Introduction to Real Options

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It is 1982, and your firm is evaluating entry into the PC business.

Entry is **now or never**. Delay will concede the market to other players.

Project NPV for "Mark I" appears to be about negative, approx. – $100 million.

What about strategic motives? If you enter today, you will have an option to go on with a "Mark II" micro in a few years as the technology evolves and the market grows.

Unfortunately, based on best current information, the Mark II seems to be just a bigger and riskier project than the Mark I.

» Given the tremendous uncertainties in predicting the PC market, you feel that the NPV of Mark II is anyone's guess, but your best point estimate is –$200 million.

» In addition, you are keenly aware of the vast risk associated with the follow-on project.
Risk and Opportunities

- Conclusion: you go ahead with the project, *precisely because Mark II is so "risky."*
- Why?

- In three years, the Mark II will not be as uncertain as it is today: you will have a better sense of its NPV.

- NPV of Mark II in three years will be:
  - –$900 million if the PC market flops
  - –$200 million if the PC market is mildly successful
  - +$500 million if the PC market takes off

- Expected NPV is indeed –$200 million. Is this a bet worth taking?
The Mark II Option

- **Absolutely.** In three years you have the *option* to pursue the Mark II. You can always walk away from the Mark II then. Conditional on your go-ahead in three years, NPV will be:
  - 0 if the PC market flops
  - 0 if the PC market is mildly successful
  - $500 million if the PC market takes off

- With equal probabilities, the Mark II represents a "lottery ticket" on the PC industry, with expected payoff of $167 million.
When Mark II is Riskier

- The more uncertain you are about the prospects of the Mark II, the more you should be willing to pursue the investment.
- Suppose the forecasts are:
  - $1000 million if the PC market flops
  - $200 million if the PC market is mildly successful
  - $600 million if the PC market ignites
- Expected NPV is still $200 million.
- Conditional on your go-ahead in three years, NPV will be:
  - 0 if the PC market flops
  - 0 if the PC market is mildly successful
  - $600 million if the PC market takes off
- The expected payoff of your "ticket" is now $200 million.
Investing in Mark I is like buying a Call Option

- The *option* to invest is worth most precisely when "you don't have a clue" what NPV will be. You will pay up for the right to invest in the later stage if it turns out to be great, but to walk away if it turns out poorly.

- The negative NPV of the Mark I is the "price" of acquiring a call option on the Mark II.

- How can we value such options?
Valuing the Mark I Option

This is precisely the payoff to a call option, and suggests that option pricing models may help us to place a value on real options -- that is, options on real (as opposed to financial) assets.
Contingent Claims Valuation

- Option valuation models are based on the notion of replication.

Form a replicating portfolio by buying 1/2 share of IBM, financing the purchase in part by issuing a one-period IOU with face value $25.

The portfolio "replicates" the payoff of the call. Therefore, it must have the same value, \(0.5 \times $100 - \text{PV}(\$25)\).
Real Options and Decision Trees

- Replication allows us to value the real option without knowing the probability distribution of stock prices and, more specifically, without making any assumptions about the expected rate of return on the stock.

- This is the important difference between the "real options" approach and the related "decision tree" approach to valuation.
  - It brings the discipline of financial markets to corporate strategy.
  - Shows that, when properly managed, uncertainty can provide valuable opportunities.

- What about the more realistic case in which there are more than two states?
In a small neighborhood around $S_0$, the call option value function is "approximately linear" around the tangency line.
Real options formulation

**Modeling the Mark II option as a call**

- **Mark I buys a 3-year call on Mark II.**
  - \( S_0 = 400 \) (current estimate of PV from Mark II)
  - \( X = 500 \) (investment needed for Mark II)
  - \( T = 3 \) years
  - \( s = 40\% \)

- **Black-Scholes Price of Call = $98 million**

- **With $50m “cost”, Mark I buys an option worth $98m**
Option Pricing: Intuition

• If the stock price can move by only small amounts in small time periods (note that this is an assumption about continuity), then over the next small time period, $\Delta t$, the option and the stock will be perfectly correlated.
• In this case, the option return can be perfectly hedged by the stock, or equivalently, the option return can be perfectly replicated by a combination of the stock plus some borrowing position.
• Again, instantaneous perfect correlation allows us to replicate the option return instant by instant, and thus to obtain a valuation formula without knowledge of the probability distribution of the underlying stock.
• In a sense, the relevant information about that distribution is reflected in the stock price, which serves as a "sufficient statistic."
Going from CCA to RO

- Imperfect replication: convenience yield, “tracking error”.

- Complex decisions: compound options

- Sub-optimal decisions: organizational constraints (decision rights, incentives, budgets)
Imperfect Replication

- right to buy traded firm at fixed price in 6 months (*traded stock*)
- right to buy an inventory of copper at fixed price in 6 months (*commodity with convenience yield*)
- contract to buy 1 months of refining capacity in 6 months. Will only operate if crack spread is greater than operating margin. (*crack spread with time varying, state dependent convenience yield*) Akin to contracting for olive presses before the harvest
- contract to buy 1 month of generating capacity in 6 months (*spark spread with basis risk and convenience yield*)
- contract to buy 1 month of chip making capacity in 6 months (*SOX/SXE chip index*). Similar to the *Band-X index* contract for telecom bandwidth.
- right to launch new product in 6 months (*tracking error with proxy traded firm: KSR*)
Modeling the ‘basis’

- Observable payouts
- Impute convenience yield from futures market
- Use index as proxy
- Use equilibrium risk-pricing models to get convenience yield
Complex decisions

- Operating a copper mine (Critical copper prices for shut down and startup, abandonment)
- Staged R&D (continue, stall, abandon)
- Wide set of choices
- Investment decisions may influence future prices (imperfect competition)
The Real Options Frontier

Distance from Markets

But, securitization is pushing out the frontier….
More Real Options

- Investment timing. Consider a $10 million investment with a PV of $100. Should the firm proceed with the investment?

