

Dynamic Strategic Planning

Evaluation of Real Options

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Previously Established

- **The concept of options**
 - Rights, not obligations
 - A Way to Represent Flexibility
 - Both Financial and REAL
- **Issues in Valuing Flexibility**
 - Traditional NPV Analysis is insufficient
 - Decision Analysis may be impractical
 - Need to define discount rate correctly
- **Options Analysis => Theoretically Correct Way**
 - Adjusts Situation so that Risk-Free Discount Rate applies
 - Leads to Formulas or Processes which can be computed
- **Critical Assumption of Options Analysis**
 - Risk can be associated with a exogenous (market) risk with known statistical distribution (a history that we presume will continue)

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Issue for System Design

- **How do we value Flexibility?**
- **Choice of Method not Obvious**
 - No one approach always best:
 - Decision Analysis has theoretical and practical issues
 - Options Analysis may be impractical because data unavailable
- **What do we do in practice?**

Outline for Evaluation of Real Options

- **Review of Possible Real Options**
- **Range of Possible Analyses**
 - Two Prototypical Practical Analyses
 - Merck (Well Defined 'Generic' Product)
 - Kodak (Unique Product)
- **Drivers of Choice**
 - Degree of Project and Market Risk
 - Organizational Sponsors of Project
- **Neely's Hybrid Method**
 - Practical integration of Options and Decision Analysis

Options are part of Real Systems

- **Projects often contain option-like flexibilities**
 - Rights, not obligations
 - Provide Asymmetric Returns
 - Exercise only when advantageous
- **Lease car with option to buy**
 - Lessee decides at end of contract
 - Action is to buy car at end of lease (or to walk away)
 - Lease period defined up-front (typically 2-3 years)
 - Car purchase price defined in lease contract
- **Flexible manufacturing processes**
 - Ability to select mode of operation (e.g. heater that burns gas or oil)
 - Switching between modes is action
 - Continuous opportunity (can switch at any time)
 - Switching modes often entails some cost (e.g. set-up time)

Three Classes of Generic Real Options

- **Call-like**
 - Permit capture of benefits from increases in project value
 - Exercise typically involves putting more money into project
 - Exercise when expectations of positive return increase
- **Put-like**
 - Insure against losses from decreased project value
 - Exercise may involve costs or salvage value
 - Exercise when expectations of gains decrease
- **Compound (nested)**
 - Projects might contain multiple options
 - Exercise decisions based on overall profit maximization

Call-Like Real Options

- **Waiting to Invest**

- A profitable project today, could be more valuable by waiting
- Leaving open opportunity to invest is like holding a call
- Influences include uncertainty and foregone profits
- Choice based on: Max [immediate investment, waiting, 0]

- **Expand**

- Accelerate effort or broaden level of involvement
- Allows more participation in gains by increasing exposure
- Cost of expansion acts like strike price
- Choice based on: Max [status quo, expanded project]

- **Restart Temporarily Closed Operations**

- Similar to waiting to invest or expand (a special case)
- Choice based on: Max[remain closed, re-open]

Put-Like Real Options

- **Abandon**

- Ability to halt further investment
- Eliminates further exposure
- Abandoning may include shut-down costs and salvage values
- Choice based on: Max [continuing, abandoning]

- **Contract**

- Decelerate or narrow involvement
- Reduces participation level and exposure to potential losses
- Often incur short-term scale down costs

- **Temporarily Shut Down Operations**

- A Special case of contraction
- Eliminates Variation, but may incur shut-down costs
- Choice based on: Max[status quo, temporary shut-down]

