

0 Options: Outline

- Objective:
 - To describe the basic financial option contracts.
 - To identify the payoffs to financial options at maturity.
 - To identify the factors affecting the value of an option prior to maturity
 - To compute the value of an option prior to maturity if the asset can take only two possible values.
 - To apply these methods to valuing equity in a distressed firm.
- Options: Terminology and Quotes
 - Trading and Payoffs
- Option Strategies and Other Options
 - ESO, embedded options, distressed equity and convertible bonds
- Fundamentals of Option Valuation
 - Five factors determining an option's price
 - Valuing a call option in terms of stock and riskless asset.
- Equity as a call Option
- Pricing call options $C_0 = H^*[S_0 - PV(S_L)] + PV(C_L)$ (more general than text)

Terminology

- Option - contract giving holder right, but not obligation, to buy (sell) an asset at fixed price (strike or exercise price) at any time on or before an expiration date.
 - Call - right to buy an asset at fixed price.
 - Put – right to sell an asset at fixed price.
- Exercise – using option contract to buy (sell) the underlying asset.
 - American - can be exercised any time before
 - European - can be exercised only at expiration
- Moneyness
 - In the Money_- exercise of option would be profitable
Call (asset price $>$ exercise price) Put (asset price $<$ exercise price)
 - Out of the Money_-
Call (asset price $<$ exercise price) and Put (asset price $>$ exercise price)
- Other terminology
 - Intrinsic value –
 - Time value – difference between current option price and intrinsic value

