CHAPTER 8

Financial Options and Applications in Corporate Finance

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This chapter is about financial options. However, this course is concerned with real options rather than financial options. We do this chapter to allow us to discuss and detect real options.

Need to Absorb - Definitions and terms related to options, such as put, call, long, short, in-the-money, at-the-money, out-of-the-money, strike, exercise price, real option, etc. Be able to compute the value at expiration, and net profit for puts and calls in both long and short positions. Be able to compute the value of a call option or put option using a 1-period binomial option pricing model. Be able to compute the value of assets, calls, puts, and bonds using the put-call parity formula. Be aware of the inputs into valuing options as listed with the Black-Scholes Options Pricing Model. When given information on real options, be able to identify the type of option, who is long, who is short, the underlying asset, the exercise price, and sometimes the premium.

Do not need to know - You will not be asked to value options using the Black-Scholes Options Pricing Model on exams.

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Need to Read – You need to read the Chapter. While reading, have the Chapter 8 Excel Toolkit open, so that you can work the chapter examples. Re-read Chapter 11 as it relates to real options. This topic is difficult for most, so you might want to read some of the supplemental links I provide in the structured study guide.

Need to Do - Make 100 on the quiz. Spend enough time on valuing options (at expiration, with put-call parity, and the binomial model) that you understand the arbitrage valuation methods (as opposed to the discounted cash flow analysis used elsewhere in the course). Try to identify and classify some real options in your life, you need to apply this material to ingrain this material. Be able to answer all of the end of chapter Questions, Self-test problem 1, end of chapter problems on put-call parity on page 369, Problems 1, 2, 4, 6, and 7.

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Topics in Chapter

- Financial Options Terminology
- Option Price Relationships
- Black-Scholes Option Pricing Model
- Put-Call Parity

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Discounted Cash Flow versus Arbitrage Valuation

- Discounted Cash Flow
  - Time Value of Money
  - Future Cash Flows
  - Risk Adjusted Discount Rate
- Arbitrage
  - Things with the same risk and return have the save value
  - Discount rate is the risk free rate

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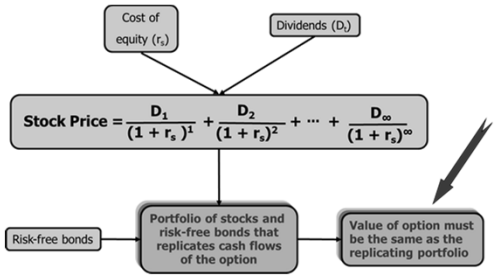
The Big Picture: The Value of a Stock Option



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What is a financial option?

- An option is a contract which gives its holder the right, but not the obligation, to buy (or sell) an asset at some predetermined price within a specified period of time.

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Option Terminology

- Long Call option: An option to buy a specified number of shares of a security within some future period.
- Long Put option: An option to sell a specified number of shares of a security within some future period.

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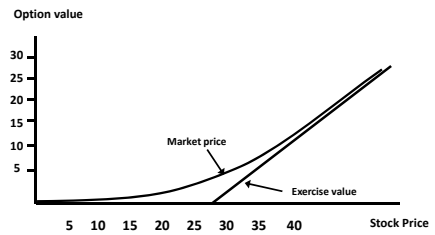
Long Call Time Value Diagram



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Ways to value options

- Value at expiration
- Put-call parity
  - Money ball
- Binomial Option Pricing Model
- Black Scholes Option Pricing Model

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Value of Option at Expiration

- Long Call = Maximum (Asset Value – Exercise Price, or 0)
- Short Call = Minimum (Exercise Price - Asset Value, 0)
- Long Put = Max (Exercise – Stock, 0)
- Short Put = Min (S-X,0)

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Overall Profit of Option at Expiration

- Long Call = Maximum (Asset Value – Exercise Price, or 0) - Premium
- Short Call = Minimum (Exercise Price - Asset Value, 0) + Premium
- Long Put = Max (Exercise – Stock, 0) - Premium
- Short Put = Min (S-X,0) + Premium

