ongoing projects as to whether to deploy, abandon, or continue their development.

The Black-Scholes Formula is the fundamental means to evaluate the worth of a call option, which is basically what a research project represents. The full Black-Scholes Formula for call options can be written as:

$$C = S\, e^{-yt}\, N(d_1) - K\, e^{-rt}\, N(d_2) \qquad \text{where:}$$

$$d_1 = \frac{\ln(S/K) + (r - y + \sigma^2/2)\, t}{\sigma \text{ sbt}}$$

$$d_2 = d_1 - \sigma \text{ sbt}$$

S = Current value of the stock
K = Strike or exercise price of the option
r = Risk-free interest rate corresponding to the life of the option
σ = Standard deviation in the value of the stock
y = Dividend rate of the stock
t = Time to expiration of the option

Where N(d) is the probability that a random draw from a standard normal distribution (where the mean is zero and σ is one) will be less than d. Of course "e" is the base for the natural logarithm (e = 2.718...) and "ln" is the natural logarithm.

While this formula is a little complicated, it can easily be evaluated by using a spreadsheet model. I have created an Excel spreadsheet model for this formula, named "Real Options Pricing Model.xls", that is available to perform these calculations. Most of the input parameters can also easily be estimated, with the possible exception of the standard deviation. For stock market situations, the input parameters are pretty obvious. However, for other types of situations, such as research projects or natural resources, estimating these inputs is not as straightforward. To help in this understanding, some simple examples will be given in this paper.

NREL is an avid user of real options. NREL has even set up a web site to allow online evaluations of real options: http://analysis.nrel.gov/realoptions/default.asp. At this site they have two online models for real options valuations of renewable energy R&D and valuation of distributed generation assets. The point is that NREL has used real options to support their programs and sees merits in this approach. It is time for NETL to begin using the real options approach as well.

There is a general conclusion that can be made. Research expenditures should have much higher option value in those industries or technologies that are more volatile, since the variance in the future cash flows are much higher. For a NETL example, consider natural gas fired power generation versus coal fired power. Since natural gas prices are much more volatile than coal prices, the development of a better natural gas fired technology has greater option value than development of a coal fired technology, in general. Of course, this doesn't mean that any natural gas fired technology is more valuable than a coal technology – the actual situation needs to be evaluated – but that companies can profit from the uncertainty in the natural gas industry. It does give the "edge" to natural gas fired power generation, however.

Introduction

A real option is a way of calculating the value of a future option in an uncertain world. They were originally conceived in the financial markets as a way to bet on the future. There are two basic kinds of options: call and put, with call options being more common (and useful for our purposes). In the stock market, a call option gives the owner the right, but not the obligation, to purchase the stock at given price for a certain period of time.

For example, say you buy a call option on XYZ stock with an exercise price of $100, good for 90 days. If at the end of the 90-day period, XYZ's stock price is less than $100, then the option is worthless. If however, XYZ is worth $120 at the end of the period, then the call option is worth $20. In other words, as long as XYZ is worth more than $100 at the end of the time period, the call option has a real value. However, if the time period has not yet expired and XYZ worth less than $100, the call option still has a real value since there is always the chance that the stock could be worth more than a $100. This is the idea behind real options – that even a stock (or project) which appears to have no current value, can have a real value in an uncertain world.

In the stock market world, these (unexpired) call options would be valued by the buying and selling of these options, similar to what happens to the underlying stocks themselves. For a long time, this was the only way that options could be valued, i.e., by the market itself. However, some economists have since derived a mathematical formula for valuing options, the famous Black-Scholes Formula. Economists Myron Scholes, Robert Merton, and the late Fischer Black developed this formula, which earned them the 1997 Nobel Prize in Economics.

So why are real options of interest to us? Because they provide a way of valuing research and energy projects in terms of future benefits. Options provide a way of estimating benefits for projects that may or may not become economically viable in the future, but are nevertheless valuable in much the same way that an insurance policy protects its owner, whether or not an actual claim is filed. They can also be used as a tool to evaluate ongoing projects as to whether to deploy, abandon, or continue their development.

