Options

Why are they important? They play a big role in these reasons:

-Many corporate securities are similar to the stock options that are traded on organized exchanges

-Almost every issue of corporate stocks and bonds has option features

-In addition, capital structure and capital budgeting decisions can be viewed in terms of Options. Each slice of the pie, debt and equity, can be viewed as some form of option.

Options market is separate, in Chicago. Options are everywhere! Knowledge of them helps us work with other securities.

CALL OPTION

-A call option gives the holder the **right**, **but not the obligation**, to buy an asset on a given date (or perhaps before), at a price agreed upon today.

Example:
On Dec. 31, 2006, you have the right to buy an IBM stock for $50

Weather or not you buy the stock depends on the price of the stock on the date of the option. If the price of the asset is lower than the option exercise price there is no point to exercising the option. Only when the price is higher can a profit be made.

Many features in the options contract: price, date we can exercise to, and so on.

Terminology

-Exercising the option
The act of buying the underlying asset through the option contract

-Exercise (strike) price
Refers to the fixed price in the option contract at which the holder can buy the underlying asset

-Expiration date (maturity date, expiry)
The last day (and perhaps the only day) on which the option can be exercised

- EUROPEAN versus AMERICAN options
- **European** options can be exercised **only at expiry**
- **American** options can be exercised at **any time up to expiry**

-In-the-Money
The exercise price is less than the price of the underlying asset.
Stock price higher than the strike price (we will profit).

-At-the-Money
The exercise price is equal to the price of the underlying asset.

-Out-of-the-Money
The exercise price is more than the price of the underlying asset.
Stock price lower than the exercise price. (do not exercise!)

-Intrinsic value of the option
The difference between the exercise price of the option and the price of the underlying asset

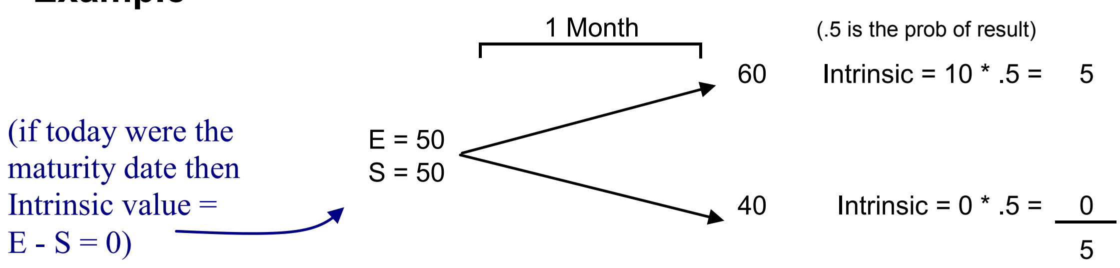
E (exercise price) =	$50
S (stock price) =	$60
Intrinsic Value =	$10
(profit in this case)	

-Speculative (time) value of the option
The difference between the option premium and the intrinsic value of the option
If the option expires today: Intrinsic = Premium Value.

-The value of the option is sometimes called the **OPTION'S PREMIUM**:
Time increases the value of the option (time until the expiration date). The Option Premium Value will usually be higher than the Intrinsic Value because the time left until maturity increases the value.

Option's Premium = Intrinsic Value + Speculative Value

Example



Option Premium = Intrinsic Value + Time Value
15 = 10 + 5

If the price goes to $40 in one month we do not exercise so the price is 0.
If the price goes to $40 in one month we make 60-50 = 10 profit.
This example shows that time generates some positive value with some probability (each state has probability ½ in this example (50%)). Time gives the price of the option the chance to go up or down while our losses are limited to 0. This is the time value of options!

The result is that the **Option Premium** will usually be higher than the **Intrinsic Value**.

<u>**CALL OPTION PAYOFFS**</u>

-At expiry, an American call option is worth the same as a European option with the same characteristics

• If the call is in-the-money, it is worth S_T **- E**

• If the call is out-of-the-money, it is worthless

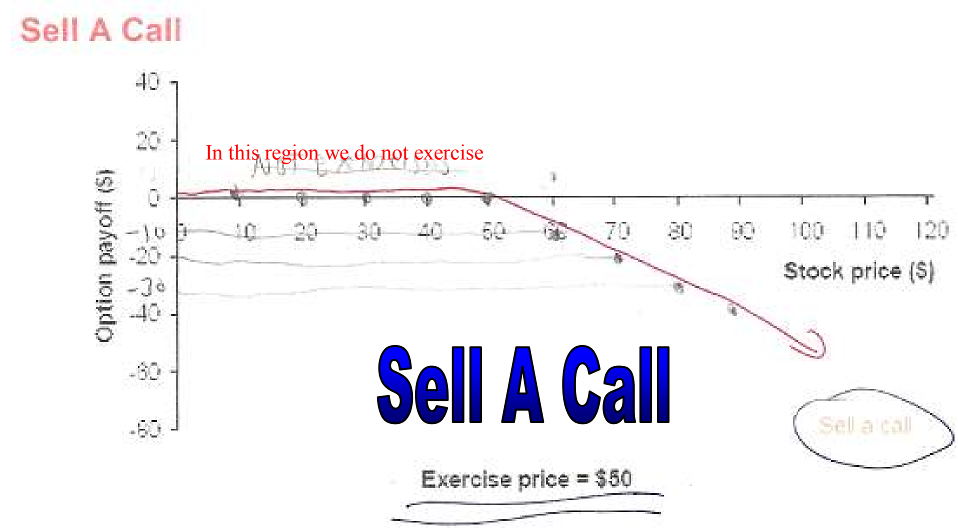
• In general: **C = Max[** S_T **- E, 0]**

Where:
S_T is the value of the stock at expiry (maturity time T)
E is the exercise price
C is the value of the call option at expiry

If $S_T - E > 0$ then we exercise and get the difference.

