INSEAD The Business School for the World®

ACF Sessions 12–13: Real options and MW Petroleum

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Antin: Recap

Course map

Part 1. Financial Policy

- The Brick House
- Debt Policy at UST
- The Loewen Group
- Infineon Technologies
- MCI

Part 2. Valuation

- AirThread Connections
- Yell Group
- Infrastructure/PE Antin
- **Real Options/ MW Petroleum**
- Rhone Poulenc Rorer

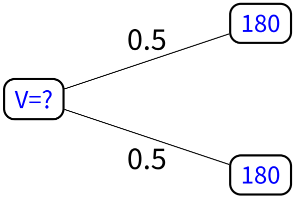
Poll: **If a firm's debt-to-equity ratio is constant, the correct discount rate is the WACC.**

a) True

b) False

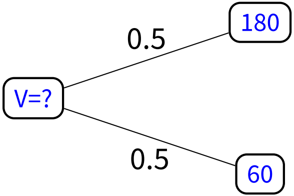
An example [1/4]

The firm is considering investing in a project with risk-free cash flows. The project requires an initial investment of 170 and is expected to generate cash flows at $t = 1$ of 180 in both boom and bust scenarios (each with probability 0.5). The project will be financed using the same debt-to-equity ratio as the firm's current capital structure. The firm's WACC is 20%, and the risk-free rate is 8%. What is the value of the project? What is an appropriate discount rate?



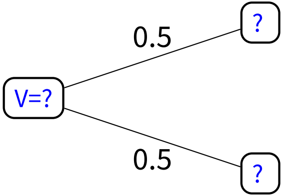
An example [2/4]

Now suppose that the firm is expanding its existing operations. The project requires an initial investment of 110 and is expected to generate cash flows at t=1 of 180 in a boom scenario and 60 in a bust scenario (each with probability 0.5). The project will be financed using the same debt-to-equity ratio as the firm's current capital structure. The firm's WACC is 20%, and the risk-free rate is 8%. What is the value of the project? What is an appropriate discount rate?



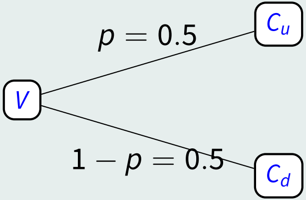
An example [3/4]

Now suppose the firm can choose when to expand. It may invest 110 either at $t = 0$ or at $t = 1$. In both cases, the project will generate cash flows beginning at $t = 1$, with a time-1 value of 180 in a boom scenario and 60 in a bust scenario (each with probability 0.5). What is the value of the project?



Valuation: FMV, ACF, or CFP way?

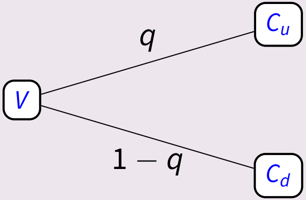
In FMV (and in this course) we have used **DCF**



$$V = \frac{p \times C_u + (1-p) \times C_d}{1 + r_f + \text{Risk Premium}}$$

Works well when we can estimate the risk premium.

In CFP you learned another technique: **risk-neutral valuation**

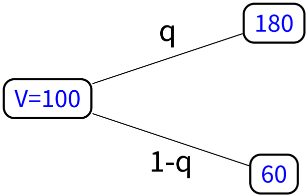


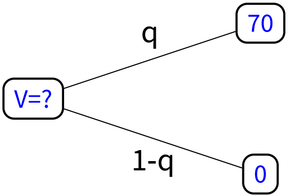
$$V = \frac{q \times C_u + (1-q) \times C_d}{1 + r_f}$$

Let's redo our example using the risk-neutral valuation.

Discount rate issues: an example [4/4]

Use the valuation of the $t = 1$ expansion project to impute the risk-neutral probability q (WACC$\rightarrow q$). Then apply q to value the real option:





Real option valuation

- DCF approach:
  - Discounts *expected cash flows* at a rate reflecting their risk
  - Assumes both *future cash flows* and *risk* are fixed
- In reality:
  - Cash flows and their riskiness change as managers respond to new information
  - Managers have **flexibility** to adapt decisions as uncertainty unfolds
- Real option valuation:
  - Captures the **value of managerial flexibility** — the ability to adjust risk and return as information arrives

When to use real option valuation?