- The investment timing decision is analogous to the problem of when to exercise an American option. You would not exercise as soon as it goes in the money by some trivial amount.

- FDIC insurance. The FDIC is on the hook for $\text{max}(L - A, 0)$.

- This is a put option. Interesting issue: we've seen that uncertainty affects option value. Here, asset volatility is in the hands of the bank. What is the moral hazard problem? Why doesn't limited liability make other borrowers just as subject to moral hazard as the thrifts turned out to be?
More Real Options

➡ Why would a municipality build a 6-lane bridge that is part of a 4-lane highway system?

➡ Why do firms invest in excess IT capacity?

➡ Under what conditions would a utility build a dual-fuel power plant?

➡ What are the operating options embedded in a petroleum refinery?

➡ What are the options in a gold mine?
More Real Options

- Why is the market value of Lucent $100, when Earnings $2.21 per share, Capitalization rate = 15%, Price based on current earning = $14.65?

- An in house analysis to expand a chemical plant shows a positive NPV on a conventional discounted cash flow basis. You want to get a better fix on product demand before proceeding. What real option would the in house analysis have ignored?

- A major river development project in Brazil involves irreversible changes to the ecosystem. A thorough cost-benefit analysis which takes into account all effects arising from the project indicates that the project is marginally feasible, i.e., has a small positive net present value. How would real option considerations affect your decision?
More Real Options

- East West Telecom (a semi-government communications equipment manufacturer in Korea) proposes a fully integrated, automated production line for new digital switches. They have rejected more standard, less expensive equipment because the automated line is more efficient overall, according to a conventional discounted cash flow analysis. What real option may be ignored in their analysis?

- Western Telecom commits to production of digital switching equipment specially designed for the European market. The project has a negative discounted cash flow NPV, but is justified by the need for a strong market position in the rapidly growing, and potentially very profitable, market. How has Western Telecom implicitly taken into the embedded real options?
Problem 1


The XYZ firm can invest in a new DRAM chip factory for $500 million. The factory, which must be invested in today, has cash flows two years from now that depend on the state of the economy. The cash flows when the factory is running at full capacity are described by the following tree diagram:

In year 1, the firm has the option of running the plant at less than full capacity. In this case, workers are laid off, production of memory chips is scaled down, and the subsequent cash flows are half of what they would be when the plant is running at full capacity.

An alternative use for the firm's funds with similar risk is an investment in the market portfolio. In the states that correspond to the branches of the tree to the left, $1 invested in the market portfolio grows as follows:

Assume that the risk-free rate is 5% percent per year, compounded annually. Compute the project's present value (a) with the option to scale down and (b) without the option to scale down. Compute the difference between these two values, which estimates the value of the scaling option.
Problem 2

Vacant land has been zoned for either one 10,000-square-foot five-unit condominium or two single-family homes, each with 3,000 square feet. The cost of constructing the single-family homes is $100 per square foot and the cost of constructing the condominium is $120 per square foot. If the real estate market does well next year, the homes can be sold for $300 per square foot and the condominiums for $230 per square foot. If the market performs poorly, the homes could be sold for $200 per square foot and the condos for $140 per square foot. Today the homes could be sold for $225 per square foot and condos for $180 per square foot. First-year rental rates (paid at the end of the year) on the condos and homes are 20 percent and 10 percent, respectively, of the initial sales prices.

a. What is the implied risk-free rate, assuming that short selling is allowed?

b. What is the value of the vacant land, assuming that building construction will take place immediately or one year from now? What is the best building alternative?
Widget production and sales take place over a one-year cycle. For simplicity, assume that all costs (revenue) are paid (received) at the end of the one-year cycle. A factory with a life of three years (from today) has a capacity to produce 1 million widgets each year (which are to be sold at the end of each year of production). Widgets produced within the last year have just been sold.

Each year, production costs can either rise or decline by 50 percent from the previous year’s cost. Over the coming year, widgets will be produced at a cost of $2 per widget. Unlike production costs, which vary from year to year, the revenue from selling widgets is stable. Assume that in the coming year and in all future years the widget selling price is $4 per widget.

The performance of a portfolio of stocks in the widget industry depends entirely on expected future production costs. When widget production costs increase by 50 percent from date t to date t + 1, the return on the industry portfolio over the same interval of time is assumed to be -30 percent. If the production costs decline by 50 percent, the portfolio return is assumed to be 40 percent over that time period.

Assume that the factory producing the widgets is to be closed down and sold for its salvage value whenever the cost of extraction per widget exceeds the selling price of a widget. This closure occurs at the beginning of the production year.

Value the factory, assuming that its salvage value is zero and that the risk-free return is 12 percent per year.
A new product has two major potential markets. The product will succeed in both or fail in both, with equal probability. The markets are otherwise independent. You may enter the markets sequentially or simultaneously either now, one year from now, or two years from now. Later entry is not feasible. Market A requires an initial investment of $100 regardless of when it is entered. If the product is successful, market A will have a present value of $150 one year after entry. If the product fails, market A will be worth $90 one year after entry. Market B requires an initial investment of $55 regardless of when it is entered. One year after entry, B will have a present value of $130 or $20 for success and failure, respectively. For simplicity, perform all discounting in the problem at 5%.

a. What is the NPV for each market, assuming each is entered immediately?

b. What entry strategy is optimal? Is there a general rule?