A Common, Non-Financial Option: Insurance

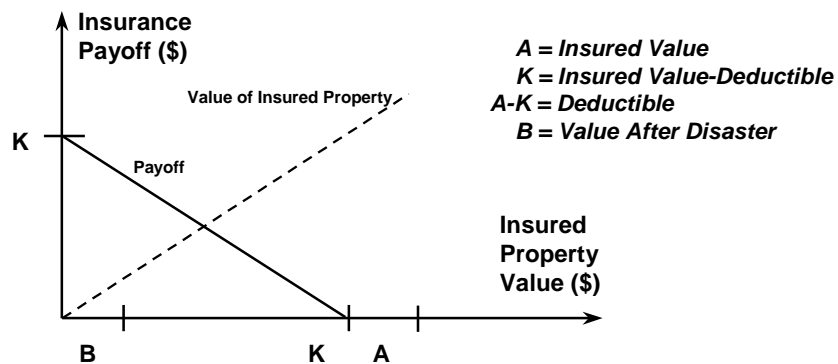
- Insurance policy
 - Small annual premium provides protection from potential losses
 - Payoff equals amount of damage (minus a deductible)
 - Claim is filed (option exercised) if damage total exceeds deductible
- Payoff is different from value
 - On average, expected net payoff to policyholder is less than premium
 - Otherwise insurance companies go bankrupt
 - People still buy insurance, because they are risk averse
 - Implies value exceeds expected payoff

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A Payoff Diagram for Insurance

- Maximum payoff is insured value minus deductible
- Minimum payoff is zero
- Payoff resembles put option



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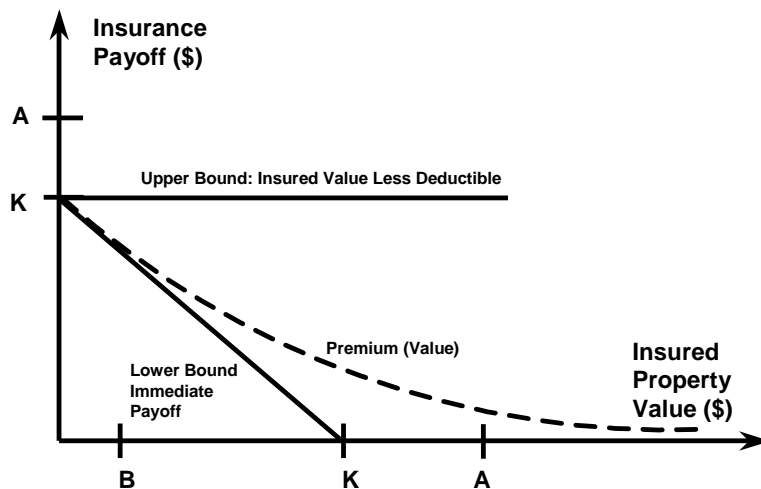
Boundaries on Insurance Premium (Value)

- **Insurance premium approximates value**
 - Willingness to pay for protection
 - Reflects value to least risk-averse policyholder
- **Can identify boundaries on the premium**
- **Upper bound is value of apartment less deductible**
 - Even if total loss is certain, this is the limit of the payoff
 - Since damage is uncertain, premium will be less
- **Lower bound is zero**
 - Insurance companies are in business to make money
- **If insuring already damaged property were possible**
 - Lower bound would exceed immediate payoff (exercise value)

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An Approximate Estimate of Insurance Premium (Value)



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Note Features of Insurance

- **Payoff increases with:**
 - Reduction in value of property
 - Decreases in deductible (increases in strike point)
 - Timeframe of policy
 - Likelihood of damage occurring

Same general trends as a put option

Insurance is like a put option on the insured property

Compound or Nested Options

- **Combinations of Options**
 - Many real options exist simultaneously
 - Can choose between abandon, contract, or temporarily shut
 - Complex problem because value of multiple real options may not be additive
 - Values of above listed options interdependent
 - Exercising one may eliminate others (abandon ends project)
- **Switching Between Modes of Operation**
 - Flexible systems contain an infinite series of options
 - Allow continual switching between modes of operation
 - If switching modes has a cost, it acts like a strike price
 - Will discuss example of a dual-fuel boiler burner
- **For compound options, must value as system**

