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

<table>
<thead>
<tr>
<th>Time</th>
<th>Oil Prices</th>
<th>Gas Prices</th>
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<tbody>
<tr>
<td>0</td>
<td>$0.75</td>
<td>$1.00</td>
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<tr>
<td>5</td>
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<td>$0.95</td>
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<tr>
<td>10</td>
<td>$1.25</td>
<td>$0.85</td>
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## Cash Flows Under Certainty

<table>
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<tr>
<th>Year</th>
<th>0</th>
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<th>2</th>
<th>3</th>
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<th>7</th>
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<tr>
<td>Gas Plant</td>
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<tr>
<td>Revenue</td>
<td>1.16</td>
<td>1.21</td>
<td>1.27</td>
<td>1.34</td>
<td>1.40</td>
<td>1.47</td>
<td>1.55</td>
<td>1.63</td>
<td>1.71</td>
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<tr>
<td>PV Net</td>
<td>-2.50</td>
<td>0.15</td>
<td>0.17</td>
<td>0.20</td>
<td>0.23</td>
<td>0.25</td>
<td>0.27</td>
<td>0.28</td>
<td>0.29</td>
<td>0.30</td>
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<td>0.28</td>
<td>0.29</td>
<td>0.30</td>
<td>0.30</td>
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<tr>
<td>NPV</td>
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</tr>
</tbody>
</table>

| Oil Plant |     |     |     |     |     |     |     |     |     |     |     |
| Revenue   | 1.16| 1.21| 1.27| 1.34| 1.40| 1.47| 1.55| 1.63| 1.71| 1.79|     |
| Cost      | 2.50| 0.79| 0.83| 0.87| 0.91| 0.96| 1.01| 1.06| 1.11| 1.16| 1.22|
| PV Net    | -2.50| 0.34| 0.32| 0.30| 0.29| 0.27| 0.26| 0.25| 0.24| 0.23| 0.22|
| PV Net Cash Flow | -2.50| 0.34| 0.32| 0.30| 0.29| 0.27| 0.26| 0.25| 0.24| 0.23| 0.22|
| NPV      | 0.24|     |     |     |     |     |     |     |     |     |     |

| Flexible Plant |     |     |     |     |     |     |     |     |     |     |     |
| Revenue       | 1.16| 1.21| 1.27| 1.34| 1.40| 1.47| 1.55| 1.63| 1.71| 1.79|     |
| Cost          | 3.00| 0.79| 0.83| 0.87| 0.91| 0.96| 1.00| 1.00| 1.00| 1.00| 1.00|
| PV Net        | -3.00| 0.34| 0.32| 0.30| 0.29| 0.27| 0.26| 0.25| 0.24| 0.23| 0.22|
| PV Net Cash Flow | -3.00| 0.34| 0.32| 0.30| 0.29| 0.27| 0.26| 0.25| 0.24| 0.23| 0.22|
| NPV          | -0.03|     |     |     |     |     |     |     |     |     |     |

### 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?

![Oil Prices Graph]

Cash Flows with Uncertainty

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
<th>8</th>
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<th>10</th>
</tr>
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<tbody>
<tr>
<td>Oil Plant</td>
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<td>1.55</td>
<td>1.63</td>
<td>1.71</td>
<td>1.79</td>
<td></td>
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<tr>
<td>Cost (High) p=0.3</td>
<td>2.50</td>
<td>1.88</td>
<td>1.94</td>
<td>1.90</td>
<td>1.87</td>
<td>1.83</td>
<td>1.79</td>
<td>1.76</td>
<td>1.73</td>
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<tr>
<td>Cost (Medium) p=0.4</td>
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<td>0.79</td>
<td>0.83</td>
<td>0.87</td>
<td>0.91</td>
<td>0.96</td>
<td>1.01</td>
<td>1.06</td>
<td>1.11</td>
<td>1.17</td>
<td></td>
</tr>
<tr>
<td>Cost (Low) p=0.3</td>
<td>2.50</td>
<td>0.39</td>
<td>0.41</td>
<td>0.43</td>
<td>0.45</td>
<td>0.47</td>
<td>0.50</td>
<td>0.52</td>
<td>0.55</td>
<td>0.58</td>
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</tr>
<tr>
<td>Cost (Avg.)</td>
<td>2.50</td>
<td>0.79</td>
<td>0.83</td>
<td>0.87</td>
<td>0.91</td>
<td>0.96</td>
<td>1.00</td>
<td>1.05</td>
<td>1.11</td>
<td>1.16</td>
<td></td>
</tr>
<tr>
<td>PV Net Cash Flow</td>
<td>-2.50</td>
<td>-0.34</td>
<td>-0.32</td>
<td>-0.30</td>
<td>-0.29</td>
<td>-0.28</td>
<td>-0.26</td>
<td>-0.25</td>
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<td>NPV</td>
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</tr>
</tbody>
</table>

| Flexible Plant |
| Revenue | 1.16 | 1.21 | 1.27 | 1.34 | 1.40 | 1.47 | 1.55 | 1.63 | 1.71 | 1.79 |
| Cost (High) p=0.3 | 3.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cost (Medium) p=0.4 | 3.00 | 0.79 | 0.83 | 0.87 | 0.91 | 0.96 | 1.00 | 1.00 | 1.00 | 1.00 |
| Cost (Low) p=0.3 | 3.00 | 0.39 | 0.41 | 0.43 | 0.45 | 0.47 | 0.50 | 0.52 | 0.55 | 0.58 |
| Cost (Avg.) | 3.00 | 0.73 | 0.75 | 0.78 | 0.80 | 0.83 | 0.85 | 0.86 | 0.86 | 0.87 |
| PV Net Cash Flow | -3.00 | -0.39 | -0.38 | -0.37 | -0.37 | -0.36 | -0.35 | -0.36 | -0.36 | -0.35 |
| NPV | | 0.63 | | | | | | | | |
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>Response</th>
<th>High Uncertainty</th>
<th>Low Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid</td>
<td>Exposed to Risk</td>
<td>Focused Strategy</td>
</tr>
<tr>
<td>Flexible</td>
<td>Flexible Strategy</td>
<td>Wasteful Flexibility</td>
</tr>
</tbody>
</table>
Extending the Flexibility Case

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