Chapter 18
Real Options and Cross-Border Investment

Options on real assets

- A real option is an option on a real asset
- Real options derive their value from managerial flexibility
  - Option to invest or abandon
  - Option to expand or contract
  - Option to speed up or defer

Options on real assets

- Simple options
  - European - Exercisable at maturity
  - American - Exercisable prior to maturity
- Compound option
  - An option on an option
  - Switching option - An alternating sequence of calls and puts
- Rainbow option
  - Multiple sources of uncertainty

Two types of options

- Call option
  An option to buy an asset at a pre-determined amount called the exercise price
- Put option
  An option to sell an asset

The conventional theory of investment

Discount expected future cash flows at an appropriate risk-adjusted discount rate

$$NPV = \Sigma_t\, [E[CF_t] / (1+i)^t]$$

- Include only incremental cash flows
- Include all opportunity costs

Three investment puzzles

1. MNC's use of inflated hurdle rates in uncertain investment environments
2. MNC's failure to abandon unprofitable investments
3. MNC's negative-NPV investments in new or emerging markets

Puzzle #1
Firms' use of inflated hurdle rates

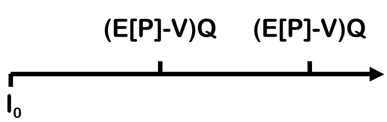
Market entry and the option to invest

- Investing today means foregoing the opportunity to invest at some future date, so that projects must be compared against similar future projects
- Because of the value of waiting for more information, corporate hurdle rates on investments in uncertain environments are often set above investors' required return

An example of the option to invest

- Investment $I_0 = PV(I_1)$ = $20 million
  The present value of investment is assumed to be $20 million regardless of when investment is made.
- Price of oil P = $10 or $30 with equal probability
  ⇒ E[P] = $20
- Variable production cost V = $8 per barrel
- E[production] = Q = 200,000 barrels/year
- Discount rate i = 10%

Valuing investment today as a now-or-never alternative



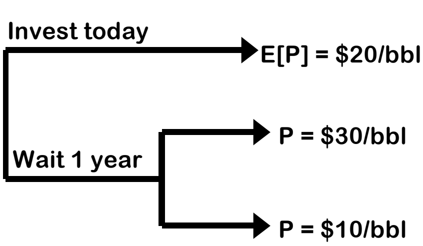
$$NPV = [(E[P]-V)Q / i] - I_0$$

The option to invest as a now-or-never decision

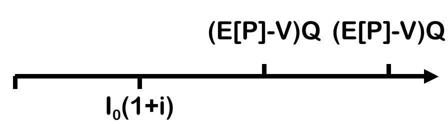
NPV(invest today)
= ($20-$8) (200,000) / .1 - $20 million
= $4 million > $0

⇒ invest today (?)

Invest today or wait for more information



The option to wait one year before deciding to invest



$$NPV = [(E[P]-V) Q / i] / (1+i) - I_0$$

In this example, waiting one year reveals the future price of oil

The investment timing option

NPV(wait 1 year | P=$30)
= (($30-$8)(200,000) /.1) / (1.1) - $20,000,000
= $20,000,000 > $0
⇒ invest if P = $30

NPV(wait 1 year | P=$10)
= (($10-$8)(200,000) /.1) / (1.1) - $20,000,000
= -$16,363,636 < $0
⇒ do not invest if P = $10

⇒ NPV(wait 1 year | P=$10) = $0

The investment timing option

NPV(wait 1 year)
= Probability(P=$10) (NPV | $10)
+ Probability(P=$30) (NPV | $30)

= ½ ($0) + ½ ($20,000,000)

= $10,000,000 > $0

⇒ wait one year before deciding to invest

Option value = intrinsic + time values

Intrinsic value
= value if exercised immediately

Time value
= additional value if left unexercised

The opportunity cost of investing today

Option Value
= Intrinsic Value + Time Value

NPV(wait 1 year)
= Value if exercised immediately + Additional value from waiting

