Real Options II

Introduction

- Developed an introduction to real options
  - Relation to financial options
  - Generic forms
  - Comparison of valuation in practice

- Now,
  - Value of flexibility (examining projects with compound real options)
  - A final look at the real options and decision analysis debate
  - Pointers to other course and materials
Flexibility

- **Flexible systems**
  - Allow owner to adapt operating conditions
  - Trigger for action is some internal or external stimulus
- **For example, flexible manufacturing systems can**
  - Allow fast product change-overs
  - Accept a variety of raw materials
  - Can efficiently process a wide range of batch sizes
- **Flexibility often costs extra to acquire**
  - Equipment might require special configurations
  - Production management more complex
- **But, flexibility can reduce total operating costs**
  - Costs less to adapt to variability and change
  - Allows better use of inputs or production of outputs

An Options Perspective of Flexibility

- **Flexible systems enable advantageous actions**
  - Resembles a series of options
  - Can continually respond to changing conditions
- **Demonstrate value using case of a flexible burner**
  - Based on Kulatilaka and Marcus paper
- **Electric power turbines can be powered by**
  - Gas burners
  - Oil burner
  - Flexible burner (accepts either oil or gas)
- **Fixed technologies cost less to acquire**
- **When might flexible systems be valuable?**
Starting Assumptions for Dual-Fuel Burner Example

- Examine 10 years of operation
- Discount cash flows at 10%
- Price of gas remains fixed at $1 per energy unit
- Price of oil increases over time
  - At present oil costs $0.75 per energy unit
  - Price increases by 5% per year
- Installation in Year 0; Operations in Year 1
- Revenues are independent of technology

What is the NPV for each burner?

Case 1: Oil and Gas Prices are Known with Certainty

- Oil burner cheaper to operate until Year 6

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<th>Time</th>
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Oil and Gas Prices

- Oil
- Gas
## Cash Flows Under Certainty

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### Results of Certainty Case

- **Rank of technologies**
  - Oil
  - Flexible
  - Gas

- **Oil burner captures early cost advantages over gas**
  - Time value of money means early gains more significant than later losses

- **Oil burner also better than flexible**
  - Both capture cost advantages early-on
  - Flexible advantageously switches to gas in Year 6
  - Extra costs of acquiring flexible overshadow later gains

- **Critical assumption:** input prices are predictable
Case 2: Uncertainty in Oil Prices

What if oil could follow one of three price paths?

<table>
<thead>
<tr>
<th>Oil Prices</th>
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<tbody>
<tr>
<td>High</td>
</tr>
<tr>
<td>Medium</td>
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<tr>
<td>Low</td>
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Price

$0.20 $1.00 $1.40 $1.80

Time

0 5 10

Cash Flows with Uncertainty

<table>
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<tr>
<th>Year</th>
<th>0</th>
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<th>2</th>
<th>3</th>
<th>4</th>
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NPV

<table>
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<tr>
<td>NPV</td>
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Engineering Systems Analysis for Design
Massachusetts Institute of Technology
Richard de Neufville, Joel Clark, and Frank R. Field
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Results of Uncertainty Case

- Rank of technologies
  - Flexible
  - Oil
  - Gas (same NPV as before since gas price remains fixed)

- Flexible technology enabled beneficial switching
  - For high oil price case, do better than oil burner
  - For high gas prices, do better than gas burner
  - Benefits accrue early on when uncertainty in prices is considered
  - Operating cost savings outweigh extra acquisition costs

- Input price uncertainty increased value of flexibility
  - Option value driven by cost of inputs
  - Uncertainty in prices represents volatility

General Point of Flexibility Case

- 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

<table>
<thead>
<tr>
<th>High Uncertainty</th>
<th>Flexible Strategy Appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposed to Risk</td>
<td>Focused Strategy Appropriate</td>
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<tr>
<td>Low Uncertainty</td>
<td>Wasteful Flexibility</td>
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<tr>
<td>Rigid</td>
<td>Flexible</td>
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<tr>
<td>Response</td>
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</table>
Extending the Flexibility Case

- Uncertainty in oil prices treated by 3 price paths
- Flexible technology switched modes once, if at all

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- In reality, oil price continually moves up and down
- Might repeatedly switch between oil and gas
- Modeling using tables rapidly becomes unwieldy

Estimating the Value of Flexibility in Practice

- Because problem involves a series of options
  - Can be difficult to evaluate using simple tables or decision trees
  - Black-Scholes does not apply either (multiple, dependent options)

- Typically requires computerized simulation
  - Based on binomial technique
  - Structurally similar to decision trees
  - Draws upon dynamic programming discipline

- Dual-fuel case was later extended using simulation
A Few Final Remarks on Real Option Valuation

- Conditions when financial models work well
  - One or a few uncertainty variables (underlyings)
  - Underlyings have an established market price history

- Conditions when decision analysis works well
  - Likelihood and timing of critical uncertainties and decisions understood
  - Information sources more focused on individual project
  - Variables without an established price history are important

- Real options approaches can be more compact
  - Decision trees rapidly become bushy
  - Simulation techniques are rooted in operations research

- Significant value in the mind-set
  - Approximate values can be a vast improvement

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 and ease of use

- Beware of false sense of precision
If You Want to Pursue this Topic Further...

**Courses**
- Basic finance theory: 15.401 and 15.402
- Options: 15.437
- Corporate finance: 15.434
- Decision analysis: 15.065
- Others in operations research and at Sloan related to simulation

**References**
- Real Options, Lenos Trigeorgis, MIT Press 1996
- Real Options in Capital Investment, Trigeorgis, ed Praeger, 1995
- Real Options and Investment under Uncertainty, Schwartz and Trigeorgis, eds, MIT Press, 2001
- Investment Under Uncertainty, Dixit and Pindyck, Princeton U. Press, 1994
- Journal of the Financial Management Association, 22(3), Autumn 1993 (Special Section on in Real Options …)
Conclusions:
What We Hope You Learned

- Project options can be major sources of value
- Value of options depends on several factors
- Finance models and decision analysis are valuation bases
- You should be aware of merits and limitations of each
- Most practical valuation framework depends on situation

Conclusions
You Can Add Value To Projects By:

- Recognizing the value of options
- Looking for opportunities to build options into project when appropriate
- Doing the valuation (do not blindly justify efforts as "strategic")