The Black-Scholes Formula and Its Input Parameters

The Black-Scholes Formula is the fundamental means to evaluate the worth of a call option, which is basically what a research project represents. While the derivation of this formula is complicated, a brief description of its methodology may be useful. The basic idea behind the formula (in financial situations) is that an investor can precisely replicate the payoff to a call option by buying the underlying stock and financing part of the stock purchase by borrowing. Considering the previous example, suppose that instead of owning the call option, you purchased a share of XYZ stock itself and borrowed the $100 exercise price. At the option’s expiration date, you sell the stock for $120, pay back the $100 loan, and you are left with the $20 difference less the interest on the loan. Note that at any price above the $100 exercise price, this equivalence exists between the payoff on the call option and the payoff from the “replicating portfolio”.

But what about before the call option expires? You can still match its future payoff by creating a replicating portfolio. However, you must buy a *fraction* of a share of the stock and borrow a *fraction* of the exercise price. How much are these fractions? That is what the Black-Scholes Formula tells you.

It states that the price of a call option, C, is equal to a fraction – $N(d_1)$ – of the stock’s current price, S, minus a fraction – $N(d_2)$ of the exercise price. The fractions depend upon six factors, five of which are directly observable. They are: the price of the stock, the exercise price of the option, the risk-free interest rate, the dividend yield for the stock, and the time to maturity of the option. The only unobservable is the volatility of the underlying stock price.

The full Black-Scholes Formula for call options can be written as:

$$C = S\,e^{-yt}\,N(d_1) - K\,e^{-rt}\,N(d_2)$$

where:

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While this formula is a little complicated, it can easily be evaluated by using a spreadsheet model. I have created an Excel spreadsheet model for this formula, named "Real Options Pricing Model.xls", that is available to perform these calculations. Most of the input parameters can also easily be estimated, with the possible exception of the standard deviation. For stock market situations, the input parameters are pretty obvious. However, for other types of situations, such as research projects or natural resources, estimating these inputs is not as straightforward. To help in this understanding, some simple examples will be given.

Various Examples of Using Black-Scholes

Stock Market Call Option

Let's start with a simple stock market example. Suppose we wanted to evaluate the price for a call option for XYZ stock. The current stock price is $100, and the call option has a strike price (or exercise price) of $95, with a life of 90 days. In a simple deterministic (or absolutely certain) world, the call option would be worth exactly $5, since that is the difference between the current price and the strike price. However, in the real world of uncertainty, there is a reasonable chance that the stock could be worth more than $100 in the next 90 days. Hence, the option is worth more than $5.

The risk-free interest rate is the U.S. Treasury rate for notes of 90-day maturity (the same length of time as the option), which is currently around 2.2%. The stock does not have a dividend and the standard deviation of the ln(stock price) is 0.20. Note that the natural log of the stock price is used instead of the price itself. This is because stock prices can never go below zero, as required for standard distributions. Hence the natural log transformation to allow for negative values.

The actual input parameters are as follows:

S = 100 the current stock price
K = 95 the current exercise price
r = 0.022 risk-free interest rate
σ = 0.20 standard deviation of ln(stock price)

y = 0.0 dividend rate of the stock
t = 0.25 time to expiration of option in years

Plugging these values into the Black-Scholes Formula gives us a call option value of $7.247. Note that this is higher than the difference between the stock and exercise prices, which is due to the effect of interest rates and the fluctuation of stock prices. If the interest rate and the standard deviation were both set to zero in the formula, then the option price would be $5. Conversely, the higher the interest rate and the standard deviation are, the more the option is worth. Greater uncertainty makes options more valuable.

Natural resource – Valuing an Oil Reserve

Consider an offshore oil property with an estimated oil reserve of 50 million barrels. The cost to develop the reserves is expected to be $600 million, and the development lag is two years. The firm has the rights to exploit this reserve for the next 20 years, and the marginal value of the oil is $12/B. Once developed, the net production revenue each year will be 5% of the value of the reserve. The risk-free interest rate is 8%, and the variance in ln(oil prices) is 0.03. Starting with this information, we can use the Black-Scholes formula to estimate the value of the property today.

The current value of the asset, S, is equal to the value of the developed reserve discounted back the length of the development lag time at the dividend rate. $S = \$12 * 50 / (1.05)^2 =$ $544.22 million. If development is started today, the oil will not be available for sale until 2 years from now. The estimated opportunity cost of this delay is lost production revenue over the delay period; hence, the discounting of the reserve back at the dividend yield.

The exercise price, or the cost of developing the reserve, is assumed to be fixed over time. Therefore, K = $600 million.