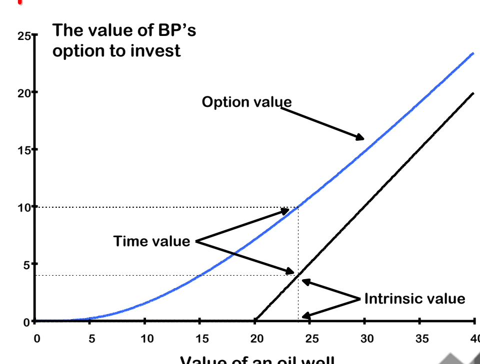
$10,000,000
= $4,000,000 + $6,000,000

A resolution of Puzzle #1
Use of inflated hurdle rates

Managers facing this type of uncertainty have four choices

- Ignore the timing option (?!)
- Estimate the value of the timing option using option pricing methods
- Adjust the cash flows with a decision tree that captures as many future states of the world as possible
- Inflate the hurdle rate (apply a "fudge factor") to compensate for high uncertainty

Option value = intrinsic + time values

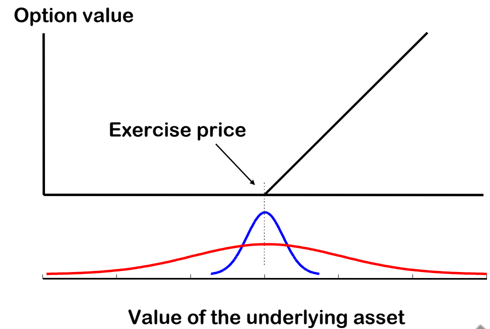


Call option value determinants

Option value determinant	Relation to call option value	BP example
Value of the underlying asset P	+	$24 million
Exercise price of the option K	-	$20 million
Volatility of the underlying asset σ_P	+	($3.6m or $40m)
Time to expiration of the option T	+	1 year
Riskfree rate of interest R_F	+	10%

Time value = f (P, K, T, σ_P, R_F)

Volatility and option value



Exogenous price uncertainty

Exogenous uncertainty is outside the influence or control of the firm

Oil price example

P_1 = $35 or $5 with equal probability

⇒ E[P_1] = $20/bbl

NPV(invest today)

= (($20-$8)(200,000) /.1) - $20 million

= $4,000,000 > $0 ⇒ invest today?

Exogenous price uncertainty

NPV(wait 1 year | P_1=$35)

= (($35-$8)200,000 /.1)/1.1 - $20 million

= $29,090,909 > $0

⇒ invest if P_1=$35

NPV(wait 1 year | P_1=$5)

= (($5-$8)(200,000) /.1)/1.1 - $20 million

= -$25,454,545 < $0

⇒ do not invest if P_1=$5

Exogenous price uncertainty

NPV(wait one year)

= (½)($0)+(½)($29,090,909)

= $14,545,455 > $0

⇒ wait one year before deciding to invest

Time value & exogenous uncertainty

Option value = Intrinsic value + Time value

±$10

$10,000,000 = $4,000,000 + $6,000,000

±$15

$14,545,455 = $4,000,000 + $10,545,455

The time value of an investment option increases with exogenous price uncertainty

Puzzle #2
Failure to abandon losing ventures

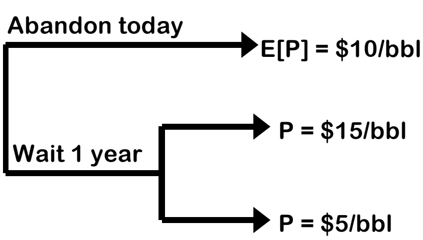
Market exit & the option to abandon

- Abandoning today means foregoing the opportunity to abandon at some future date, so that abandonment today must be compared to future abandonment
- Because of the value of waiting for additional information, corporate hurdle rates on abandonment decisions are often set above investors' required return

An example of the option to abandon

- Cost of disinvestment $I_0 = PV(I_1)$ = \$2 million
- Price of oil P = \$5 or \$15 with equal probability
  ⇒ E[P] = \$10
- Variable production cost V = \$12 per barrel
- E[production] = Q = 200,000 barrels/year
- Discount rate i = 10%

Abandon today or wait for more information



The option to abandon as a now-or-never decision

NPV(abandon today)
= -(\$10-\$12) (200,000) / .1 - \$2 million
= \$2 million > \$0

⇒ abandon today (?)

