Using real options

FN 451

Topics

- Valuation with real options
- What are real options?
- Limitations of DCF approach
- Review of Black & Scholes Option Pricing
- Options embedded in projects
  - Option to abandon project
  - Option to delay project
  - Option to expand project

What are real options?

- An option on a non-traded asset such as an investment project.
- Sometimes they are referred to as "strategic options" as the represent opportunities that arise from the ability to alter a project midcourse.
- Real/strategic options are valued with the same option pricing strategies you've learnt. We will focus on Black and Scholes method.

Investment Decision and Call Option

Investment Opportunity		Call Option
PV of project's operating assets to be acquired	S	Stock Price
Expense required to acquired the proj's assets	X	Exercise Price
Length of time the decision may be deferred	T	Time to Expiration
Time value of money	r_f	Risk-free Rate of Return
Riskiness of project assets	σ^2	Variance of Return on Stock

Limitations of DCF approach

DCF Assumptions
- Decision making is static. Assumes no new information arriving during life of project.
- Discount rate is known and constant throughout life of project.

Reality
- Managers need to account for interim information during life of project.
- Managers has discretion in making future operations that will tend to affect risk of project under consideration.

Next year's project value

- DCF $$V_1 = \frac{E(PVCF)}{(1+WACC)}$$

- Valuation with real options

$$V_2 = \frac{E(PVCF)}{(1+WACC)} + f$$

Real Option Value :

Improve upside potential

limit downside losses

Strategic NPV = Static NPV + value of options from active management

Basic Properties of Option Prices

- Option prices without assumptions about volatility and probabilistic behaviour of stock prices.
- Long position on European call is
$$\max(S_T - X, 0)$$
- Long position on European put is
$$\max(X - S_T, 0)$$

Basic Properties of Option Prices

- Put-Call parity: The value of European call with a certain exercise price and exercise date can be deduced from value of European put with same exercise price and date, and vice versa.
- In other words, the value of a portfolio with one European call plus an amount of cash equal to Xe^{-rT} should be equal to the value of a portfolio with one European put plus one share.
- At expiration both portfolios are worth $\max(S_T, X)$
- This means the following must hold today,

$$c + Xe^{-rT} = p + S_0$$

Basic idea of Black-Scholes-Merton Option Pricing Formula

- S is lognormally distributed. Define g(S) as the probability density function of S. It follows that,

$$E[\max(S-X),0] = \int_X^\infty (S-X)g(S)d(S)$$

- Now assume existence of risk free rate r, the call price is given by,

$$c = e^{-rT}E[\max(S_T - X),0]$$
$$c = e^{-rT}E[S_0e^{rT}N(d_1) - XN(d_2)]$$

Black-Scholes Option Pricing Formula without dividends

- Black-Scholes

$$c = S_0N(d_1) - Xe^{-rT}N(d_2)$$
$$p = Xe^{-rT}N(-d_2) - S_0N(-d_1)$$
$$c + Xe^{-rT} = p + S_0$$

where

$$d_1 = \frac{\ln(S_0/X) + (r + \sigma^2/2)T}{\sigma\sqrt{T}}$$
$$d_2 = d_1 - \sigma\sqrt{T}$$

The cumulative normal distribution

- N(x) is the cumulative probability distribution function for a variable that is N~(0,1).
- The expression $XN(d_2)$ is the strike price times the probability of that the option will be exercised.
- The expression $S_0N(d_1)e^{rT}$ is the expected value of a variable that equals S_T when $S_T > X$ and is zero otherwise.

Black-Scholes without dividends

- Example: A stock price six months from expiration of an option is Bt42, the exercise price of the option is Bt40, the risk-free interest rate is 10% per year and volatility is 20% per year. Compute the value of the option,

$$d_1 = \frac{\ln(42/40) + (0.1 + 0.2^2/2)\cdot 0.5}{0.2\sqrt{0.5}} = 0.7693$$

$$d_2 = \frac{\ln(42/40) + (0.1 - 0.2^2/2)\cdot 0.5}{0.2\sqrt{0.5}} = 0.6278$$

- N(0.7693) = 0.7791 N(-0.7693) = 0.2209
- N(0.6278) = 0.7349 N(-0.6278) = 0.2651

- C = 42N(0.7693) – 38.049N(0.6278) = 4.76
- P = 38.049N(-0.6278) – 42N(-0.7693) = 0.81

Black-Scholes Option Pricing Formula with dividends

$$c = S_0 e^{-\gamma T} N(d_1) - X e^{-rT} N(d_2)$$

$$p = X e^{-rT} N(-d_2) - S_0 e^{-\gamma T} N(-d_1)$$

$$c + X e^{-rT} = p + S_0$$

Where,

$$d_1 = \frac{\ln(S_0/X) + (r - \gamma + \sigma^2/2)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