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Net Profit of Option

- Long Call = Maximum (Asset Value – Exercise Price, or 0) - Premium
- Short Call = Minimum (Exercise Price - Asset Value, 0) + Premium
- Long Put = Max (Exercise – Stock, 0) - Premium
- Short Put = Min (S-X,0) + Premium

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Binomial Model (three models)

- **Risk- Neutral Method**
- 1. At each point, determine the two possible outcome values.
- 2. Recognize the value of an out-of-the-money option is 0 and an in-the-money option is (P_0-X) for a call and (X-P_0) for a put.
- 3. If an investor is risk-neutral the expected return = interest rate.
- 4. Solve for the probability of a price rise using the following formula:
- Risk-free interest rate, rf = [(Prob. Of rise) x % Increase in price] + [(1- Prob. of rise) x % Decrease in price]
- 5. Solve for the expected future value of the option using the following formula: Expected FV of option = [(Prob. of rise) x Option value if price increase] + [(1-Prob. of rise) x Option value if price decrease]
- 6. Value of the option = Expected future value of the option / (1 + rf)

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What are the three equations that make up the Black Scholes OPM?

$$V_C = P[N(d_1)] - X\, e^{-r_{RF}t}\,[N(d_2)]$$

$$d_1 = \frac{\ln(P/X) + [r_{RF} + (\sigma^2/2)]t}{\sigma\ t^{0.5}}$$

$$d_2 = d_1 - \sigma\ t^{0.5}$$

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Put-Call Parity Relationship

- Portfolio payoffs are equal, so portfolio values also must be equal.
- Put + Stock = Call + PV of Exercise Price
- Moneyball
- Stock = Call + PV of Exercise Price – Put
  - Real Stocks cash flow's = Synthetic Stock's cash flows

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What is a real option?

- Real options exist when managers can influence the size and risk of a project's cash flows by taking different actions during the project's life in response to changing market conditions.
- Alert managers always look for real options in projects.
- Smarter managers try to create real options.
- Strategic NPV = Passive NPV + Value of Real Options – Cost of Real Options

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Real Options

- Need to ID type, who is long and short, underlying asset and exercise price
- Long Call – right to accept something good
- Long Put – right to avoid something bad
- Short Call – obligation to accept something bad
- Short Put – obligation to give up something good

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Topics in Chapter

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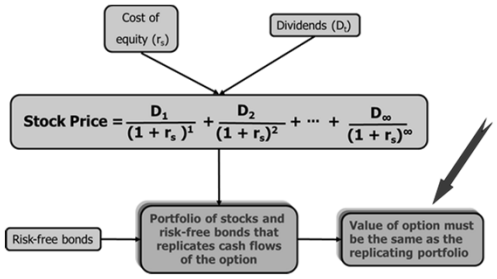
The Big Picture: The Value of a Stock Option



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What is a financial option?

- An option is a contract which gives its holder the right, but not the obligation, to buy (or sell) an asset at some predetermined price within a specified period of time.

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What is the single most important characteristic of an option?

- It does not obligate its owner to take any action. It merely gives the owner the right to buy or sell an asset.

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Option Terminology (1 of 8)

- Call option: An option to buy a specified number of shares of a security within some future period.
- Put option: An option to sell a specified number of shares of a security within some future period.

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Option Terminology (2 of 8)

- Strike (or exercise) price: The price stated in the option contract at which the security can be bought or sold.
- Expiration date: The last date the option can be exercised.

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Option Terminology (3 of 8)

- Exercise value: The value of a call option if it were exercised today =
  - Max[0, Current stock price - Strike price]
  - Note: The exercise value is zero if the stock price is less than the strike price.
- Option price: The market price of the option contract.

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Option Terminology (4 of 8)

- Time value: Option price minus the exercise value. It is the additional value because the option has remaining time until it expires.