Range of Possible Analysis of Real Options

- **Two Prototypical Practical Analyses**
- **Merck (Well Defined 'Generic' Product)**
 - Thousands of drugs go through standard FDA review
 - Extensive Statistics of success rates and on market valuation of start-up drug companies
 - Nichols, N.A. (1994) "Scientific Management at Merck: An Interview with Judy Lewent," Harvard Business Review, Jan.-Feb., pp. 89-99
- **Kodak (Unique Product)**
 - Few Examples of similar products
 - No obvious measure of Market Risk
 - Faulkner, T.W. (1996) "Applying Options Thinking to R&D Valuation," Research Technology Management, May-June, pp. 50-56

Choosing a Real Options Valuation Basis in Practice

- **Compare efforts at two companies**
 - Merck (financial options)
 - Kodak (decision analysis)

Examine factors that influenced choice

- Business/industry structure
- Type of information available

Is goal precise valuation or estimation?

Key findings

- Importance is recognizing presence of real options
- Valuation is a balance between "precision" and implementability

Situations at Merck and Kodak

	Merck	Kodak
R & D Process	Homogeneous	Heterogeneous
Product	Single Drug	Color Printers
Estimation of Benefits	Easy	Moderate
Organizational Driver	Finance Department	Research Department
Evaluation Method	Real Options	Decision Analysis

Source: Neely doctoral dissertation

Real Options at Merck

- **Merck values real options using financial frameworks**
 - Black-Scholes formula
 - Other models for support (Monte-Carlo simulation)
 - Applies to variety of areas: R&D and acquisitions specifically mentioned
- **Example: Gamma project**
 - Options used to value a development contract with a biotech company
 - Investment in R&D created option for future scale-up and commercialization

Real Options at Merck (cont'd)

- **Project Gamma as a call option**
 - Value of project cash flows acted as underlying asset (stock equivalent)
 - Cost of manufacturing scale-up comparable to strike (exercise) price
 - Time before expiration was varied between 2-4 years
 - Risk-free rate based on U.S. Treasuries
 - Volatility was varied between 40-60 percent (based on biotech stock database)

Real Options at Kodak

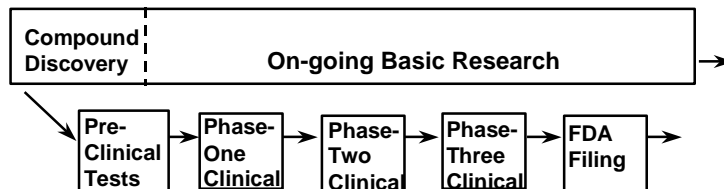
- **Kodak often values real options using decision analysis**
 - Understanding financial frameworks informs process
 - Occasionally, might use more strict financial framework
- **Example: color printer project**
 - R&D project faces technical and market uncertainties
 - Must decide separately if R&D and commercialization are worth pursuing
 - R&D creates option to commercialize

Real Options at Kodak (cont'd)

- **Color printer project as a real option**
 - Project cash-flows serve as underlying asset
 - Commercialization scale-up costs act as strike price
 - Timeframe is two years (1993-1995)
 - Discount rate of 12% used
 - Volatility of payoffs implied by considering range of outcomes

Drivers of Framework Selection: Business Structure

- **Merck**
 - Pharmaceutical development process highly regulated
 - All products travel through same path to market (10-11 years to FDA filing)
 - Reasonable to speak in terms of an average project and estimate volatility



Drivers of Framework Selection: Business Structure (cont'd)

- **Kodak**
 - Involved in multiple businesses: film, imaging, printing, etc.
 - Product development processes might be similar, but do have variation
 - Hard to think of what an average project might be

Drivers of Framework Selection: Information Availability

- **Merck: structure yields significant historical information**
 - Average drug takes \$359 million and 10 years to market
 - 1/10,000 compounds tested becomes a drug
 - Fraction of population with disease X known (especially with Medco acquisition)
 - Successes and failures at each testing step documented and averaged
 - Database of pharmaceutical and biotech stock performance created

Drivers of Framework Selection: Information Availability (cont'd)

