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

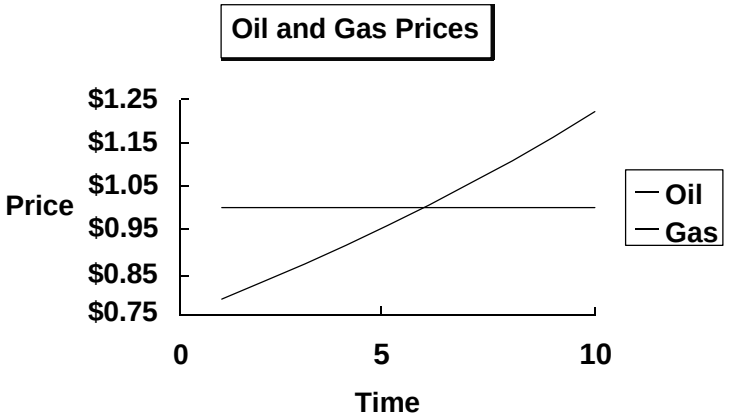
- Flexible systems enable advantageous actions
  - Resembles a series of options
  - Can continually respond to changing conditions
- Demonstrate value using case of a flexible burner
  - Based on Kulatilaka and Marcus paper
- Electric power turbines can be powered by
  - Gas burners
  - Oil burner
  - 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



Cash Flows Under Certainty

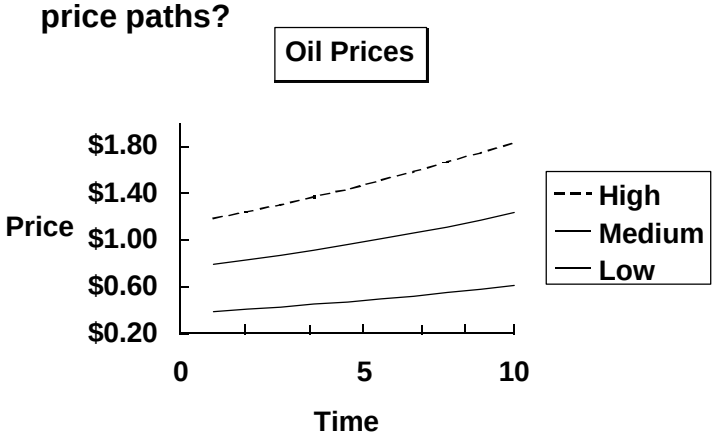
Year	0	1	2	3	4	5	6	7	8	9	10
Gas Plant											
Revenue		1.16	1.21	1.27	1.34	1.40	1.47	1.55	1.63	1.71	1.79
Cost	2.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
PV Net Cash Flow	-2.50	0.15	0.17	0.20	0.23	0.25	0.27	0.28	0.29	0.30	0.30
NPV	-0.05										
Oil Plant											
Revenue		1.16	1.21	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 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 Cash Flow	-3.00	0.34	0.32	0.30	0.29	0.27	0.27	0.28	0.29	0.30	0.30
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?**



Cash Flows with Uncertainty

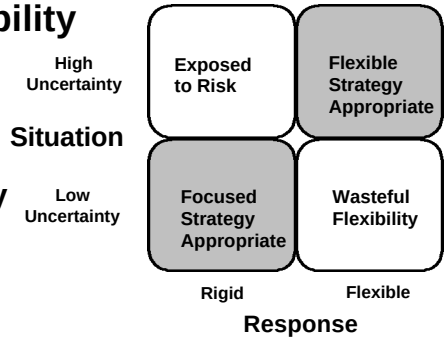
Year	0	1	2	3	4	5	6	7	8	9	10
Oil Plant											
Revenue		1.16	1.21	1.27	1.34	1.40	1.47	1.55	1.63	1.71	1.79
Cost (High) p=0.3	2.50	1.18	1.24	1.30	1.37	1.43	1.51	1.58	1.66	1.74	1.83
Cost (Medium) p=0.4	2.50	0.79	0.83	0.87	0.91	0.96	1.01	1.06	1.11	1.17	1.23
Cost (Low) p=0.3	2.50	0.39	0.41	0.43	0.45	0.47	0.50	0.52	0.55	0.58	0.61
Cost (Avg.)	2.50	0.79	0.83	0.87	0.91	0.96	1.00	1.05	1.11	1.16	1.22
PV Net Cash Flow	-2.50	0.34	0.32	0.30	0.29	0.28	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 (High) p=0.3	3.00	1.00	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	1.00
Cost (Low) p=0.3	3.00	0.39	0.41	0.43	0.45	0.47	1.00	0.52	0.55	0.58	0.61
Cost (Avg.)	3.00	0.73	0.75	0.78	0.80	0.83	0.85	0.86	0.86	0.87	0.88
PV Net Cash Flow	-3.00	0.39	0.38	0.37	0.37	0.36	0.35	0.36	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

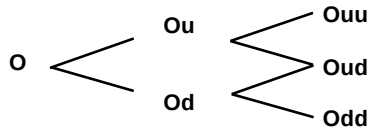
General Point of Flexibility Case

- 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



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

If You Want to Pursue this Topic Further...

- References
  - Real Options, Lenos Trigeorgis, MIT Press 1996
  - Real Options in Capital Investment, Trigeorgis, ed Praeger, 1995
  - Project Flexibility, Agency and Competition, Brennan and Trigeorgis, eds, Oxford U. Press, 2000
  - Real Options and Investment under Uncertainty, Schwartz and Trigeorgis, eds, MIT Press, 2001
  - Investment Under Uncertainty, Dixit and Pindyck, Princeton U. Press, 1994
  - Investment Science, Luenberger, 1998, Oxford U. Press.
  - 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")