The abandonment timing option

NPV(wait 1 year | P=\$5)
= -((\$5-\$12)(200,000) /.1) / (1.1) - \$2 million
= \$10,727,273 > \$0
⇒ abandon if P=\$5

NPV(wait 1 year | P=\$15)
= -((\$15-\$12)(200,000) /.1) / (1.1) - \$2 million
= -\$7,454,545 < \$0
⇒ do not abandon if P=\$15

The abandonment timing option

NPV(wait 1 year)
= Probability(P=\$5) (NPV | \$5)
+ Probability(P=\$15) (NPV | \$15)

= ½ (\$10,727,273) + ½ (\$0)

= \$5,363,636 > \$0

⇒ wait one year before deciding to abandon

Opportunity cost of abandoning today

Option Value
= Intrinsic Value + Time Value

NPV(wait 1 year)
= NPV(abandon today) + Additional value from waiting 1 year

$5,363,636
= $2,000,000 + $3,363,636

Hysteresis

Cross-border investments often have different entry and exit thresholds

- Cross-border investments may not be undertaken until the expected return is well above the required return
- Once invested, cross-border investments may be left in place well after they have turned unprofitable

Puzzle #3 Negative-NPV entry into emerging markets

- Firms often make investments into emerging markets even though investment does not seem warranted according to the NPV decision rule
- An exploratory (perhaps negative-NPV) investment can reveal information about the value of subsequent investments

Growth options and project value

$$V_{Asset} = V_{Asset\text{-}in\text{-}place} + V_{Growth\ options}$$

Consider a negative-NPV investment

- Initial investment $I_0 = PV(I_1)$ = $20 million
- Price of Oil P = $10 or $30 with equal probability
  ⇒ E[P] = $20
- Variable production cost V = $12 per barrel
- E[production] = Q = 200,000 barrels/year
- Discount rate i = 10%

The option to invest as a now-or-never decision

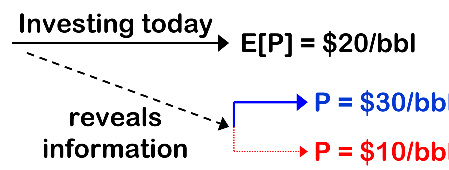
NPV(invest today)
= ($20-$12) (200,000)/.1 - $20,000,000
= -$4 million < $0

⇒ do not invest today (?)

Endogenous price uncertainty

- **Uncertainty** is **endogenous** when the act of investing reveals information about the value of an investment
  - Suppose this oil well is the first of **ten identical wells** that BP might drill
  - and that the quality and hence **price** of oil from these wells **cannot be revealed without drilling a well**

Invest today in order to reveal information about future investments



The investment timing option

NPV(wait 1 year | P=$30)
= (($30-$12)(200,000) /.1) / (1.1) - $20,000,000
= $12,727,273 > $0
⇒ invest if P = $30

NPV(wait 1 year | P=$10)
= (($10-$12)(200,000) /.1) / (1.1) - $20,000,000
= -$53,272,727 < $0
⇒ do not invest if P = $10

A compound option in the presence of endogenous uncertainty

NPV(invest in an exploratory well)
= NPV(one now-or-never well today)
+ Prob($30) (NPV of 9 more wells | $30)
= -$4,000,000 + ½ (9) ($12,727,273)
= $53,272,727 > $0

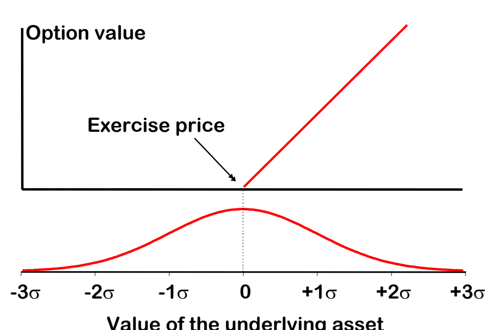
⇒ invest in an exploratory oil well and reconsider further investment in one year…

A resolution of Puzzle #3 Entry into emerging markets

The value of growth options

- Negative-NPV investments into emerging markets are often out-of-the-money call options entitling the firm to make further investments should conditions improve
- If conditions worsen, the firm can avoid making a large sunk investment
- If conditions improve, the firm can choose to expand its investment

Why DCF fails



Why DCF fails

- **Nonnormality**
  Returns on options are not normally distributed even if returns to the underlying asset are normal
- **Option volatility**
  Options are inherently riskier than the underlying asset
- **Changing option volatility**
  Option volatility changes with changes in the value of the underlying asset

The option pricing alternative

- Option pricing methods construct a replicating portfolio that mimics the payoffs on the option
- Costless arbitrage then ensures that the value of the option equals the value of the replicating portfolio