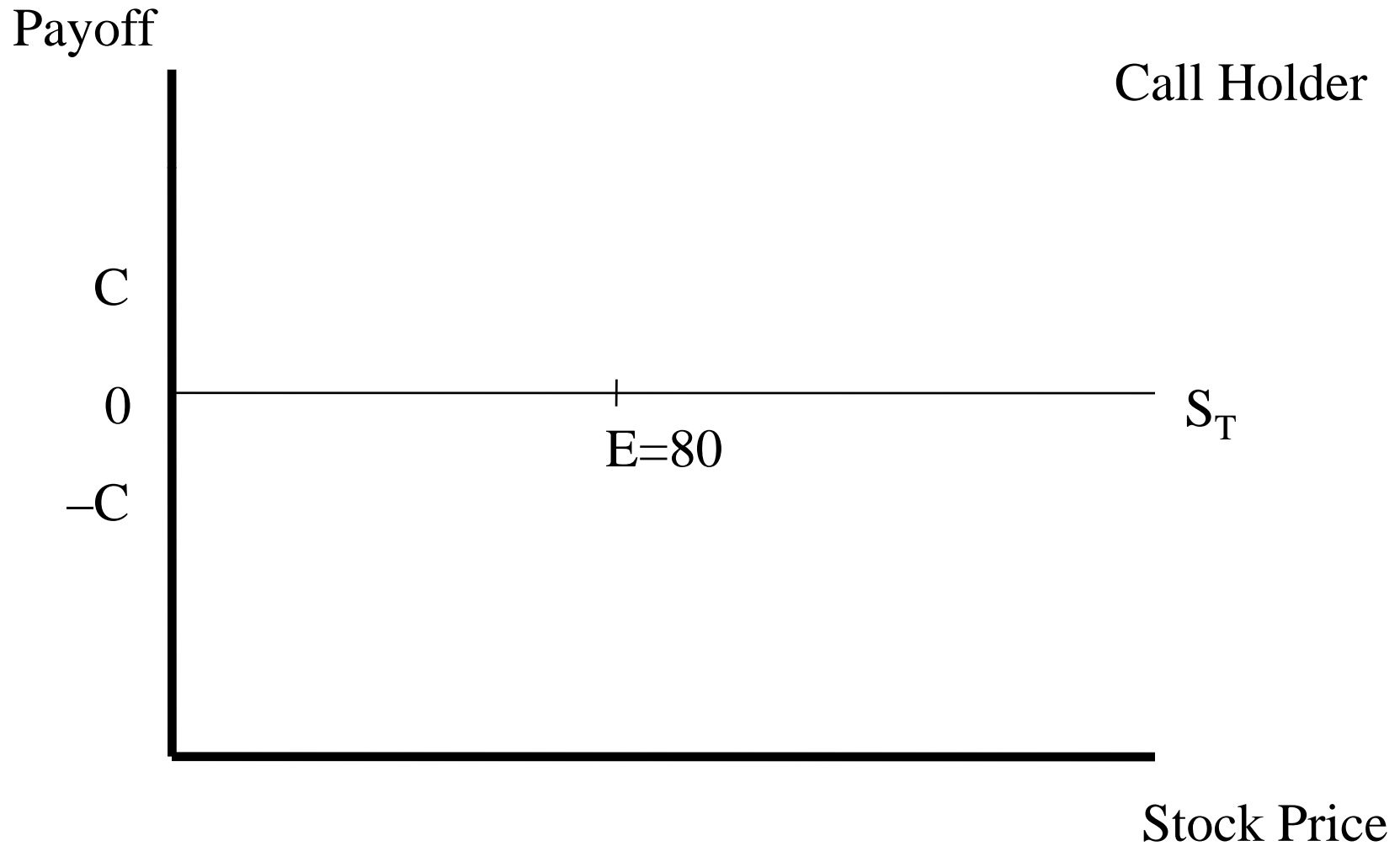
2 Payoffs at Expiration

- .Quotes – Contracts are for 100 shares, so contract costs $price * 100$.
 - Prices increase with time to expiration
 - Calls with low strikes worth more than corresponding puts
 - Calls with high strikes worth less than corresponding puts
 - Expire on third Friday of expiration month; trade in nickel increments.
 - Option quotes on Web <http://finance.yahoo.com>
 - Consider options with strike of $E = \$80$ and stock price at expiration of S_T .

Final Stock Price	Payoff to Long Call	Payoff to Long Put
74		
77		
80		
83		
86		
Payoff at S_T	$\text{Max}[(S_T - E), 0]$	$\text{Max}[(E - S_T), 0]$
Profit	$\text{Max}[(S_T - E - C), -C]$	$\text{Max}[(E - S_T - P), -P]$
Option Written	$\text{Min}[-S_T + E + C, +C]$	$\text{Min}[-E + S_T + P, +P]$

3 Option Payoffs: Calls

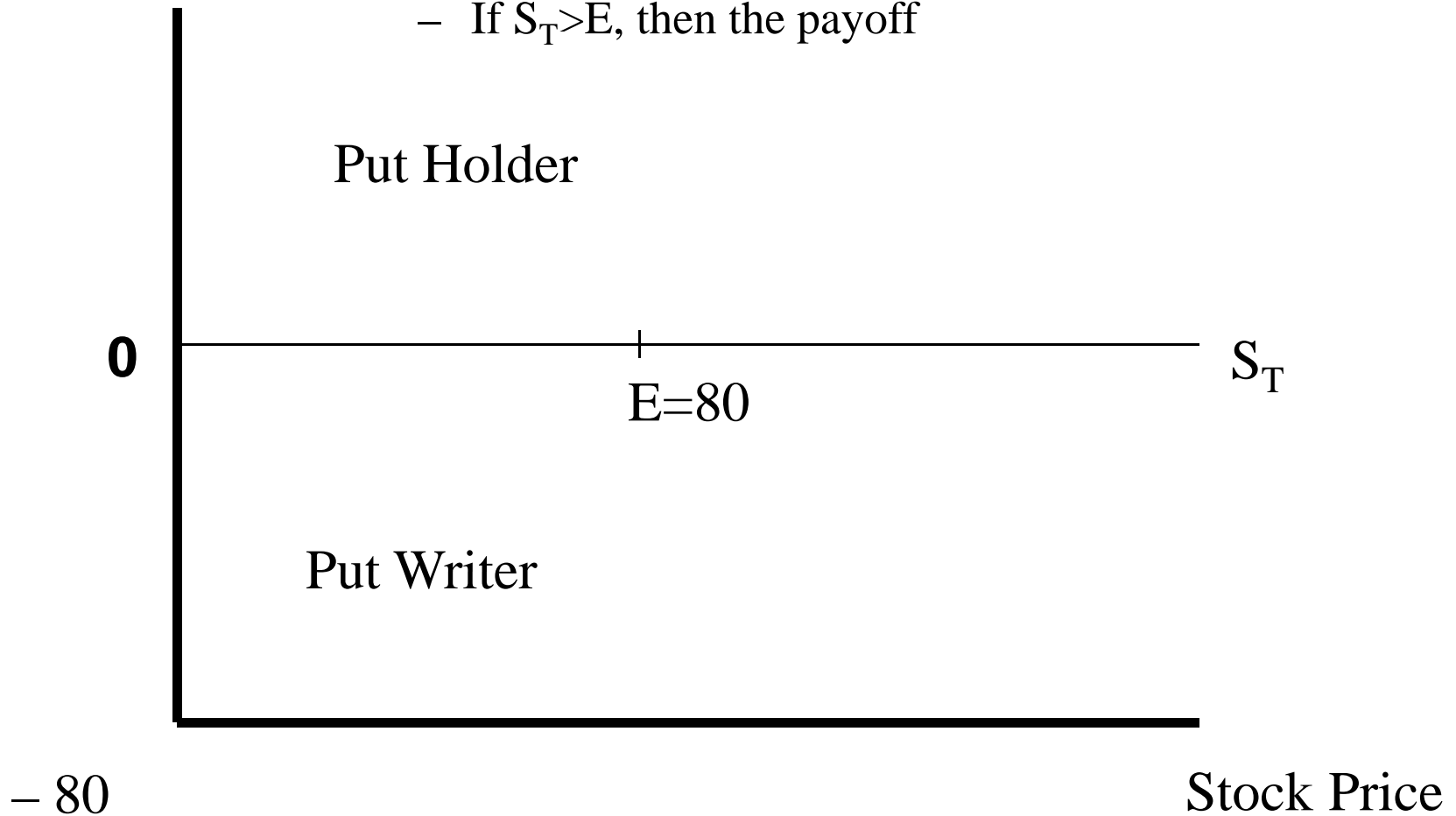
- Value of call at expiration is intrinsic value: $\text{Max}(0, S_T - E)$
 - If $S_T < E$, then the payoff is
 - If $S_T > E$, then the payoff is