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Option Terminology (5 of 8)

- Writing a call option: For every new option, there is an investor who "writes" the option.
  - A writer creates the contract, sells it to another investor, and must fulfill the option contract if it is exercised.
  - For example, the writer of a call must be prepared to sell a share of stock to the investor who owns the call.

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Option Terminology (6 of 8)

- Covered option: A call option written against stock held in an investor's portfolio.
- Naked (uncovered) option: An option written without the stock to back it up.

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Option Terminology (7 of 8)

- In-the-money call: A call whose strike price is less than the current price of the underlying stock.
- Out-of-the-money call: A call option whose strike price exceeds the current stock price.

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Option Terminology (8 of 8)

- LEAPS: Long-term Equity AnticiPation Securities that are similar to conventional options except that they are long-term options with maturities of up to 2 ½ years.

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Consider the following data:

Strike price = $25.

Stock Price	Call Option Price
$25	$3.00
30	7.50
35	12.00
40	16.50
45	21.00
50	25.50

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Value of Option at Expiration

- Long Call = Maximum (Asset Value – Exercise Price, or 0)
- Short Call = Minimum (Exercise Price - Asset Value, 0)
- Long Put = Max (Exercise – Stock, 0)
- Short Put = Min (S-X,0)

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Net Profit of Option

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- Short Call = Minimum (Exercise Price - Asset Value, 0) + Premium
- Long Put = Max (Exercise – Stock, 0) - Premium
- Short Put = Min (S-X,0) + Premium

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Exercise Value of Option

Price of stock (a)	Strike/Exercise price (b)	Exercise value of call and put option (a)–(b)	
15.00	25.00	0.00	10.00
20.00	25.00	0.00	5.00
$25.00	$25.00	$0.00	0.00
30.00	25.00	5.00	0.00
35.00	25.00	10.00	0.00
40.00	25.00	15.00	0.00
45.00	25.00	20.00	0.00
50.00	25.00	25.00	0.00

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Market Price of Call Option

Price of stock (a)	Strike price (b)	Exer. val. (c)	Mkt. Price of opt. (d) (aka Premium)
$25.00	$25.00	$0.00	$3.00
30.00	25.00	5.00	7.50
35.00	25.00	10.00	12.00
40.00	25.00	15.00	16.50
45.00	25.00	20.00	21.00
50.00	25.00	25.00	25.50

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Time Value of Call Option

Price of stock (a)	Strike price (b)	Exer. Val. (c)	Mkt. P of opt. (d)	Time value (d) – (c)
$25.00	$25.00	$0.00	$3.00	$3.00
30.00	25.00	5.00	7.50	2.50
35.00	25.00	10.00	12.00	2.00
40.00	25.00	15.00	16.50	1.50
45.00	25.00	20.00	21.00	1.00
50.00	25.00	25.00	25.50	0.50

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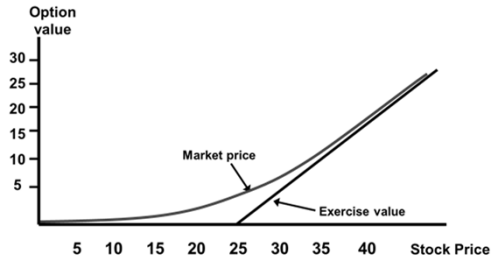
Call Time Value Diagram



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Option Time Value Versus Exercise Value

- The time value, which is the option price less its exercise value, declines as the stock price increases.
- This is due to the declining degree of leverage provided by options as the underlying stock price increases, and the greater loss potential of options at higher option prices.

