Real Options – Introduction

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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

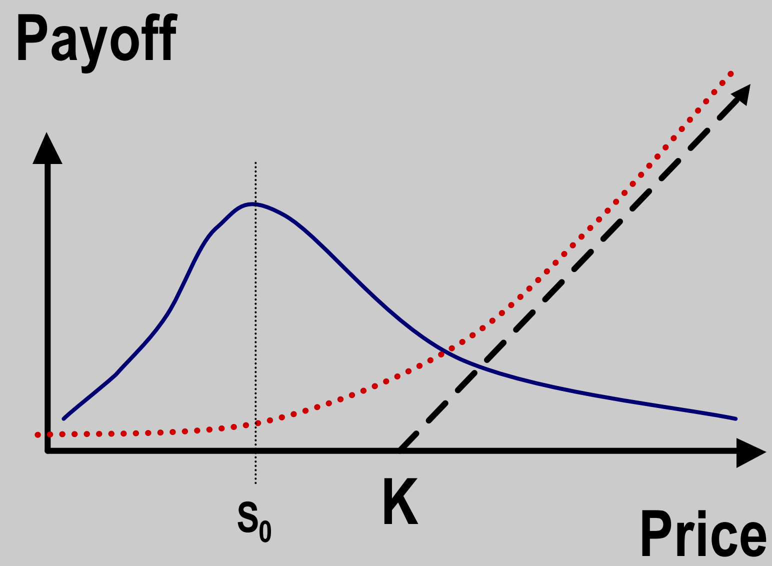
What is real about "real" options

- **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

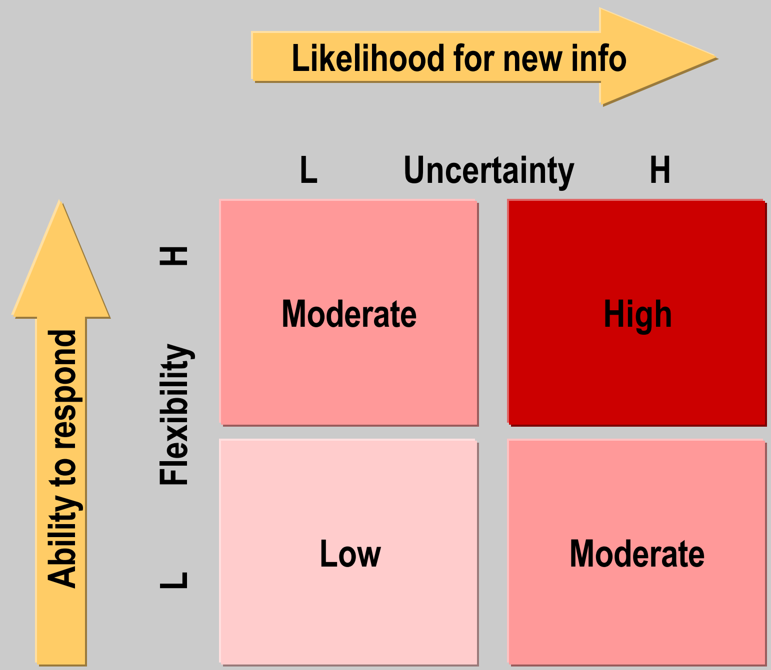
- **Defer an investment for later, contingent on new information**
  - An American call option
- **Expand, extend the life of a project**
  - A portfolio of American calls
- **Scale back, abandon a project**
  - A portfolio of American puts
- **Switch between two fuel types, two modes of operation**
  - 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**



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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…*