Black-Scholes with dividends

- Example: A European call option where there are ex-dividend dates in two months and five months. The dividend on each ex-div date is expected to be $0.50. The current share price is $40, X = $40, and volatility = 30% per year, r = 9% per year, and time to maturity is six months. What is the call price?
- PV of dividends is $0.5e^{-(2/12)\cdot 0.09} + 0.5e^{-(5/12)\cdot 0.09} = 0.9741$
- Option price from BS formula, S0 = 40-0.9741 = 39.0259, X = 40, r =0.09, σ =0.3, and T = 0.5.
- Plugging in variables in BS formula gives value of call price = $3.67.

Inputs for real option valuation

- ***Value of underlying asset:*** This is value of project itself, that is, the PV is expected CFs from starting the project obtained from standard capital budgeting.
- ***Variance of asset value:*** 1) Use variance of similar CFs of similar projects in the past. 2) Run sensitivity analysis and compute variance across outcomes. 3) Use average variance of firm value of publicly traded companies which are in business of similar projects.
- ***Exercise price of option:*** Cost of making additional investments, abandonment sales value, or delayed investments.
- ***Expiration:*** How long it takes for option to expire.
- ***Dividend yield:*** Each year of project delay translate into one less year of value creating CFs. For example, if you have a patent for 10 years, the annual cost of delay is 1/n. (If n=20 years, annual cost of delay is 5% per year)

Applications: Option to expand

- The option to expand a project:
  - If demand increases suddenly, a firm may build production capacity in excess of the expected level of output.
  - In this case, management has the right but not the obligation to expand and will exercise the option only if project conditions turn out to be favourable. The option to expand is valued like a ***call option.***

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Applications: Options to expand

- Examples:
  - Options to expand allow management not to make large investment commitment, but rather retain the expansion option only if those projects appear profitable.
  - Options to expand are important to high-tech and software companies including business that has significant first-mover advantages.

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Valuing option to expand

- Home depot is considering opening a small store in France. Store will cost FF100 mn to build and PVCF from store is FF 80 mn. Thus, NPV is negative FF20mn.
- Assume that by opening store, Home depot will acquire option to expand at any time over 5 years. Cost of expansion is FF 200 mn and will be taken only if PVCF > FF 200 mn. Today, this PVCF is estimated only FF 150 mn.
- Let variance of CF = 0.08, r = 6% per year. What is value of store's NPV with option to expand?
- Value of underlying asset = PVCF now = 150 FF mn
- Strike price = cost of expansion = 200 FF mn

$$c = 150\,(0.6314) - 200\, e^{(-0.06)(5)}(0.3833) = 37.91\, mn$$

- NPV of store + expansion option = -20 mn + 37.91mn =17.91 FF mn

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Applications: Options to delay

- The option to delay:
  - The option to choose when to start a project is called an initiation or delay option.
  - The option to delay a project is exercised when the firm owning the rights to the project decides to invest in it. The cost of making this initial investment is the exercise price and are thus priced as a ***call option.***
  - If CF are evenly distributed, the annual cost of delay is 1/n. Ex. If you have project rights for 20 years, the annual cost of delay is 5% per year. This cost of delay rises each year to 1/19 in year 2, 1/18 in year 3, and so on.

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Applications: Options to delay

- Examples:
  - Initiation or delay options are particularly valuable in natural resource exploration and real estate where the firm can delay mining a deposit or construction until market conditions become favourable.

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Valuing option to delay

- Ex 1: You want to acquire exclusive rights to market new product. The rights will cost $50 mn up-front. You believe the service will generate $10 mn after tax CF each year. You also expect serious competition in next 5 years. Assume project WACC = 15%, r = 5%, STD of project CF = 42%.
- What is the project's conventional NPV?