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The Binomial Model

- Stock assumptions:
  - Current price: P = $27
  - In next 6 months, stock can either
    - Go up by factor of 1.41
    - Go down by factor of 0.71
- Call option assumptions
  - Expires in t = 6 months = 0.5 years
  - Exercise price: X = $25
  - Risk-free rate: r_{RF} = 6%

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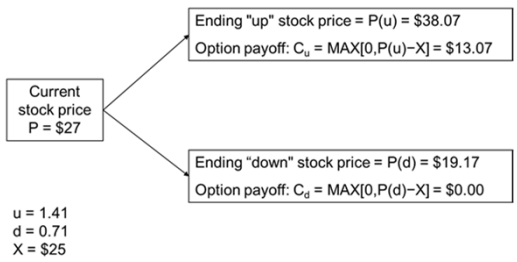
Binomial Payoffs at Call's Expiration



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Create portfolio by writing 1 option and buying N_s shares of stock.

- Portfolio payoffs:
- Stock is up: $N_s(P)(u) - C_u$
- Stock is down: $N_s(P)(d) - C_d$

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The Hedge Portfolio with a Riskless Payoff

- Set payoffs for up and down equal, solve for number of shares:
  - $N_s = (C_u - C_d) / P(u - d)$
- In our example:
  - $N_s = (\$13.07 - \$0) / \$27(1.41 - 0.71)$
  - $N_s = 0.6915$

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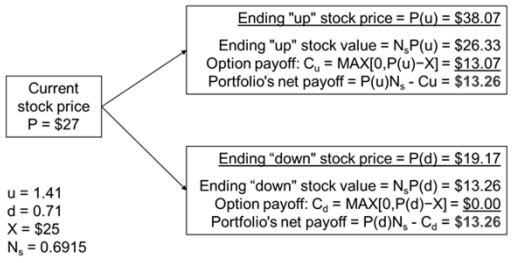
Riskless Portfolio's Payoffs at Call's Expiration: $13.26



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Riskless payoffs earn the risk-free rate of return.

- Find PV of riskless payoff. Discount at risk-free rate compounded daily.
  - N = 0.5(365)
  - I/YR = 6/365
  - PMT = 0
  - FV = −$13.26 (because we want to know how much we would want now to give up the FV)
- PV = $12.87

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Alternatively, use the PV formula (daily compounding).

$PV = \$13.26 / (1 + 0.06/365)^{365*0.5}$

$= \$12.87$

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The Value of the Call Option

- Because the portfolio is riskless:
  - $V_{Portfolio}$ = PV of riskless payoff
- By definition, the value of the portfolio is:
  - $V_{Portfolio} = N_s(P) - V_C$
- Equating these and rearranging, we get the value of the call:
  - $V_C = N_s(P)$ − PV of riskless payoff

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Value of Call

- $V_C = N_s(P) - \text{Payoff} / (1 + r_{RF}/365)^{365*t}$
- $V_C = 0.6915(\$27) - \$13.26 / (1 + 0.06/365)^{365*0.5}$
  $= \$18.67 - \$12.87$
  $= \$5.80$

($V_C = \$5.81$ if no rounding in any intermediate steps.)

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Portfolio Replicating the Call Option

- From the previous slide we have:
- $V_C = N_s(P) - \text{Payoff} / (1 + r_{RF}/365)^{365*t}$
- The right side of the equation is the same as creating a portfolio by buying N_s shares of stock and borrowing an amount equal to the present value of the hedge portfolio's riskless payoff (which must be repaid).
- The payoffs of the replicating portfolio are the same as the option's payoffs.

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Replicating Portfolio Payoffs: Amount Borrowed and Repaid

- Amount borrowed:
  - PV of payoff = $12.87
- Repayment due to borrowing this amount:
  - Repayment = $12.87 $(1 + r_{RF}/365)^{365*t}$
    Repayment = $13.26
  - Notice that this is the same as the payoff of the hedge portfolio.

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Replicating Portfolio Net Payoffs

- Stock up:
  - Value of stock = 0.6915($38.07) =$26.33
  - Repayment of borrowing = $13.26
  - Net portfolio payoff = $13.07
- Stock down:
  - Value of stock = 0.6915($19.17) =$13.26
  - Repayment of borrowing = $13.26
  - Net portfolio payoff = $0
- Notice that the replicating portfolio's payoffs exactly equal those of the option.