A real option arises under

- Uncertainty
- Flexibility

Option valuation techniques can be used if the underlying source of risk can be traded

- Form a replicating portfolio
- Obtain necessary information such as volatility

Areas of application

Real option approach most successful on capital-intensive, long-lived investments where key source of uncertainty is traded commodity (such as energy and ore)

- Option values are always increasing in volatility and usually increasing in time to maturity

Examples?

- Oil and gas field development
- Mine operation and expansion
- Generation of power ("spark spread")
- Valuation of foresting and fishing rights
- "Crack spread" valuation of refineries
- Gas storage valuation

Example: Tolling deals in electricity

Tolling deals = synthetic power plants

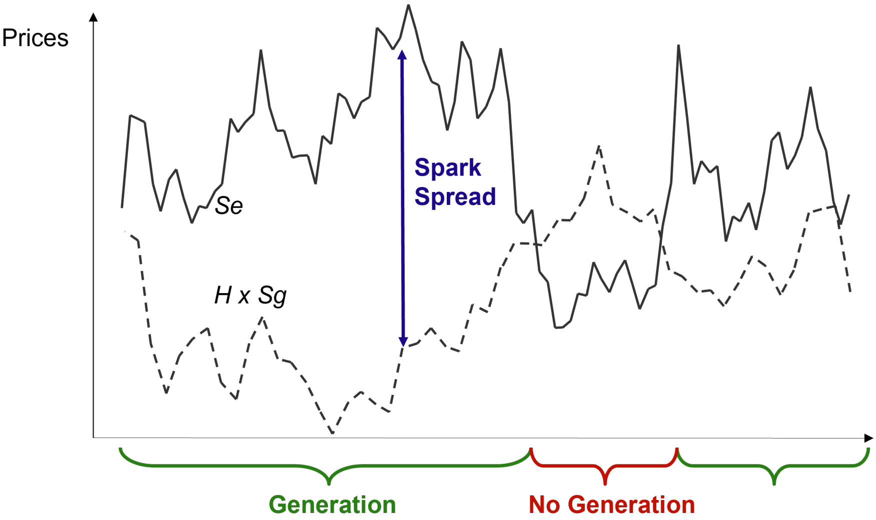
- Gas producer *rents* a plant to convert gas to power when profitable.
- Dispatch rule: run only if power price exceeds generation cost.
- Spark spread (for heat rate H):

$$\text{Spread} = S_e - H\,S_g$$

where H = amount of fuel per 1 MWh of electricity, S_e = electricity price, S_g = gas price.

- Interpretation: value per MWh of turning gas into electricity.

Tolling valuation



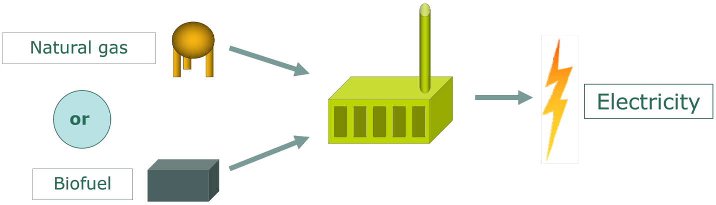
Tolling valuation

Tolling deals are just options on the spark spread

- When spark spread is negative electricity is not produced
- When spark spread is positive electricity is produced
- Payoff of the (call) option is $Max(0, S_{e,t} - H \times S_{g,t}, 0)$
- Value of a plant is just then a series of call options: $\sum_{t=1}^{T} Max(0, S_{e,t} - H \times S_{g,t}, 0)$

Biofuel tolling

Some plants can use biofuels or traditional fossil fuels



Without constraints or set up costs, the valuation of the asset is a simple real option problem

$$\sum_{t=1}^{T} Max(S_{e,t} - H_g \times S_{g,t}, S_{e,t} - H_{bio} \times S_{bio,t}, 0)$$

How to implement

1. Identify the investment's flexibilities
   - E.g., owning a field gives you an option to develop it **provided that** it is profitable to do so.
2. Describe the flexibility in terms of a financial option

Financial option	**Real option**
	Option type
	Cost of acquiring field
	Cost of developing field
	Value of producing field

3. Value the investment using option valuation

Real option vs DCF

How much should you bid for the right to exploit an oil field?