The risk-free interest rate is 8%, and the time to expiration of the option is 20 years.

For this example, we will assume that the only uncertainty is in the price of the oil, and the variance becomes the ln(oil prices) = 0.03.

The dividend yield is the (net production revenue)/(value of the reserve) = 5%.

Using these values and the Black-Scholes formula, we can calculate the value of the reserve to be $97.1 million. While this oil reserve is not viable at current prices, it is still a valuable property because of its potential if oil prices go up.

R&D Projects – Valuing a Patent

Consider a bio-technology firm has developed a patented drug called Wonderdrug, which has passed FDA approval to treat a disease. Assume that you are trying to value the patent to the firm, and you wish to use the Black-Scholes formula for its value.

An internal analysis of the drug today, based upon the potential market and the price that the firm can expect to charge, yields a present value of the cash flows of $3.422 billion, prior to considering the initial development cost. The initial cost of developing the drug for commercial use is estimated to be $2.875 billion, if the drug is introduced today. Thus, from a simple net present value analysis, the value of the project is $3.422 billion – $2.875 billion, for a positive $547 million. In other words, this project would be undertaken in a certain world. However, let's consider the option value in this situation.

The rest of this situation is that the firm has a patent on the drug for the next 17 years, and the corresponding long-term treasury bond rate is 6.7%. While it is difficult to predict the uncertainty or variance in cash flows and present values, the average variance in publicly traded bio-technology firms is 0.224.

It is assumed that the potential for healthy returns exists only during the patent life, and after the patent expires, competition will limit returns to an industry average return. Thus, any delay in introducing the drug, will cost the firm one year of patent-protected healthy returns. Then the dividend rate, or the cost of the delay will be 1/17, and the next year it will be 1/16, etc. Based on these assumptions, we can estimate the following input values to the option pricing formula.

$S = \$3.422$ billion	the present value of the cash flows from drug
$K = \$2.875$ billion	the initial cost of developing drug today
$r = 0.067$	risk-free interest rate for 17 years
$\sigma = 0.224^{0.5} = 0.473$	standard deviation of expected present values
$y = 1 / 17 = 0.0589$	cost of delay (or dividend rate)
$t = 17$ years	patent life

Plugging these values into the Black-Scholes formula gives us a call option value of $0.907 billion, or $907 million. Note that the option value is higher than the NPV value of $547 million, although both values are positive. Thus, it would be profitable whether the company developed the drug right away, or waited.

The additional $360 million value of the option value over the NPV value represents the premium for the optional value created by uncertainty. This can be interpreted to mean that the firm would be better off waiting than developing the drug immediately, never minding the cost of delay. However, the cost of delay will increase over time, and make development of the drug more likely.

Of course, there are many other factors to consider in a real world decision, but this illustrates the potential benefit of such an analysis. And in reality, the firm would consider many other perturbations before making such a decision.

NREL's Real Options Analysis Center

NREL is an avid user of real options. NREL has even set up a web site to allow online evaluations of real options: http://analysis.nrel.gov/realoptions/default.asp. At this site they have two online models for real options valuations of renewable energy R&D and valuation of distributed generation assets. Supposedly, one can go to this web site and run different cases. However, when I visited the distributed generation site, I could not change any of the parameters. But you can see the results of their cases.

In addition, NREL has posted the results of their real options analysis as it applies to renewable energy technologies. They have also collaborated with the Colorado School of Mines to publish a paper: "Optimizing the Level of Renewable Electric R&D Expenditures Using Real Options Analysis", dated June 5, 2001, by Graham A Davis of the Colorado School of Mines, and Brandon Owens of NREL.

The point of mentioning all of this is that NREL has used real options to support their programs and sees the merits in this approach. It is time for NETL to begin using the real options approach as well.

Getting & estimating data for calculations

While the Black-Scholes Formula only has six input parameters, estimating the values for these can often be challenging for real-world situations – even for stock market experts. While the previous examples should be helpful, let's discuss each of the six parameters and how they can be estimated in some more detail.

S, or the current asset value

This is the current value of the project itself, excluding the cost of the up-front investment cost, which is often prepared for standard capital budgeting analysis. While there is often a lot of noise or uncertainty in these estimates, this should not be viewed as a problem, but rather is the reason for performing the option pricing analysis in the first place. If the future cash flows were known with certainty, there would be no reason for options pricing since the options price would be zero.