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Replicating Portfolios and Arbitrage

- The payoffs of the replicating portfolio exactly equal those of the call option.
- Cost of replicating portfolio
  $= N_s(P) - \text{Amount borrowed}$
  $= 0.6915(\$27) - \$12.87$
  $= \$18.67 - \$12.87$
  $= \$5.80$
- If the call option's price is not the same as the cost of the replicating portfolio, then there will be an opportunity for arbitrage.

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Arbitrage Example

- Suppose the option sells for $6.
  - You can write option, receiving $6.
  - Create replicating portfolio for $5.80, netting $6.00 −$5.80 = $0.20.
- Arbitrage:
  - You invested none of your own money.
  - You have no risk (the replicating portfolio's payoffs exactly equal the payoffs you will owe because you wrote the option.
  - You have cash ($0.20) in your pocket.

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Arbitrage and Equilibrium Prices

- If you could make a sure arbitrage profit, you would want to repeat it (and so would other investors).
- With so many trying to write (sell) options, the extra "supply" would drive the option's price down until it reached $5.80 and there were no more arbitrage profits available.
- The opposite would occur if the option sold for less than $5.80.

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Multi-Period Binomial Pricing

- If you divided time into smaller periods and allowed the stock price to go up or down each period, you would have a more reasonable outcome of possible stock prices when the option expires.
- This type of problem can be solved with a binomial lattice.
- As time periods get smaller, the binomial option price converges to the Black-Scholes price, which we discuss in later slides.

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Assumptions of the Black-Scholes Option Pricing Model

- The stock underlying the call option provides no dividends during the call option's life.
- There are no transactions costs for the sale/purchase of either the stock or the option.
- Risk-free rate, r_{RF}, is known and constant during the option's life.

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Assumptions

- Security buyers may borrow any fraction of the purchase price at the short-term risk-free rate.
- No penalty for short selling and sellers receive immediately full cash proceeds at today's price.
- Call option can be exercised only on its expiration date.
- Security trading takes place in continuous time, and stock prices move randomly in continuous time.

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What are the three equations that make up the OPM?

$$V_c = P\left[N(d_1)\right] - X\, e^{-r_{RF}t}\left[N(d_2)\right]$$

$$d_1 = \frac{\ln(P/X) + \left[r_{RF} + \left(\frac{\sigma^2}{2}\right)\right]t}{\sigma\sqrt{t}}$$

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

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What is the value of the following call option according to the OPM?

- Assume:
- P = $27
- X = $25
- r_{RF} = 6%
- t = 0.5 years
- σ = 0.49

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First, find d_1.

$$d_1 = \frac{\ln(P/X) + \left[r_{RF} + \left(\frac{\sigma^2}{2}\right)\right]t}{\sigma\sqrt{t}}$$

$$d_1 = \frac{\ln(\$27/\$25) + \left[0.06 + \left(\frac{0.49^2}{2}\right)\right](0.5)}{(0.49)\sqrt{0.5}}$$

$$d_1 = 0.4819$$

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Second, find d_2.

- $d_2 = d_1 - \sigma\sqrt{t}$
- $d_2 = 0.4819 - 0.49\sqrt{0.5}$
- $d_2 = 0.1355$

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Third, find $N(d_1)$ and $N(d_2)$

- $N(d_1) = N(0.4819) = 0.6851$
- $N(d_2) = N(0.1355) = 0.5539$
- Note: Values obtained from Excel using NORMSDIST function. For example:
- $N(d_1)$ = NORMSDIST(0.4819)

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Fourth, find value of option.

- $V_C = \$27(0.6851) - \$25\, e^{-(0.06)(0.5)}(0.5539)$
- $= \$18.4977 - \$13.4383$
- $= \$5.06$

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- Office Phone (678)839-4816 and Cell Phone (770)301-8648, target is under 24 hours

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What impact do the following parameters have on a call option's value?