- **Kodak: less homogeneous historical project data**
 - Significant variation between and within business units
 - Not impossible, but more difficult to assemble relevant databases
 - Projects might vary widely from averages anyway

Goals of Applying Options Valuation at Merck and Kodak

- **Both companies recognize value of project options**
- **Mind-set more important than precision**
 - Kodak states this explicitly
 - Merck does sensitivity analysis (varies volatility and time)
- **Choice of Method based on implementability**
 - Merck finance department uses financial models and has necessary data
 - Kodak R&D department uses decision analysis on a case by case basis

Goals of Applying Options Valuation at Merck and Kodak (cont'd)

- **Hard to argue that one or the other is more precise**
 - Mis-priced financial options create arbitrage opportunities: market reacts
 - Error in real options value estimation less obvious
 - Sensitivity analysis helps to address remaining uncertainties

Drivers of Choice of Method of Evaluation of Real Options

- **Two Dominant Drivers of Choice**
 - Degree of Project and Market Risk
 - Organizational Sponsors of Project
- **Financial models work well when**
 - The financial cost and benefits are due to one or a few underlying uncertainty variables
 - These underlying variables have an established market price
- **Decision Analysis Better when**
 - Project risks most important
 - There is no effective market for drivers of uncertainty
- **Organizational Issues also important**
 - Methods used has to be understood by organization
 - Method used has to be a means of communication within and between groups

Neely's Hybrid Approach

- **A Process of Evaluation of Real Options combining best of available techniques**
 - Options approach for market risk uncertainties
 - Decision analysis for project risks
 - risk-free rate of evaluation
- **Also, Process for incorporating non-financial benefits and costs**

- **Reference**
 - Neely, J.E.III (1998) "Improving the Valuation of Research and Development: A Composite of Real Options, Decision Analysis and Benefit Valuation Frameworks," Ph.D. dissertation, MIT Technology, Management and Policy Program

Steps to Apply Hybrid Evaluation

- **Step 1: Define Scope of Assessment**
 - Money only, or other non-financial effects
- **Step 2: Collect Data**
 - Costs, Benefits, and Decision Opportunities
 - Endogenous, Project Risks
 - Exogenous, Market Risks
- **Step 3: Transform Data**
 - Monetizing Non-financial benefits
 - Exogenous effects into Risk Neutral Cash Flows
 - Establishing Cash flows
 - Calculating NPV on basis of risk-neutral discount rate
- **Step 4: Decision Tree Analysis**
- **Step 5: Sensitivity Analysis**

Details of Hybrid Evaluation Process

- **Step 1: Define Scope of Assessment**
 - What are financial benefits and costs
 - What are non-financial benefits and costs, such as those that affect the environment (e.g.: decrease in air pollution) or the quality of the product (e.g.: improved reliability)
- **Step 2: Collect Data**
 - Costs and Benefits
 - Decision Points -- specifically, what are the opportunities to change project (wait, continue, stop, slow-down, speed-up, abandon)
 - Project Risks -- use known statistics on like projects or subjective assessments from experts
 - Market Risks -- Identify factor driving project revenues (e.g.: oil price) and relate to market of known statistics

Details of Hybrid Evaluation Process (cont'd)

- **Step 3: Transform Data**
 - Utility of Non-Financial Benefits and Costs => Money equivalents (see Neely dissertation Chap.5)
 - Market Risks => Risk Neutral Quantities (Use binomial method, e.g., Neely Chap. 3)
 - Cash Flows => Present Values using Risk-free discount rate
 - Risk-free rate applies because cash flows from market risks have been adjusted, and because it is assumed that investors (the company or outsiders) have many projects and can diversify away the project risk.
- **Step 4: Decision Tree Analysis**
- **Step 5: Sensitivity Analysis**
 - for key unknowns with inadequate historical records