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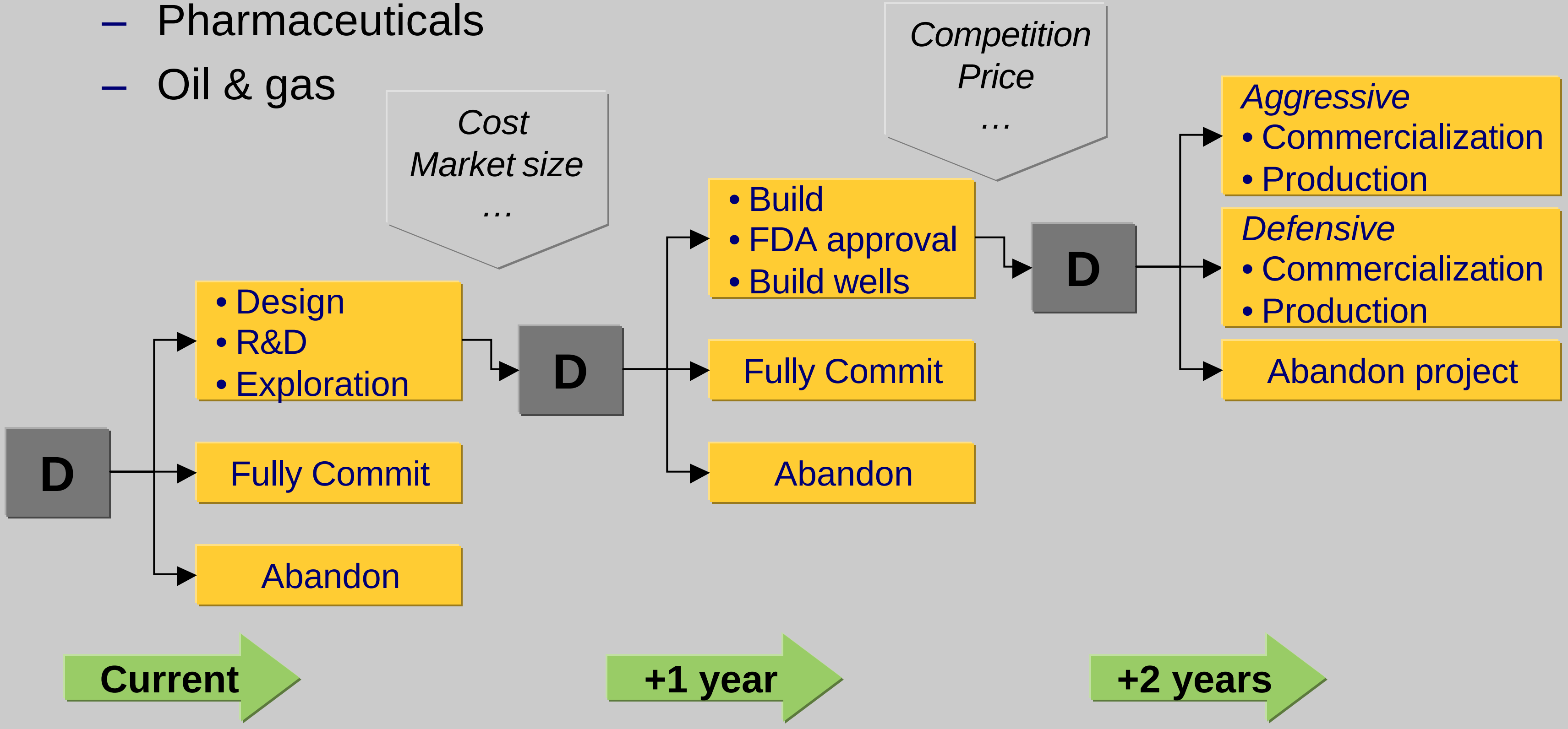
Example in Aircraft sales – embedded options

- **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



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

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Quotes…

- *"Many unspoken assumptions in standard corporate finance textbooks", Myers (2002)*
- *"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)*
  - Þ *Pay-out profile: \$55k, \$0*
- **One uncertainty Þ one security S:**
  - Period-0 price: \$20
  - Period-1 prices: \$34, \$13

  (Bank account B with return: r_f=108%)
- **The portfolio; S shares, B cash:**

  S \$34 + B r_f = \$55k } ***solve:***

  S \$13 + B r_f = \$0 } *S=2.6; B=-31.5*

  Þ ***PV_0 = S \$20 -\$31.5 = \$21k***

Þ ***Implies that no arbitrage is possible***

RISK NEUTRAL PROBABILITIES

- **Short cut method:**
  - Security prices: **P**
  - Portfolio weights: w
  - Option payout:: p

  Set: $\mathbf{P}\, w = p \;\Rightarrow\; w = \mathbf{P}^{-1} p$
- **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:

  ⇒ ***risk-neutral probabilities***
- **PV_0 = “E”[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)** ® *R=118%*
  - Input likelihood of each CF_1 (state)
  - Use R to value perfectly correlated asset (not traded) → *PV_0=\$100k*
- **Alternatively use replicating portfolio approach: *twin security and cash***
  - *Law of one price*: same payouts in each state ⇔ same price → *PV_0*
- **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:**

  Þ ***NPV = \$21k*** *(see previous slide !)*

Þ **Total option value: \$21k - -\$6k = \$27k**

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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: $w = \mathbf{P}^{-1} p$
  - 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
  - Phased approach: 1. Seismic, 2. Well logs, 3. Production
- **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