- Current stock price: Call option value increases as the current stock price increases.
- Strike price: As the exercise price increases, a call option's value decreases.

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Impact on Call Value (1 of 2)

- Option period: As the expiration date is lengthened, a call option's value increases.
  - Longer time to expiration increases probability of very high stock price, which has big payoff.
  - Also increases the probability of a very low stock price, but payoff is zero for any price below the strike price.
- Risk-free rate: Call option's value tends to increase as r_{RF} increases (reduces the PV of the exercise price).

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Impact on Call Value (2 of 2)

- Stock return variance: Option value increases with variance of the underlying stock.
  - Higher variance increases probability of very high stock price, which has big payoff.
  - Also increases the probability of a very low stock price, but payoff is zero for any price below the strike price.

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Put Options

- A put option gives its holder the right to sell a share of stock at a specified stock on or before a particular date.

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Put-Call Parity

- Portfolio 1:
  - Put option,
  - Share of stock, P
- Portfolio 2:
  - Call option, V_C
  - PV of exercise price, X

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Portfolio Payoffs at Expiration Date T for $P_T<X$ and $P_T \geq X$

	$P_T<X$		$P_T \geq X$	
	Port. 1	Port. 2	Port. 1	Port. 2
Stock	P_T		P_T	
Put	$X-P_T$		0	
Call		0		P_T-X
Cash		X		X
Total	X	X	P_T	P_T

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Put-Call Parity Relationship

- Portfolio payoffs are equal, so portfolio values also must be equal.
- Put + Stock = Call + PV of Exercise Price
- Put + P = $V_C + Xe^{-rRFt}$
- Put = $V_C - P + Xe^{-rRFt}$

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Spotting Real Options

CHARLES HODGES

Spotting Real Options

- Strategic NPV = Passive NPV + Value of Real Options – Cost of Real Options
- Four Basic Positions
  - Long Call – right to accept something good
  - Short Call – obligation to sell something you do not want to sell
  - Long Put – right to avoid something bad
  - Short Put – obligation to buy something you do not want to buy
- No obligation = no real option
- Often the "world" is taking the other side of the option

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Real vs. Synthetic Real Options

- Put-Call Parity
  - Stock + Put = Call + Present Value of Bond
- Real Stock/Asset = Stock
  - Synthetic Stock/Asset = Call + PV of Bond - Put
- Real Call = Call
  - Synthetic Call = Stock + Put – PV of Bond
- Moneyball and Sabermetrics (https://en.wikipedia.org/wiki/Sabermetric)
  - Replacing skilled real person with lower cost combinations (https://www.youtube.com/watch?v=yGf6LNWY9AI)
  - Used in professional sports
  - Equipment versus people in industry
  - Financial Advisors versus Robo-advisors plus human voice
  - Professors versus lower cost Instructors plus textbook website

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Identifying Real Options

- Type = Call or Put
- Long = Right to exercise option
- Short = Obligation
- Underlying Asset = Item/concept whose value change triggers option exercise
- Exercise Price = Amount paid/received when option is exercised
- Premium = Cost to enter the option contract

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You have the right to buy the Disneyland for $ 500 million anytime within the next two years.

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

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You have the right to buy the Disneyland for $ 500 million anytime within the next two years.

Type _Call_
Who is long __You_
Who is short _Current Owner__
Underlying Asset _Disneyland Value__
Exercise Price _$500 million___
Premium _none stated__

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Your name is Ronald Wayne and you own 10% of a company named Apple. Your partners, Steve J. and Steve W. have made a binding offer to buy your 10% stake for $800.

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

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Your name is Ronald Wayne and you own 10% of a company named Apple. Your partners, Steve J. and Steve W. have made a binding offer to buy your 10% stake for $800.