4 Option Payoffs: Puts

80 Payoff

- Value of put at expiration is intrinsic value $\text{Max}(0, E - S_T)$
 - If $S_T < E$, then the payoff
 - If $S_T > E$, then the payoff



Options: Trading

- OTC – market is relatively small, but allows contract to be tailored
 - Need to hedge your \$5M of incentive-based call options?
- Exchanges (CBOE, Amex) - y
 - Options on indiv stocks expires within 3 months (otherwise LEAPS)
 - Strike prices set at \$2.50 or \$5 intervals; market makers post bid and ask.
- Option Clearing Corporation –
 - All trades cleared by OCC members (brokerages).
 - OCC randomly assigns firms to honor exercise.
 - Writer posts margin - depends on underlying asset, money-ness, covered.
- Types of options
 - Stock Options –
 - Index Options –
 - Foreign Currency Options
 - Interest Rate Options – T-bills, T-notes aT-bonds.
 - Futures Options – options on futures contracts.

6 Other Options

- Employee Stock Options - given to employees as part of benefits package
 - Incentive SO (VP+) vs Non-qualified SO (different tax treatment).
 - Vest in 1-3 yrs; May expire in 10 yrs; Cannot be sold;
 - In 00-01 many exercised, incurred tax liability, then stock crashed.
- Equity – call option on assets of a levered firm, with E equal to par value of debt.
 - If assets > debt, stockholders exercise option (debt repaid) and retain ownership
 - Warrants -
- Bonds – call provision allows company to repurchase bond before maturity.
 - Convertible bonds - conversion ratio is #shares received at conversion

Q: Suppose you have 10% bond and maturing in 15 yrs. Par is \$1000 and YTM on similar straight bonds is 9%. Bond is convertible with conversion price of \$100. Stock sells for \$110. What is minimum price of bond?

A1: Value of straight bond:

A2: Value of option: Conv ratio = par/conv price =

Conv value = 10 shares*\$110 = \$1100.

Common Option Strategies

- Protective Put - long stock and long put (out-of-money).
 - Protects against falling stock price, like buying insurance.
 - Suppose you buy stock ($S_0=100$) and put option ($E=100$; $P_0=2.67$;).
 - Q: What happens if the stock price drops to 50?
 - A:

 - Q: What happens if the stock price rises to 150?
 - A:

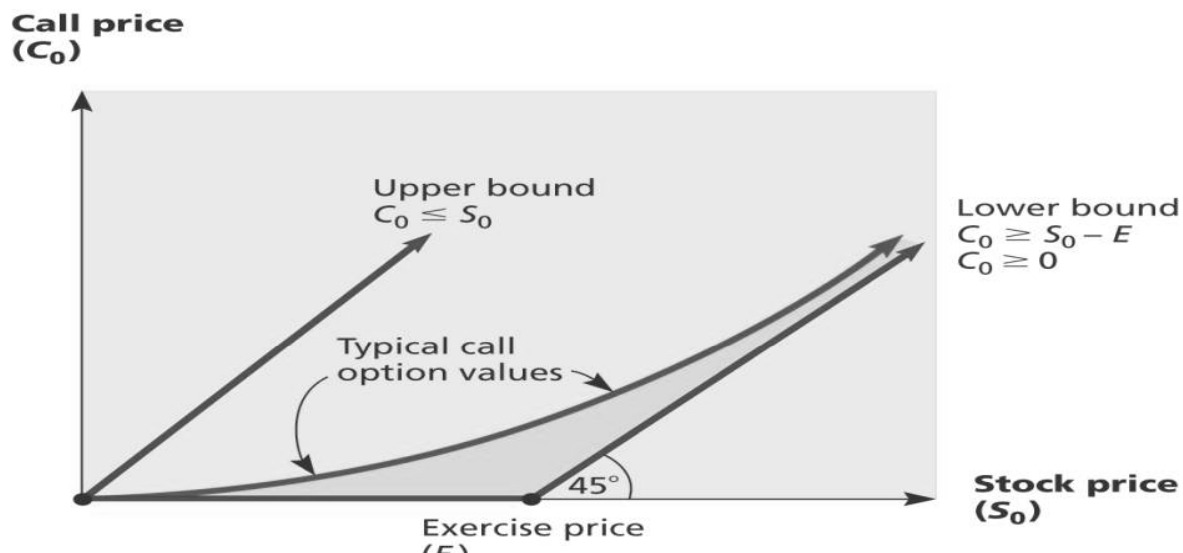
- Covered Call - long stock and write call (out-of-money).
 - Forgo upside, but earn premiums.
 - Suppose you buy stock ($S_0=100$) and sell call option ($E=100$; $C_0=3.09$;).
 - Q: What happens if stock price drops to 50?
 - A:

 - Q: What happens if stock price goes to 150?
 - A:

- Other examples: Straddles, collars, butterfly spreads.

8 Valuing Calls Prior to Expiration 1/3

- Factors affecting option prices. An increase the following causes
 - Stock price –
 - Exercise price –
 - Time to expiration –
 - Variance – .
 - Risk-free rate –
- What is value of call about prior to expiration?
 - Upper bound - Call price must be \leq to the stock price
 - Lower bound - Call price must be $\geq \max(0, S-E)$



9 Principle of Arbitrage

- What is the value of a call option prior to expiration?
 - Typically it is worth more than 0.
 - More specific estimates can be pinned down by “arbitrage.”
- Pure Arbitrage – ability to earn profits with no net investment and no risk.
 - Alternatively, investments with same payoff in every state must cost the same.
 - Investments with same risk (or no risk) must have same expected return.
 - A good example requires that we know about short sales.
- Review of “selling short” -
 - Your broker borrows securities from another client and sells on open mkt.
 - You must eventually buy and return securities; paying any missed dividends.
- Assumptions –
 - no transactions costs; same tax rate on all profits.
 - borrowing and lending rates are the same risk-free rate.
 - arbitrage opportunities are exploited.

10 Examples of Arbitrage

- Q1: A zero coupon T-bond costs \$90. Another zero coupon T-bond costs \$95. Both have par value of \$100 and mature in 1 yr. What will investors do?

- A1:

		CF(0)	CF(T)	Gross Return
	Buy cheap bond	-90	+100	$100/90=111.2\%$
	Short expensive bond	+95	-100	$100/95=105.2\%$

- Q2: A bond issued by IBM costs \$94. Another bond from G.E. costs \$92. Both have par value of \$100, mature in 1 yr and zero coupon. What will investors do?
- A2:

11 Examples of Arbitrage

- Q3: A 10-yr bond issued by IBM 9 yrs ago is priced at \$90. It will be worth either par or zero in one year, depending on whether the firm goes bankrupt. A new bond issued by IBM today has the same features, except it matures in one-year. At what price will it trade?

- A3:

		CF(0)	CF(T)	Gross Return
	Buy 10-yr bond	-90	+100 or 0	$100/90=111.2\%$
	Short 1-yr bond	+??	+100 or 0	$100/95=105.2\%$

- This kind of arbitrage links the prices all Treasury bonds and foreign currencies, for example.
- Q4: Arbitrage with a call option – Suppose a share of stock will be worth either \$110 or \$130 in 1 yr ($S_T=110$ or 130). A call option expiring in one year has $E = \$120$. What will be the value of the option immediately prior to expiration?
- A4:

12 Pricing a call option by arbitrage 1/3

- For simplicity, suppose a stock will be worth either \$110 or \$130 in one year. The stock currently trades for \$100. What is the value today of a call option expiring in 1 yr with E=\$120? That is: $S_0 = 100$; $S_T = 110$ or 130 ; $E=120$; $r=20\%$
- Consider the payoff from (1) owning the stock versus (2) investing the PV of \$110 (S_L) in T-bills plus two call options.