- Lease length: 3 years
- Development cost: \$100m
- Current estimated value: \$90m
- Volatility of fields' return: 40%/year
- Risk-free rate: 5%/year

DCF/NPV ignoring option value:

$$NPV = -100 + 90 < 0$$

Real option vs DCF

How much should you bid? Using real options (Black–Scholes):

Underlying value S	90
Exercise price X	100
Time to expiry T	3
Volatility σ	0.40
Risk-free rate r	0.05

Black–Scholes value of the option = 25.7. That is the value of the lease.

If volatility were higher, the lease value would be higher (upside grows, downside unchanged).

When should one exercise the option to drill?

When should one exercise the option to drill?

Econometrica, Vol. 92, No. 1 (January, 2024), 29–60

DRILLING DEADLINES AND OIL AND GAS DEVELOPMENT

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Oil and gas leases between mineral owners and extraction firms typically specify a date by which the firm must either drill a well or lose the lease. These deadlines are known as primary terms. Using data from the Louisiana shale boom, we first show that well drilling is substantially bunched just before the primary term deadline. This bunching is not necessarily surplus-reducing: using an estimated model of firms' drilling and input choices, we show that primary terms can increase total surplus by countering the effects of leases' royalties, as royalties are a tax on revenue and delay drilling. These benefits are reduced, however, when production outcomes are sensitive to drilling inputs and when drilling one well indefinitely extends the period of time during which additional wells may be drilled. We enrich the model to consider mineral owners' lease offers and find small effects of primary terms on owners' revenue.

Summary

- Value the **flexibilities** embedded in investment projects (e.g. develop an oil field only if oil price is high).
- Apply techniques from financial option pricing — but requires a **traded underlying** (e.g. oil).
- Most useful for **long-lived projects with high uncertainty** (e.g. bidding for an oil field).

Case time! Valuation of oil reserves in the case of “MW Petroleum” is coming up.

MW Petroleum Corporation

Sources of value creation

Which method of valuation (for the whole deal)?

APV with several components:

1. DCF of developed reserves
   - Unlevered cost of capital
2. Real option value of undeveloped reserve
   - Proven, possible and probable
3. Other opportunities ($25 million)
4. Tax shields (attached to each project)

Parameters for valuation

	Financial option	Real option
X (K)	Strike price	Expenditures required to recover reserve
S	Current asset price	Value of reserves using current price
T	Time to expiration	Length of time until decision has to be made
σ	Annual volatility of asset returns	Annual vol. of return on producing fields
r	Risk free rate	10-year US treasury yield

Timeline

1991 — Today

1998 (T)

- Option matures
- If exercised, production starts

2013 — Production ends

Parameters for valuation

	Financial option	Real option
X (K)	Strike price	Expenditures required to recover reserve
S	Current asset price	Value of reserves using current price
T	Time to expiration	Length of time until decision has to be made
σ	Annual volatility of asset returns	Annual vol. of return on producing fields
r	Risk free rate	10-year US treasury yield

Possible reserves	T	T+1	T+2	T+3	T+4	T+5	T+6	T+7	T+8	T+9	T+10	T+11	T+12	T+13	T+14
Cash from operations	1.0	6.8	8.9	10.5	10.4	9.3	13.2	14.5	19.2	19.1	23.6	20.2	18.8	16.9	14.3
Capital expenditures	9.7	9.8	22.4	38.9	27.4	6.8	0.7	1.0	0.7	3.0	2.3	-	0.1	-	-
Cash Flows (in millions)	(8.7)	(3.0)	(13.5)	(28.4)	(17.0)	2.5	12.5	13.5	18.5	16.1	21.3	20.2	18.7	16.9	14.3
Terminal value															72.3
Extraordinary Capex	9.7	9.8	22.4	38.9	27.4	6.8	-	-	-	-	-	-	-	-	-
r_F	8.03%														
Total Extraordinary Capex															
Cash Flows Excluding Extra. Capex	1.0	6.8	8.9	10.5	10.4	9.3	12.5	13.5	18.5	16.1	21.3	20.2	18.7	16.9	14.3
r_A	13%														
PV of Cash Flows Excluding Extra. Capex	69.6														
PV of Terminal Value	11.6														
Total Value Excluding Extra. Capex															