Type _Put_
Who is long _Ronald_
Who is short _the Steve's_
Underlying Asset _Value of 10% of Apple__
Exercise Price _$800__
Premium _None stated_

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The Federal Deposit Insurance Corporation insures deposits, up to $250,000 in banks. There have been four local banks fail near you in the past year. No depositor has lost any money and no depositor has had to wait more than one week to get their money from a failed bank. However without insurance, the average depositor would have lost about 40% of their money and would have waited about one year. The annual premium varies, but each depositor pays about 10 cent per $100 deposited. Describe the depositor's pre-failure real option.

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

CENGAGE

The Federal Deposit Insurance Corporation insures deposits, up to $250,000 in banks. There have been four local banks fail near you in the past year. No depositor has lost any money and no depositor has had to wait more than one week to get their money from a failed bank. However without insurance, the average depositor would have lost about 40% of their money and would have waited about one year. The annual premium varies, but each depositor pays about 10 cent per $100 deposited. Describe the depositor's pre-failure real option.

Type _Put__
Who is long _Depositor___
Who is short __FDIC____
Underlying Asset _loss of 40% of money and 1 year to receive__
Exercise Price _100% of money and one week___
Premium _Premium varies by risk, but annually about 10 cent per $100 deposited __

CENGAGE

For a new product, you must decide between the use of an efficient specialized (higher production, less waste) machine with no salvage value versus a less-efficient general machine with large salvage value. Describe the Call option.

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

CENGAGE

For a new product, you must decide between the use of an efficient specialized (higher production, less waste) machine with no salvage value versus a less-efficient general machine with large salvage value. Describe the Call option.
Type _Call__
Who is long _Your Company__
Who is short _world___
Underlying Asset _increased production_
Exercise Price _Buy specialized machine_
Premium _Price Difference and lower salvage__

CENGAGE

For a new product, you must decide between the use of an efficient specialized (higher production, less waste) machine with no salvage value versus a less-efficient general machine with large salvage value. Describe the Put option.

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

CENGAGE

For a new product, you must decide between the use of an efficient specialized (higher production, less waste) machine with no salvage value versus a less-efficient general machine with large salvage value. Describe the Put option. Note, the video uses a different description.

Type _Put__
Who is long _Your Company__
Who is short _World__
Underlying Asset _Value of low sales and profits__
Exercise Price _Salvage Value (amount received if shut down production)_
Premium _Difference in Machine Price and lower production___

CENGAGE

Amazon Prime is offered to you for one year at a cost of $119. This entitles you to free 2-day shipping on many items for one year, as well as many other benefits. What is the option associated with the free shipping?

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

CENGAGE

Amazon Prime is offered to you for one year at a cost of $119. This entitles you to free 2-day shipping on many items for one year, as well as many other benefits. What is the option associated with the free shipping?

Type _Call__
Who is long _You__
Who is short _Amazon and other suppliers_
Underlying Asset _Item cost & shipping cost__
Exercise Price _ Item cost _____
Premium _$119 per year__

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In Florida, there is a minimum mandatory prison sentence of 5 years for anyone using a gun in a robbery. Because of prison overcrowding, almost no one gets more than the minimum sentence. For political reasons, prosecutors always prosecute gun robberies. Danny, a Florida resident, was laid off from work after 30 years at age 59. Danny is now unemployed, hungry, has no insurance, and is homeless having lost his house to foreclosure. Danny finds a gun lying outside a convenience store.

Type _____
Who is long _____
Who is short _____
Underlying Asset _____
Exercise Price _____
Premium _____

CENGAGE

In Florida, there is a minimum mandatory prison sentence of 5 years for anyone using a gun in a robbery. Because of prison overcrowding, almost no one gets more than the minimum sentence. For political reasons, prosecutors always prosecute gun robberies. Danny, a Florida resident, was laid off from work after 30 years at age 59. Danny is now unemployed, hungry, has no insurance, and is homeless having lost his house to foreclosure. Danny finds a gun lying outside a convenience store.

Type _Call____
Who is long __Danny___
Who is short _Florida_____
Underlying Asset _a jail to live in for 5 years___
Exercise Price _rob store with gun_____
Premium __give up current life_____

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