Pricing financial options

- Underlying asset values are observable
  - For example, the price of a share of stock
- Low transactions costs allow arbitrage
  - Most financial assets are liquid
- A single source of uncertainty
  - Contractual exercise prices & expiration dates result in a single source of uncertainty
- Exogenous uncertain
  - Most financial options are side bets that don't directly involve the firm, so uncertainty is exogenous

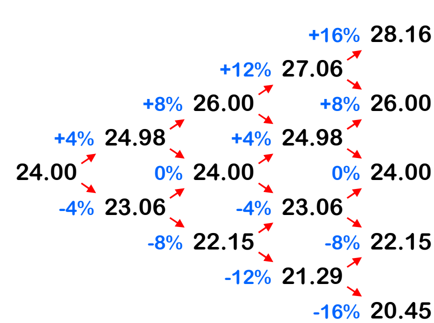
Pricing real options

- Underlying asset values are unobservable
  - What is the value a manufacturing plant?
- High transactions costs impede arbitrage
  - Real assets are illiquid
- Multiple sources of uncertainty
  - e.g. exercise prices can vary over time
  - e.g. exercise dates are seldom known
- Endogenous uncertain
  - Investing reveals information

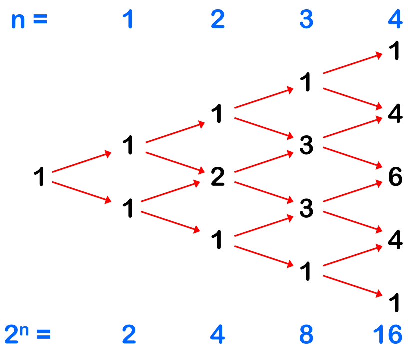
Advanced: Pricing real options

- Suppose the value of an oil well bifurcates by a continuously compounded ±4 percent per year for 4 years
- 4 successive bifurcations result in $2^4 = 16$ price paths
- Value after 1 year is $P_1 = P_0 e^{\pm 0.04}$
  ($24m)$e^{-0.04}$ = $23.06m
  ($24m)$e^{+0.04}$ = $24.98m
  each with 50 percent probability

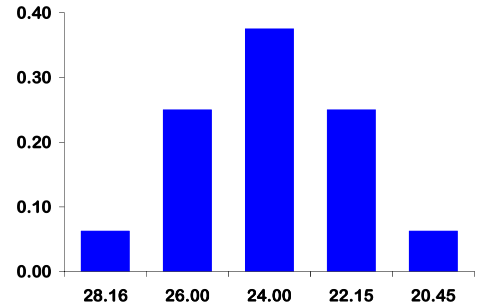
±4 percent for 4 periods



2^4 = 16 possible price paths



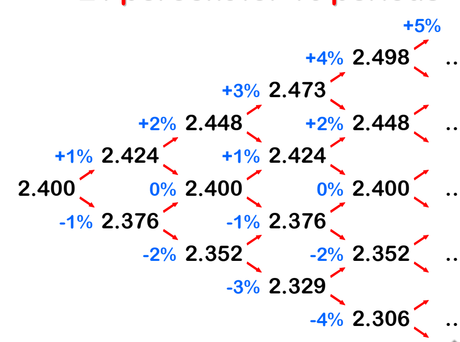
End-of-period distribution for n = 4



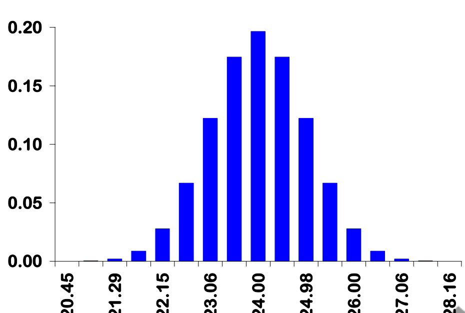
More frequent compounding…

- Rather than 4% per annum for 4 years, suppose we apply the binomial model with 1% per quarter for 16 quarters
- This results in $2^n = 2^{16}$ = 256 price paths and n-1 = 15 possible end-of-period prices

±1 percent for 16 periods



End-of-period distribution for n = 16



The Binomial and B-S OPMs

- As the binomial process generating up and down movements bifurcates over shorter and shorter intervals
  - the binomial distribution approaches the normal distribution
  - and continuous-time option pricing methods such as the Black-Scholes option pricing model can be used