K, or the exercise price of the option

This is the investment cost for the option. It is assumed that this cost remains constant in present value dollars and that any uncertainty associated with the project is reflected in the future cash flows.

r, or the risk-free interest rate, and t, or the time to expiration

This is the interest rate for U.S. Treasury notes (which are the risk-free standard) for the length of time for the option to be valid. Note that interest rates often change dramatically and quickly as a result of both financial conditions and the actions of the Federal Reserve. While it is easy enough to determine the treasury yields as a function of time from any financial publication, the trickier part is determining what the time to expiration is. While in some cases, such as patent protection, this time period is clear, in many more cases the length of time becomes much fuzzier. In cases of technological innovation, this time period is the time for which the innovation has a clear advantage over the alternatives. Since competitive advantage fades over time, the number of years that the option can be invoked becomes more of an educated guess than a certainty. Thus, in real situations, both the risk-free interest rate and the time to expiration become somewhat difficult to estimate.

σ, or the standard deviation of the expected returns

Of all the parameters that must be estimated, the standard deviation is probably the most difficult. First of all, it's not likely to be a quantity that most people track or even think much about. Second, even if this variable is tracked, it becomes difficult to accurately measure. And finally, there is always the problem that while historic values may be known, that "this time is different". With these difficulties in mind, how does one estimate the standard deviation? This question cannot be ignored, since the existence of the deviation is the reason for the value of real options – if there were no deviation, the real option value would be zero. There are at least three practical ways to estimate the standard deviation.

1. If similar projects have been undertaken in the past, the variance in the cash flows from those projects can be used as an estimate. This is probably the best way if the latest project is not too different from the previous projects.

2. Either decision tree or Monte Carlo analyses can be performed to estimate the total variance or deviation across all likely scenarios. With decision trees, probabilities can be assigned to various market scenarios, the cash flows estimated under each scenario, and the variance estimated across the present values. Monte Carlo analyses are usually performed with spreadsheet add-on software such as @Risk or Crystal Ball where probability distributions are estimated for each of several key input parameters – market size, market share, profit margins, etc – and simulations run to determine the variance in the present values.

3. The variance of the value of companies involved in the same business as the project being considered can be used as an estimate for the variance. For example, the variance of the stock price of a natural gas exploration company can be used as a proxy for the variance in a natural gas field development project.

y, or the dividend rate

The dividend rate is also considered to be the cost of delay, which is the more appropriate concept for NETL evaluations. If we were interested in only stock market options, the dividend rate is the appropriate term to employ here. In the stock market, the company is paying dividends, and thus its future value is reduced by the dividend payments. Thus, it is part of the cost for the option holder not to receive these dividends while waiting.

However, for our purposes, the better concept is the cost of delay (which is really the same idea in different words). Since the project expires after a fixed time period (or at least loses value), each year of delay translates into one less year of cash flows. If the cash flows are evenly distributed over time, then the annual cost of delay is 1/(life in years), or 1/t in terms of the Black-Scholes formula input parameters. Thus, if the life of the project is 10 years, then the annual cost of delay is 1/10 or 10%. Note too, that the cost of delay rises each year to 1/9 in year 2, 1/8 in year 3, etc.

Conclusions

Real options analysis can provide useful insight into decision making since it incorporates the uncertainty in the future – and uncertainty is inevitable. Real options, quantified via the Black-Scholes formula, provide a sound mathematical and financial basis for estimating the value of this uncertainty.

There are some other observations that should be fairly obvious by now. First, research expenditures should have much higher option value in those industries or technologies that are more volatile, since the variance in the future cash flows are much higher. For a NETL example, consider natural gas fired power generation versus coal fired power. Since natural gas prices are much more volatile than coal prices, the development of a better natural gas fired technology has greater option value than development of a coal fired technology, in general. Of course, this doesn't mean that any natural gas fired technology is more valuable than a coal technology – the actual situation needs to be evaluated – but that companies can profit from the uncertainty in the natural gas industry. It does give the "edge" to natural gas fired power generation, however.

Finally, the real options tool, like any other tool, must be used wisely. If used blindly, real options may be used to justify bad decisions. Real options are just another way of viewing and analyzing a decision. Real options can be used or abused just as any other analysis method can be. Ultimately, there is no replacement for common sense.