Valuation with Simulation of Flexibility “on” and “in” a System

Capital Investment and Engineering Flexibility in the development of the Antamina mine (Peru)
Definition; “on” and “in” flexibility

Class focuses on design features that enable systems to evolve easily (e.g., more floors to garage). This is flexibility “in” system.

We can also discuss flexibility to abandon a project, to delay its opening. Such flexibilities have nothing to do with design. This kind of flexibility is known in finance as a “real option”. More about those important flexibilities later in course. This is flexibility “on” a system.
Note

This presentation is based on the case developed by Peter Tufano and Alberto Moel from the Harvard Business School.

It contains simplifications. The figures appearing here differ from those presented by Tufano and Moel. They reflect the assumptions of the authors of this presentation about the treatment of uncertainty and the cash flows projection.
Antamina Project Description

- State-owned copper and zinc mine in Peru, ~480km (300 miles) north of Lima
- Privatization in 1996: call for bids. Small upfront payment + promise to develop
- Little reliable geological information
- Geological study to take two years, start after the bidding, be available before construction
- Proceed with development if survey suggested the mine could be developed economically
Antamina Auction Process

- **Government Required:**
  - Bidding on 2-stage process
  - Companies must bid for right to explore and must decide on development in 2 years
  - Big penalty for not developing (why?)
Antamina Mine Time Line

- Step 1: explore geology, topography for access
- Step 2: decide to develop and spend 3 years on building facilities before getting profits in Year 6
Project Time Line

- Bid & Win
  - Explore (years 0 to 2)
  - Year 2
  - Walk away

- Develop: CapEX (years 2 to 5)

- Produce Metal (from year 5 until closure)

- Close mine

This is Flexibility “on” System. Why?
Antamina Mine Flexibilities

• “on” Flexibility
  – Winning Company has flexibility to **abandon** mine in 2 years

• “in” Flexibility
  – Designers can create flexibility “in” system
  – Ex: create port during exploration period, to provide flexibility to expedite development to 2 years (from 3) – and thus advance revenue stream by 1 year and increase NPV
Antamina Mine Simulation

- System Model: NPV depends on:
  - ore quality, quantity
  - cost of mining
  - value of metals (mostly copper, zinc and “moly”)

- Distributions for Key parameters
  - Estimated: Technical Cost Models (of mine ops)
  - Assumed: Market data (historical data)
  - Guessed: Expert Judgment on ore quality
Sources of Uncertainty

Revenues
- Mine’s life
- Future prices of zinc and copper
- Quantity of ore

Costs
- Operation expenses
- Capital Expenditures

Uncertainty treatment
- Deterministic
- Stochastic process (Lattice, Years 0 to 2)
- Probability distributions
  Monte Carlo simulation
Sources of Uncertainty

- Price and quantity uncertainty prevails only during the first two years
- Price risk is assumed to be eliminated in year 2 by entering forward contracts to sell the output of the mine (this is assumption M&T made – a bit of a stretch…)
- All other sources of uncertainty are modeled in the Monte Carlo simulation after year 2

→ Simulation result: Realization of expected NPV
Monte Carlo Simulation

1. Probability values for significant factors
2. Random selection of factors according to their pdf
3. Determine NPV for each combination
4. Repeat process and obtain NPV distribution
Antamina Mine Valuation

- Assumed operators could “lock in” price for metal by long-term contracts over life of mine
  - Probably not possible. Necessary assumption to for financial analysis to get life-time NPV of mine

- Value of “on” Option = EV(all positive NPV) – EV(project without option to abandon)

- Value of “in” Option = further improvements in NPV due to flexibility provided
Results: Base Case – No Flexibility

Forecast: NPV (base case)

10,000 Trials

Frequency Chart

Mean = $550 M

Crystal Ball Student Edition
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$1,092.85 $684.28 $2,461.40 $4,238.52 $6,015.64

Probability

Frequency
Simulation Results: Flexibility to Abandon

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**Forecast: NPV (base case)**

10,000 Trials

Frequency Chart

- Mean = $819

Certainty is 75.61% from $0.00 to $6,015.64

- Frequency
- Probability

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- $1,092.85
- $819
What “rule for exercising flexibility”? 

What Rule Useful for Antamina? 

Rule for exercising flexibility defines time, conditions for choosing to exercise flexibility 

In this case:
• Only 1 time available;
• Condition obvious: get out if expect losses
Valuation: Flexibility to Abandon

Value of flexibility to abandon:
$819 - $550 = $269 million
Engineering Flexibility

- Add flexibility, add value?
- Starting engineering study earlier and faster would allow you to shorten construction to two years and ramp up production faster

➡️ What would you pay for this flexibility?
Simulation Results: Early Development

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Forecast: NPV (early development)

10,000 Trials

Frequency Chart

Mean = $567
Valuation: Flexibility of Early Development

Early Development Flexibility (alone):
$567 - $550 = $17 million
Would easily justify several million $
spent early on design work

This flexibility would in fact be compounded
with the flexibility to abandon
Generally not additive!
Simulation Results: Both Flexibilities

Forecast: NPV (early development)

10,000 Trials

Frequency Chart

Certainty is 76.09% from $0.00 to $5,926.22

Mean = $836

Probability

($947.79) $770.71 $2,489.21 $4,207.72 $5,926.22

Frequency
Valuation: Both Flexibilities Together

Value of both Flexibilities together:
$ 836 - $550 = $286 million

Incremental Value of Early Development Flexibility:
$ 836 - $819 = $17 million
Appears additive, but actually a difference.
In this case rounded out and insignificant
References

