Real Options – Introduction

Amsterdam, June 4th, 2002
Summary

I. Why should CEOs worry about “real” options – what are they?
II. Examples in Pharma, Oil & Gas, Semiconductors, Energy, Aircraft
III. Current trends; quotes from Copeland, Myers, et al.
IV. What are differences between NPV analysis, Decision Analysis, and Real Option Analysis? A quick overview.
   – Risk adjusted discount rate, twin security
   – Replicating portfolio and arbitrage arguments
V. Methods to calculate option value
   – Pros and cons of each approach
   – No discussion of stochastic processes or stochastic control theory

Sources: Copeland, Trigeorgis, Schwartz, Amram, Luenberger, Myers
Why should CEOs worry about “real” options

- The right, but not the obligation, to take an action at a pre-determined cost (exercise price), for a pre-determined period of time (time to expiration). Applies to strategic, as well as financial options.
  - Defer, expand, contract, abandon a project over time

- NPV analysis underestimates project value!
  - *Every project has embedded real options*

- CEOs will miss opportunities if they ignore option value
  - In bidding contests, a bidder needs to know full value of investment opportunity, for itself and for other bidders
  - In screening investment opportunities, low risk projects incorrectly get precedence over higher flexibility projects with increased risk.
  - CEOs intuitively understand value of flexibility – but there is a disconnect with CFOs that pre-dominantly use static DCF analyses
What is real about “real” options

- Financial options can be valued using arbitrage arguments
  - Replicate pay-offs using dynamic portfolio of traded underlying asset(s) and risk-free bond
  - Since portfolio pay-offs are equivalent to option pay-offs in each state of nature, price is the same as well

- Real options have two unique characteristics
  - Some or all of the underlying asset(s) are not traded (priced)
  - Underlying assets might, or might not have correlation with other traded assets

- Real Options Analysis (ROA) generally used for strategic decision making, traditional option analysis most used in trading
  - ROA provides plan of action contingent on future events
What is difficult about real options

**Assumptions B&S → SIMPLE**
- European – no early exercise
- One source of uncertainty
- No dividends
- General Brownian Motion
- Constant variance, exercise price

**Real options → COMPLEX**
- American – early exercise
- Multiple risk factors
- Convenience yield, Carrying costs
- Mean reversion, etc.
- Stochastic interest rates
- Incomplete markets
- Insufficient data
- Transaction costs, liquidity

**Probability distribution of price:**
- Expected (estimated), or
- Risk neutral (Martingale)

**Time value of option dependent on:**
- Distribution of underlying
- Time to expiration
Types of options on projects/investments

- Defer an investment for later, contingent on new information
  - An American call option

- Expand, extend the life of a project
  - A portfolio of American calls

- Scale back, abandon a project
  - A portfolio of American puts

- Switch between two fuel types, two modes of operation
  - A portfolio of American calls and puts
  - Trade-off the cost of flexibility versus the value of option to switch

- Invest in phase II, contingent on investment in phase I
  - Compound options
Drivers of real option value, relevance 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
  - Low
  - Moderate
  - High

- Flexibility
  - Low
  - Moderate
  - High

- Ability to respond
  - Low
  - Moderate
  - High
Simple example of valuing a startup

BUSINESS IDEA:
- Costs are known for sure:
  - Product development: $4M (2y)
  - Launch costs: $12M (after 2y)
- Expected sales: $6M per year
  - Value established firm: $22M (revenue multiple of 3.66)

STATIC NPV:
- PV development (6%) $3.8M
- PV launch (6%) $10.9M
- PV business (21%) $14.5M

Net Present Value: ($200,000)
(DCF analysis ignores flexibility)

A FINANCIAL CALL OPTION
- Option price
- Exercise price (K)
- Exercise date
- Current stock price (S)
- Return standard deviation

OPTION TO LAUNCH (EUROPEAN)
- PV of development costs
- Cost of launch (K)
- Launch date
- Current expectation of value (S)
- Firm value volatility
Simple example of valuing a startup (contd.)