NPV = -50 + 10*(PVIFa, 15%, 5) = -50 + 33.5 = -16.5 mn

- What is value of option to delay?
- Value of underlying asset (S0) = PVCF if project introduced now = 33.5 mn

$$c = 33.5e^{(-0.2)(5)}(0.2250) - 50e^{(-0.05)5}(0.0451) = \$1.018mn$$

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Applications: Abandonment option

- The option to abandon a project:
  - Whereas traditional capital budgeting analysis assumes that a project will operate in each year of its lifetime, the firm may have an option to cease a project during its life.
  - Abandonment options, which are the right to sell the cash flows over the remainder of the project's life for some salvage value, are like ***put options***. When PV of remaining cash flows falls below the liquidation value, the asset may be sold.

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Applications: Abandonment option

- Examples
  - These options are particularly important for large capital intensive projects such as nuclear plants, airlines, railroads, oil & gas exploration etc.
  - They are also important for projects involving new products where their acceptance in the market is uncertain.

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Valuing Option to Abandon

- Home depot is considering a new store that requires a net initial investment of \$9.5 mn and generates PVCF of \$ 8.563 mn.
- Assume Home depot has option to close the store any time over the next 10 years and sell land back to original owner for \$5 mn. Let STD CF = 22%, r=5% per year.
- Value of underlying asset = PVCF = \$ 8.563 mn.
- Strike price = salvage value from abandonment = \$5 mn.

$$p = 5{,}000{,}000e^{(-0.05)(10)}(1-0.4977) - 8{,}562{,}713e^{(-0.10)(10)}(1-0.7548)$$
$$p = 783{,}464$$

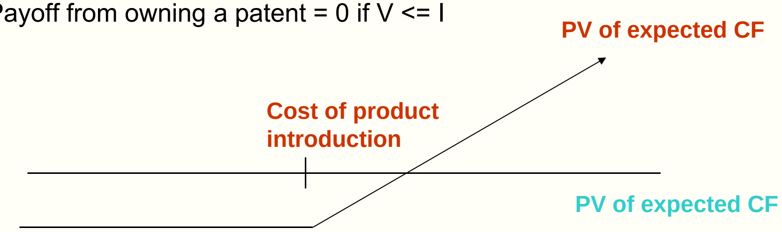
- NPV with abandonment option = \$937,287+\$783,464

Option application in valuations

- Motivation for valuing equity as an option
- DCF approach can underestimate value of firm equity
- When a firm gets significant portion of its value from patent and licenses
- When a natural resource firm has undeveloped reserves
- When a firm has negative earnings and large liabilities

Valuing firms with license

- Value of firm = DCF of developed patents + option value of patents owned but not developed + (option value of patents to be developed – R&D costs)
- Payoff from owning a patent = V – I if V > I
- Payoff from owning a patent = 0 if V <= I

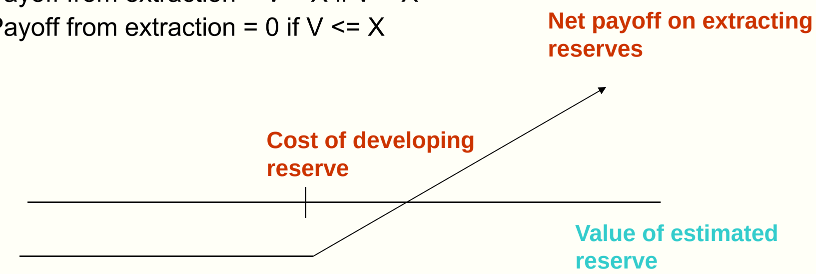


Valuing a patent

- Ex. Biogen is a biotech firm with a patent on a new drug.
- PVCIF from drug launch is \$3.422 bn before initial development cost.
- The initial cost of developing the drug for commercial use is estimated to be \$2.875 bn if introduced today.
- The firm has patent on drug for next 17 years and current risk-free = 6.7%
- The average variance of firm value for publicly traded biotech firms is 0.224.
- Compute the option value of this patent
- Value of patent = 3.422[exp(-0.06)(17)](0.8721) – 2.875[exp(-0.067)(17)](0.2076) = 0.907 bn

