An Option-Theoretic Approach to Capital Investment

*Firm Financial Decisions: Uncertainty and Real Options*

**Real Option Analysis (ROA)**

One of the more intriguing applications of options pricing theory is in the realm of large-scale, complex capital investment analysis. When options are used in this context the instrument is often referred to as a “real” option. The term “real options” is used when:

- Some or all of the underlying assets are not traded (priced in the market).
- The underlying asset(s) may, or may not, have measurable correlation with other traded assets. Hence, unlike for traded assets, ROA is designed to develop a plan of action to deal with contingent future events.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Black-and-Scholes</th>
<th>Real Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise</td>
<td>European</td>
<td>America</td>
</tr>
<tr>
<td>Sources of Uncertainty</td>
<td>Single</td>
<td>Multiple</td>
</tr>
<tr>
<td>Constant Variance</td>
<td>Yes</td>
<td>Stochastic</td>
</tr>
<tr>
<td>Dividends / Convenience Yield</td>
<td>None</td>
<td>Multiple sources</td>
</tr>
<tr>
<td>General Brownian Motion</td>
<td>General Brownian Motion</td>
<td>Stochastic Interest Rates</td>
</tr>
<tr>
<td>Constant Exercise Price</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

For example, consider the following option payoff diagram for a long position in a call option. As the price of the underlying increases, reaching and then exceeding, the strike price X, the payoff of the option increases in a linear manner. However, in the case of a real option, the payoff depends on the probability distribution of the price. The distribution may, on the one hand, be described as an expected price (estimated) or, on the other, by a risk-neutral price distribution (Martingale).
In such a case, the time value of the option is dependent on: a) the distribution of the underlying price series and b) the time to expiration. A short summary of how option contracts assist in the valuation of capital projects is provided below.

### Capital Project Decision

<table>
<thead>
<tr>
<th>Capital Project Decision</th>
<th>Type of Option(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defer an investment (e.g., adopt next year after new information becomes available).</td>
<td>American call</td>
</tr>
<tr>
<td>Expand a plant or invest in plant upgrades to extend plant life</td>
<td>Portfolio of American call options</td>
</tr>
<tr>
<td>Reduce plant scale or abandon</td>
<td>Portfolio of American puts</td>
</tr>
<tr>
<td>Switch fuel sources</td>
<td>Portfolio of American calls and puts</td>
</tr>
<tr>
<td>Switch modes of operation</td>
<td>Portfolio of American calls and puts where there is a need to value the trade-off of flexibility versus the value of the option</td>
</tr>
<tr>
<td>Second Phase Plant expansion</td>
<td>Compound options</td>
</tr>
</tbody>
</table>

**Figure 8:** Payoff vs Price

**Table 6:** Capital Project Decisions
ROA Drivers

**Figure 9:** Drivers of ROA

- **Increased project uncertainty**
  - Chance options in-the-money
- **Increased room for management flexibility (modularity)**
- **NPV without flexibility close to 0**
- **Longer time to expiration**
  - Investment horizon
- **Increased interest rates**
  - Option to defer, contract more valuable
- **Less competition (game theory)**
  - Option to defer more valuable

**Relevance of ROA**

- **Likelihood for new info**
  - H: High
  - L: Low

- **Flexibility**
  - H: High
  - L: Low

Source: Roland Berger, Strategy Consultants
Example of ROA in Large-Scale Complex Capital Investment Decisions

Source: Roland Berger, Strategy Consultants
NPV is:

- Often misapplied
- Ignores strategic values if misapplied

By contrast, Real Option Valuation:

- Values contingencies in project outcomes – where a contingency is defined as an alternative future use of the asset.
- Many types of real options – key is to identify
- Difficult to value – however, the DM can usually identify whether it adds or subtracts value to a project

**Input Mix Options or Process Flexibility**

- The option to use different inputs to produce the same output
- Example (agriculture): a beef producer will value the option to switch between various feed sources, preferring to use the cheapest acceptable alternative.
- Example (utility): An electric utility may have the option to switch between various fuel sources – an electric utility that has the option of building a coal-fired plant or a plant that burns either coal or gas.

**Output Mix Options or Product Flexibility**

- The option to produce different outputs from the same facility
- Example (Toy Industry): a manufacturer's ability to shut-down the production of a toy style that has become dated. Or, to quickly begin producing a popular new style of toy.

**Abandonment or Termination Options**

- Traditional capital budgeting assumes that a project will operate in each year of its projected lifetime.
- The firm may have the option to terminate a project during its life
- An abandonment option is the right to sell the cash flows over the remainder of the project’s life for some salvage value. That is, when the present value of the remaining cash flows falls below the liquidation value, the asset may be sold.
- This is similar to an American-style put option.
- Example – particularly important for large capital intensive projects such as nuclear plants, airlines and railroads.
- Also important for projects involving new products where their acceptance in the market is uncertain.
Temporary Stop or Shutdown Options

- Considered for a production facility where it is not optimal to operate a plant for a given period if revenues will not cover variable costs.
- Example: price of oil falls below the cost of extraction – it may be prudent to temporarily shut down the oil well until the price recovers.
- Example (farming): exercise the option if the cost of fertilizing, watering and harvesting exceeds the sale price of the product.
- Example (real-estate development): exercise the option if the cost of construction exceeds rent revenues.