S	
K	
T	7.0
σ	
r	8.03%

Possible reserves	T	T+1	T+2	T+3	T+4	T+5	T+6	T+7	T+8	T+9	T+10	T+11	T+12	T+13	T+14
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Terminal value															72.3
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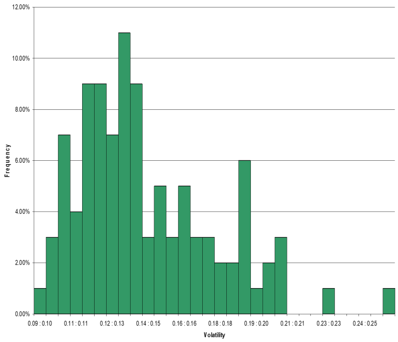
r_F	8.03%														
Total Extraordinary Capex	86.6														
Cash Flows Excluding Extra. Capex	1.0	6.8	8.9	10.5	10.4	9.3	12.5	13.5	18.5	16.1	21.3	20.2	18.7	16.9	14.3
r_A	13%														
PV of Cash Flows Excluding Extra. Capex	69.6														
PV of Terminal Value	11.6														
Total Value Excluding Extra. Capex	81.2														

S	81.2
K	86.6
T	7.0
σ	
r	8.03%

Volatility

1. Randomly draw 15-year sequences of oil and gas prices. Use the volatility and correlation of oil and gas.
2. Compute the value of the field using DCF. Use the case numbers, such as quantities produced and cost structure. Estimate the standard deviation of field return.
3. Repeat steps 1 & 2 a large number of times (say 10,000).
4. Take the average standard deviation in the sample



Estimated volatility is 15%, somewhat conservative

Monte Carlo simulation

Monte Carlo allows to link business items, decisions and sources of uncertainty in a complex (often non linear) manner. It requires:

1. A model of the sources of risk
   - Identify the sources of risk and their interaction, usually captured by their correlation.

2. A model of the business

	Possible Reserves ($millions)														
	T	T+1	T+2	T+3	T+4	T+5	T+6	T+7	T+8	T+9	T+10	T+11	T+12	T+13	T+14
Cash from operations	1.0	6.8	8.9	10.5	10.4	9.3	13.2	14.5	19.2	19.1	23.6	20.2	18.8	16.9	14.3
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Terminal value															72.3
Extraordinary Capex	9.7	9.8	22.4	38.9	27.4	6.8	-	-	-	-	-	-	-	-	-
r_F	8.24%														
Total Extraordinary Capex	86.0														
Cash Flows Excluding Extra. Capex	1.0	6.8	8.9	10.5	10.4	9.3	12.5	13.5	18.5	16.1	21.3	20.2	18.7	16.9	14.3
r_A	13%														
PV of Cash Flows Excluding Extra. Capex	69.6														
PV of Terminal Value	11.6														
Total Value Excluding Extra. Capex	81.2														

S	81.2	$d1$	1.4
K	86.6	$d2$	1.0
T	7.0	$N(d1)$	0.9
σ	**0.15**	$N(d2)$	0.8
r	8.03%	**Option**	**32.1**

Undeveloped and probable reserves

Proved Undeveloped Reserves ($millions)			
S	70.4	$d1$	3.6
K	31.3	$d2$	3.2
T	7.0	$N(d1)$	1.0
σ	0.15	$N(d2)$	1.0
r	8.03%	**Option**	**52.2**

Probable Reserves ($millions)			
S	70.0	$d1$	3.5
K	32.1	$d2$	3.1
T	7.0	$N(d1)$	1.0
σ	0.15	$N(d2)$	1.0
r	8.03%	**Option**	**51.3**

Undeveloped and probable reserves

	DCF	Real Option Valuation
Proved Developed Reserves	383.8	383.8
Proved Undeveloped Reserves	41.0	52.2
Probable Reserves	41.3	51.3
Possible Reserves	7.4	32.1
Other	25.0	25.0
Tax shield	94.5	94.5
Total value	**593.0**	**638.9**

Summary

Options embedded in investment projects can be very valuable, especially when projects have low NPV (possible reserves).

Valuing such options requires:

1. A good understanding of the business (e.g., extraordinary vs. routine CAPEX)
2. An estimate of the volatility of the underlying asset. When volatility is driven by many factors it requires a Monte Carlo analysis
   - A model of future energy prices
   - A model of the business (CF projections based on future energy prices)