Valuing natural resources firms

- Value of firm = DCF of developed reserves + option value of undeveloped reserves + (Option value of expected future reserves – Cost of exploration to generate these reserves)
- Payoff from extraction = V – X if V > X
- Payoff from extraction = 0 if V <= X



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Valuing an oil reserve

- Consider an offshore oil property with estimated oil reserve of 50 mn barrels. The cost of developing the reserve is expected at $600 mn and the development lag is 2 years. Exxon has rights to exploit this reserve for the next 20 years and the marginal value (price/barrelcost/ barrel) is $12 per barrel. Once developed, production revenue is expected to be 5% of reserve value per year (div. yield). RF = 8%, variance in oil prices is 0.03. Compute the call option value of reserve extraction.

- Current value of asset = S = Value of developed reserved discounted = 12 x 50/(1.05)^2 = $544.22
- Exercise price = cost of extraction = $600 mn
- Call value = 544.22[exp(-0.05)(20)](0.8499) – 600[exp(-0.08)(20)](0.6031) = $97.114 mn

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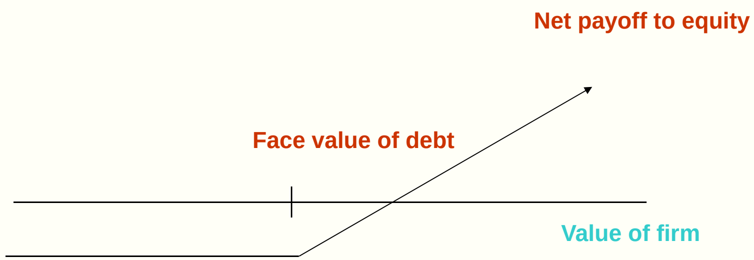
Valuing equity in troubled firms

- Payoff to equity on liquidation = V – D if V > D
- Payoff to equity on liquidation = 0 if V <= D



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Valuing equity as an option

- A firm with assets currently valued at $100 mn, STD of asset value is 40%. The face value of debt is $80 mn. (Zero coupon with 10 year left to maturity) The 10 year RF is 10%. Use the call option pricing model to value the firm's equity.
- Value of underlying asset = S = $100 mn
- Exercise price = X = $80 mn
- Life of option = T = 10 years
- STD = 40%
- RF = 6%
- Value of call (Equity) = 100*(0.9003) – 80*[exp(-0.10)(10)](0.5073) = 67.76 mn
- Thus, value of outstanding debt = 100 – 67.76 = 32.24 mn

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Valuing equity as an option

- Using the preceding example, assume that the firm value drops to $50 mn below face value of debt. What is the value of call (equity)?
- Value of equity = 50(0.7689) – 80*[exp(-
- 0.1)(10)](0.2987) = 25.35 mn
- Value of debt = 50 mn – 25.35 mn = 24.65

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Inputs for valuing equity as an option

- Obtain market values of outstanding debt and equity. (Easy if both are traded)
- Estimate market values of firm's assets with DCF method.
- Compute variance of firm value.

$$\sigma^2_{Firm} = w_E^2\sigma_E^2 + w_D^2\sigma_D^2 + 2w_E w_D \sigma_{ED}$$

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Examples of Real Options

Category	Description	Important in:
Option to Defer	Management has opportunity to wait to invest, and can see if markets warrant further investment.	Natural resources extraction, real estate, farming, technology.
Staged Investment	Staging investment creates the option to reevaluate and/or abandon at each stage.	R&D intensive industries, energy generation, start-up ventures.
Option to alter operating scale	If market conditions change, the firm can expand/contract or temporarily shut down.	Natural resources, fashion, real estate, consumer goods.
Option to abandon	If market conditions decline, management sells off assets	Capital-intensive industries, new product introductions in uncertain markets.
Option to switch	If prices or demand change, management can change product mix (product flexibility) or switch inputs (process flexibility)	Companies in volatile markets with shifting preferences, energy companies
Growth options	An early investment opens up future growth opportunities in the form of new products or processes, access to markets, or strengthening of core capabilities—like interproject compound options	High tech; industries with multiple product generations (drug companies, computers, strategic acquisitions).
Multiple Interacting Options	Projects involve a collection of various options—both put and call types. Values can differ from the sum of separate option values because they interact.	Many of the industries discussed above

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