- Launch decision is call option
  - Product development cost is price of this option
  - Launch if in 2 years: PV firm > Launch costs

- Black & Scholes:
  - Cost of launch (K): $12.0M
  - Firm value (S): $14.5M
  - Firm volatility: 40%
  - Risk free rate: 6%

  OPTION VALUE: $5.0M

- ROA analysis:
  $5M - $3.8M = $1,200,000

- Add option to abandon project
  - American; solve numerically
  - Include both options in analysis

- Value of options: $5.6M

- ROA analysis = $1,750,000

- Determine firm volatility using simulation of static DCF model
  (without management flexibility)
  - Volatility of firm is not the same as volatility of underlying
  - Examples of underlying: price, market size, etc…
Example in Aircraft sales – embedded options

- Airbus and Boeing compete for long term orders in a cyclical capacity driven industry
  - Aggressive market share targets to recoup aircraft model costs
  - Time lag between orders and delivery
- Traditional “approach”: the more purchase rights (options) handed out (at a certain exercise price) the more orders follow …
  - These options are more valuable to airlines with higher volatilities
  - Segment market – discriminate smaller more volatile airlines
  - Also control time to expiration
- Other practical issues to value embedded options:
  - Mean reversion, lead time after exercise
  - Yield on each aircraft (analogous to dividends)
  - Swap between aircraft types: switching options
Compound (rainbow) options

- Large capital, R&D, Marketing outlays upon revelation of new information in each project phase
  - Semi-conductor manufacturing
  - Pharmaceuticals
  - Oil & gas

Cost
Market size
...

Design
• R&D
• Exploration

Fully Commit
D
Abandon

Build
• FDA approval
• Build wells

Fully Commit
D
Abandon

Competition
Price
...

Aggressive
• Commercialization
• Production

Defensive
• Commercialization
• Production

Abandon project

Current
+1 year
+2 years
Examples in Gas & Power

VALUING A POWERPLANT
- Gas powerplant can be turned on and off based on demand
- Two stochastic price processes; spread is what matters most
  - Electricity demand varies with weather, etc.
  - Fuel cost varies with gas-supply, related to local storage and transportation capacity
- Powerplant is series of calls; switch on when Price > MC
  - If two fuel types: incorporates a series of switching options

VIRTUAL STORAGE
- Sell the ability to store gas when prices are low
- One stochastic process: gas price (mean reversion?)
- No simple solution
  - Path dependency
  - Constraints: empty and full
- Value using stochastic dynamic programming approach
  - Storage empty at end of lease
  - DP works backward in time
  - Storage empty at start of lease
Quotes…


- “It took decades for DCF analysis to replace payback period analysis, the same will happen for real option analysis”, Copeland (2001)

- “Airbus management was slowly persuaded of competitive advantages of valuation of embedded options in contracts”, Stonier (2001)

- “A key advantage of ROA is that it is a gradual improvement, inherently incorporating DCF analysis”, Antikarov (2001)
Developments in real option analysis

PAST
- Traded commodities
- Closed form solutions
- Single uncertainty
- Simple options
- *Limited computer power*

CURRENT DEVELOPMENTS
- Market & private uncertainties
- Rainbow options
- Compound options
- Switching options
- Barrier options
- Look-back options
- Asian options
- Mean reversion, shocks
- Stochastic term structure
- *Abundant computer power*
Option Valuation and Arbitrage