Intensity or Operating Scale Options

- These options involve the flexibility to expand or contract the scale of the project.
- In order to obtain the option to expand production if demand increases suddenly, a firm may build production capacity in excess of the expected level of output.
- In such a case, management has the right, but not the obligation to expand, and will exercise the option only if project conditions turn out to be favorable.
- Excess capacity has an initial cost but the option to expand is worth more than the project without the possibility of expansion (the extra cost is justified).
- Alternatively, a firm may build a plant whose physical life exceeds the expected duration of use, thereby providing the firm with the option of producing more by extending the life of the project.

Option to Expand

- Build production capacity or the infrastructure for the capacity in excess of expected level of output (firm can choose to produce at a higher rate if needed).
- Option – management has the right, but not the obligation, to expand.
Option to Contract

- This is equivalent to a put option
- Many projects can be engineered so that output can be contracted in the future.
- Forgoing future expenditures is equivalent to exercising the put option.
- Example: modularization of project.
Switching Option – the Option to Expand or Contract

- This is equivalent to the firm having a portfolio of call and put options.
- Restarting operations of a shut downed plant – a call option
- Shutting down a producing plant – a put option.
- Example: a project whose operations can be dynamically turned on and off (or switched to two distinct locations). This flexibility has value.

Switching Option (Expand or Contract)

Initiation or Deferment Options

- The option to choose when to start a project
- Particularly valuable in natural resource exploration where a firm can delay mining deposits until market conditions are favorable.
- Example: the purchaser of an off-shore lease can choose when, if at all, to develop property.
Intra-project vs. Inter-project Option

- Inter-project: arise when the development of one project creates value that attach to other projects.
- Example: sequencing options create value for subsequent projects as the direct result of undertaking the initial project.
- Traditional capital budgeting analytics miss this option because projects are evaluated on a stand-alone basis.

Growth Options

- The value of the firm can exceed the market value of the projects currently adopted because the firm may have the opportunity to undertake positive NPV projects in the future.
- Traditional capital budgeting techniques involve the establishment of present values based on anticipated implementation dates (implicitly assumes the firm is committed to go ahead with all positive NPV projects).
- Growth options permit management to retain the option to exercise only those projects that appear to be profitable at the time of initiation.
- Example (software): high-tech and software industries where there are significant first-mover advantages.

Shadow Costs

- Traditional valuation methods may overvalue some projects by failing to recognize the losses in flexibility to the firm that result from implementation.
- The acceptance of one project may eliminate options that attach to other projects.
- Example: building a plant in a particular city eliminates the options to expand the capacity of plants in nearby cities.

Financial Flexibility

- Choice of capital structure can affect the value of a project.
- Financial flexibility can be measured by the value of the financial options made available to the firm by its choice of capital structure.
- Interaction between financial and operating options can be strong – especially for long-term investment projects with high uncertainty.
**Detailed Real-Option Example: Abandonment**

Abbeytown Copper 2 year lease over a known deposit.

Deposit contains eight (8) million pounds of copper. Mining involves a one-year development phase, at a cost of $1.25 million immediately. Extraction costs (outsourced) at $0.85 / pound at beginning of extraction phase (one-year after development phase is initiated). Sale of copper would be at spot price of copper as of beginning of extraction phase. Current spot price of copper is $0.95 / pound. Log change in copper prices are normally distributed with mean of 7% and standard deviation of 20% (p.a.) Abbeytown’s required rate of return for this project is 10%, and the riskless rate is 5%

**Traditional NPV Analytics**

\[
\text{Expected NPV} = 1.25 + \frac{8(E[S_i] - 0.85)}{1.1}
\]

Where \(E[S_i]\) is the expected price of copper in one year’s time.

Current price of Copper, \(S_0 = 0.95\) Expected rate of return on copper, \(r = 7\%\)

Expected price of copper in one year, \(S_i = 0.95e^{0.07} = 1.0189\)

Hence \(E[\text{NPV}] = -1.25 + 8(1.0189 - 0.85) / 1.1 = -0.022\)

REJECT as NPV < 0

**Option Analysis**

\(S = 0.95 * 8 = 7.6\)

\(k = 0.85 * 8 = 6.8\)

\(r = 5\%\)

\(T = 1\) year

\(\sigma = 20\%\)
Call Value = 1.3
Option Cost = 1.25
Option – Adjusted Present Value = 0.05

ACCEPT

Why does the option to abandon have value? Management can choose to abandon the project if the price of copper is low after one year.

What is probability that the firm will abandon? 1 – Prob(exercise)

\[
= 1 - N(d2) \\
= 1 - 0.76 = 0.24
\]

End of lecture.