Example Application of Hybrid Evaluation

- **Cooperative Analysis with a Major Manufacturer**
 - For details, see Neely's dissertation
- **Step 1: Define Scope of Assessment**
 - R & D Project to reduce failure rate and weight of parts
 - In this case, all benefits and costs expressed in money
- **Step 2: Collect Data**
 - Costs of R and then D, Benefits of successful product
 - Opportunity to Develop if Research successful
 - Project Risk -- $P(\text{Success}) = 0.8$ from previous work
 - Market Risk -- Benefits = $f(\text{number of parts sold})$; this is correlated with Stock Price \Rightarrow known variability

Application of Hybrid Evaluation (cont'd)

- **Step 3: Transform Data (Neely Appendix B)**
 - Price Dynamics of Stock from records (total return = 13.2%/year, volatility = 20.7%)
 - Risk-neutral estimates of benefits from Binomial Approach \Rightarrow lognormal risk-free rate of return with 20.7% volatility
 - Net Present Value of Cash Flows of Benefits less costs of implementing project and producing parts.
- **Step 4: Decision Analysis**
 - NPV with Real Option = \$114 million (compared to only \$86 million for standard analysis)
- **Step 5: Sensitivity Analysis**
 - To Probability and Benefits of success
 - To volatility of Driver of Market Risk

Points to Keep in Mind When Selecting a Framework

- **Options theory concerned with pricing based on risk & return**
- **Decision analysis concerned with strategy development**
- **Must decide on needs**
 - Valuation according to strict finance perspective
 - Setting guidelines for strategic planning
- **Should consider**
 - level of required effort
 - ease of use
- **Beware of false sense of precision**

Concluding Remarks on Choice of Method for Evaluating Real Options

- **Decision analysis works well when**
 - Likelihood and timing of critical uncertainties and decisions understood
 - Information sources focused on individual project
 - Variables without an established price history are important
- **Real options method sometimes more compact**
 - Decision trees rapidly become bushy
 - Simulation techniques are rooted in operations research techniques anyway
- **Hybrid Approach can be a practical solution**
- **Significant value in the mind-set**
 - Approximate values can be a vast improvement

Conclusions: What we hope you learn about Methodology

- **Finance models and decision analysis provide basis for valuation of options**
- **You need to be aware of merits and limitations of both approaches**
- **Most practical valuation framework for any system depends on situation**
- **Hybrid approach may be most practical in many situations, because it combines best of both alternative approaches**

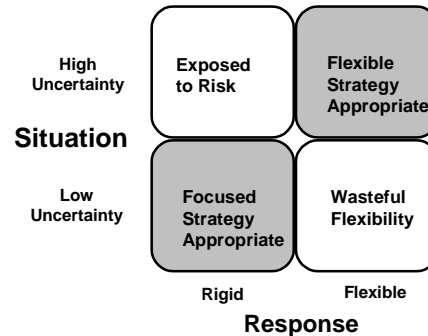
Conclusions: What we hope you learn about Options

- **Project options can be major sources of value in the design of a system**
- **Look for opportunities to build options into project when appropriate**
- **Value of options increases significantly in risky situations**
- **Doing the valuation of option carefully (do not blindly justify efforts as "strategic")**

General Point About Flexibility

- Pursue flexible strategies when uncertainty is high
- Focus when uncertainty is low
- Mis-match of flexibility to uncertainty environment leads to

Waste of flexibility
Exposure to risk



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If You Want to Pursue this Topic ...

• MIT Courses

- Basic finance theory: 15.415 or 15.412
- Options: 15.437
- Corporate finance: 15.434
- Decision analysis: 15.065
- Others in Operations Research related to simulation

• Books and Publications

- Real Options, Lenos Trigeorgis, MIT Press 1996 (ISBN 0-262-20102-X)
- Real Options in Capital Investment, Ed. L. Trigeorgis, Praeger, 1995 (ISBN 0-275-94616-9)
- Investment Under Uncertainty, A. Dixit and R. Pindyck, Princeton Press, 1994 (ISBN 0- 691-03410-9)
- Journal of the Financial Management Association, Vol. 22, No. 3, Autumn 1993 (Issue on Real Options and Applications)

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