THE REPLICATING PORTFOLIO

- **With flexibility:**
  - Investment: $115k
  - Period-1 CFs: $170k, $65k (with equal probability)
  \[ \Rightarrow \text{Pay-out profile: $55k, $0} \]
- **One uncertainty ⇒ one security S:**
  - Period-0 price: $20
  - Period-1 prices: $34, $13
  \[
  \text{(Bank account B with return: } r_f = 108\%)\]
- **The portfolio; S shares, B cash:**
  \[
  \begin{align*}
  S \times 34 + B \times r_f &= 55k \\
  S \times 13 + B \times r_f &= 0 \\
  \end{align*}
  \]
  \[ \Rightarrow \text{solve: } S = 2.6; B = -31.5 \]
  \[ \Rightarrow \text{PV}_0 = S \times 20 - B \times 31.5 = 21k \]
  \[ \Rightarrow \text{Implies that no arbitrage is possible} \]

RISK NEUTRAL PROBABILITIES

- **Short cut method:**
  - Security prices: \( P \)
  - Portfolio weights: \( w \)
  - Option payout:: \( p \)
  \[
  \text{Set: } P \times w = p \Rightarrow w = P^{-1} p \]
- **State prices:**
  - Portfolio value such that pay-out is $1 in one state, $0 in other states.
  - Price increased for “bad” states
  - Normalize with risk free rate:
  \[ \Rightarrow \text{risk-neutral probabilities} \]
  \[
  \text{PV}_0 = \frac{\text{“E”} [\text{CF}_1]}{r_f} \]
  - Risk neutral expectation “E”
  - Use for any pay-off profile
NPV Analysis versus Decision Tree Analysis versus Replicating Portfolio Approach

NPV ANALYSIS (NO OPTIONS)

- Value traded asset using DCF:
  \[ V_0 = E[CF_1] / R = $20 \] (e.g. stock)

- Back out risk adjusted discount rate (R) if \( V_0 \) is known (traded) \( \rightarrow R = 118\% \)
  - Input likelihood of each \( CF_1 \) (state)
  - Use R to value perfectly correlated asset (not traded) \( \rightarrow PV_0 = $100k \)

- Alternatively use replicating portfolio approach: twin security and cash
  - *Law of one price*: same payouts in each state \( \iff \) same price \( \rightarrow PV_0 = $100k \)

- Subtract PV of investment of $115k
  \[ NPV = PV_0 - $115k/r_f = $100k - $106k \]

DECISION TREE ANALYSIS OF OPTION

- Add option to react to new information *before* investment
  - Abandon in states where \( CF_1 < Investment \)

- Payout profile changes: due to downside protection
  \[ NPV = E[NCF] / R = $23k \]
  - Static R is wrong !!

*DTA requires changing R per node since risk level changes per node*

- Value using replicating portfolio:
  \[ NPV = $21k \] (see previous slide !)

\[ \Rightarrow \text{Total option value: } $21k - -$6k = $27k \]
Example in Oil & Gas – *private uncertainty*

- **Risk neutral probabilities** …
  - Are determined from a no arbitrage condition on traded securities
  - Do not require subjective probabilities, or an assessment of expected return (!)
  - Can be used in multi-period setting

- **Incomplete markets** …
  - If no solution to: \( w = P^{-1} p \)
  - For example technology risk, or oil reserve risk

- **Solve with traditional DTA:**
  - Use private probabilities
  - If fully uncorrelated with market: use risk free rate (CAPM)

- **Exploration and Production**
  - Future oil prices, and total reserves are unknown

- **Build multi-dimensional lattice**
  - Two risk factors
  - Mixed real- and risk neutral probabilities for private and market risks respectively
  - Discount using risk-free rate

- **Mean reversion in oil-prices can easily be incorporated**
  - Parameters can be inferred from historical data, or traded securities (*Options and futures on oil*)
Closed form versus simulation

- **Black & Scholes** – closed form solution of Differential Equation
  - No early exercise, etc…
  - Many extensions; most need to be solved numerically

- **Trees and lattices**
  - Binomial, quadranomial, multi-dimensional
  - Lattice branches recombine; *computational tractability*

- **Finite differences**
  - Similar to lattice approach, but directly solves differential equation

- **Stochastic control. Dynamic Stochastic Programming**
  - Portfolio management; limit state space to wealth level