	CF(0)	CF(T)	Symbols
Stock	-100		
T-bills plus two call options	??		

Since payoffs are equivalent, the prices must be equal!

[price of share] = [price of long calls plus T-bills]

$$S_0 = 2 * C_0 + PV(S_L)$$

$$C_0 = 1/2 * (S_0 - PV(S_L))$$

What would happen if $C_0 < \$4.167$? Or if $C_0 > \$4.167$?

13 Pricing a call option by arbitrage 2/3

— Value of call option in previous example ($C_L=0$): $S_0 = H \cdot C_0 + PV(S_L)$

- Previous example showed that to replicate the payoff from stock, buy
 - **Two** call options plus invest **PV(S_L)** in the riskless asset.
 - Second term guarantees we earn S_L (when call is worthless).
 - Buying two calls plus T-bills ensures we earn S_H

- Why did we buy *two* calls? This is related to the volatility of the stock.
 - # Calls = 1 / Hedge ratio = 1 / H = $\Delta S / \Delta C$.
 - In previous example, $\Delta S / \Delta C = (130 - 110) / (10 - 0) = 20 / 10 = 2$
 - When option is certain to be in-the-money ($S_T > E$ and $C_L > 0$), $H = 1$.
 - Hedge ratio = $\Delta C / \Delta S$

- General Formula – above formula only works when $C_L = 0$.
 - A general formula that always works is (but it not in text):

$$C_0 = H \cdot [S_0 - PV(S_L)] + PV(C_L) \quad \text{where} \quad H = \Delta C / \Delta S$$

Pricing a call option by arbitrage 3/3

- Q: For simplicity, suppose a stock will be worth either \$80 or \$120 in one year. The stock currently trades for \$100. What is the value today of a call option expiring in one year with $E=\$90$? That is: $S_0=100$; $S_T=80$ or 120 ; $E=90$; $r=5\%$

- Recall that: $C_0 = H*[S_0 - PV(S_L)] + PV(C_L)$ where $H = \Delta C / \Delta S$

- A1: Hedge ratio

- A2: C_0

- Q: Suppose the volatility of the stock price increases, so that it will be worth either \$70 or \$130. What happens to the price of the call option?

- A1: Hedge ratio =

- A2: $C_0 =$

- Q: Is this a reasonable way to price call options? Don't future stock prices have more than two possible values?

- A:

15 Equity as a Call Option 1/2

- Equity in heavily levered firm is similar to call option on firm's assets. Bondholders have claim on firm's assets. Shareholders choose whether to pay back bondholders (exercise "option") and regain claim to assets.
 - Shareholders exercise if $S_T > E$. Otherwise let expire.

$E = \text{debt pymt}; \quad S = \text{mkt value of firm assets} \quad C = \text{mkt value of equity.}$
- TC Software will issue pure discount debt (\$10M par) due in one year. At that time, the firm will be worth either \$5.5M or \$16M, depending whether a patent for their new product is granted. The assets are currently worth \$11M. If the risk-free rate is 10% what is the current value of equity and debt in TC Software?
- Q1: Find hedge ratio and value of equity (as call option).
- A1: Hedge ratio = $\Delta C / \Delta S =$
- A2: $C_0 = H * [S_0 - PV(S_L)] + PV(C_L)$
=
- Q3: Find value of debt, where Value of Firm = Debt + Equity

16 Equity as a Call Option 2/2

- What are the implications of valuing equity as an option?
 - Will shareholder's prefer more risky projects, to detriment of bondholders?
 - $E = \text{debt pymt}$; $S = \text{mkt value of firm assets}$ $C = \text{mkt value of equity}$
- Suppose that instead of assets next year being worth either \$5.5M or \$16M, TC mgt planned to undertake a more risky strategy, which would make their assets worth either \$2.5M or \$19M. What would happen to NPV? Would shareholders approve such a move? Would bondholders approve? Why?
- Q1: Find hedge ratio and value of equity (as call option)
- A1: Possible values of stock (2.5M-\$19M) and call (\$0M-9M) give
Hedge ratio – $\Delta C / \Delta S$
- A2: $C_0 = H * [S_0 - PV(S_L)] + PV(C_L)$
- Note: Shareholders don't care about additional downside risk! This is overlooked by NPV. In either low-value situation, the firm's assets go to bondholders!

Summary

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 - Trading
 - Payoffs
- Option Strategies and Other Options
 - ESO, embedded options, distressed equity
 - Convertible bonds
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