We realize a profit when we exercise the option with $S_T - E > 0$.

What cash flow does the seller see?



What does it mean to sell a call option? Why are we losing money? Because we have an asset worth $60 but due to the contract we must sell the asset at $50, so we loss $10. Seller is losing exactly what the buyer is making. Why would we make this kind of contract? Because the buyer is paying something to gain this option, this is the option price.

Now what is the net payoff for both the seller and buyer when we take into account the option price?

Say we buy an option for $20, what will the net profit of the buyer if the stock price is $30? We pay 20 and do not exercise (because current price is higher) so the buyers profit is -$20. Buyer losses the 20 all the way up to 50 because not exercising. Now if the current price of the asset is $60 our profit is -$10, we lost 20 buy then exercised the option and made back $10 for a total loss of $10. At a current stock price of $70 our net profit is 0.

What is the sellers profit? Everything the buyer earns the seller is losing. All the way to 50 the price of the stock is lower than exercise price so the seller will not exercise (we only earn the option price). Above the stock price of $50 the sellers profits decrease.

Put option

-A **PUT OPTION** gives the holder the **right**, **BUT NOT THE OBLIGATION**, **to sell an asset on a given date** (or perhaps before), at a price agreed upon today.

In the case of the put option you own the asset (option) and are under no obligation to sell it.

-**Example**:
On Dec. 31, 2006, you have the right to sell an IBM stock for $50

Exercise the option if IBM is currently selling **below** $50 (terms of option contract say it must be bought even though the buyer is realizing a loss). In this case the holder of the put option is selling something worth less than $50 for $50.

If the stock price is greater than $50 we would not exercise the put option (the buyer would just turn around and sell the asset for the value greater than 50).

"Sell a Call" means the seller must perform the transaction if someone wants to buy. (Have the right to buy the asset at a specific price).

"Put Option" says you have the right but not the obligation to exercise the transaction. (right to sell an asset at a particular price).

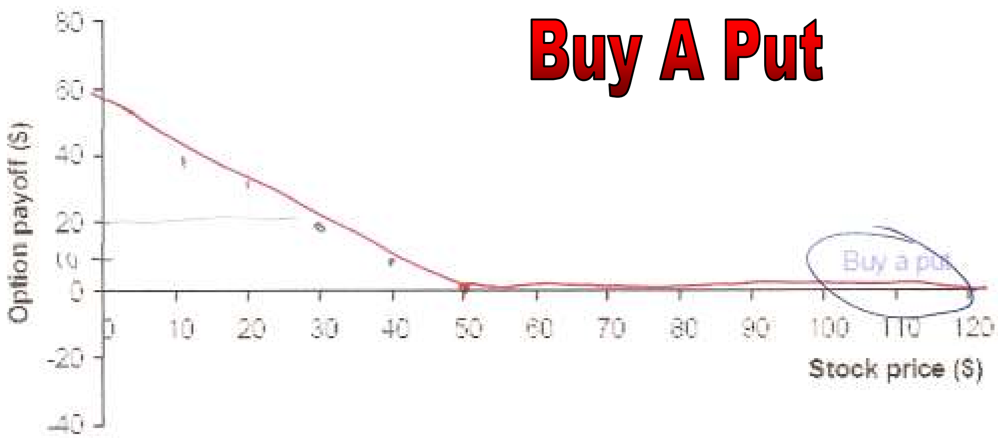
Put option payoffs

-At expiry, an American put option is worth the same as a European option with the same characteristics

• If the call is in-the-money, it is worth E - S_T
• If the call is out-of-the-money, it is worthless

In general: **P = Max[E - S_T, 0]** where **P** is the value of the call option at expiry

Max[50-70=-20, 0], will not exercise
Max[50-30=20, 0], will exercise

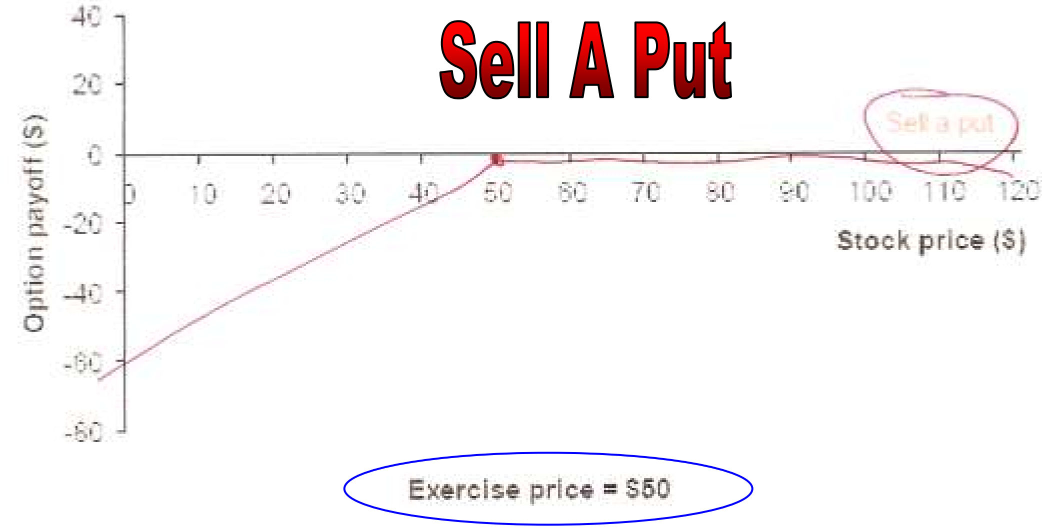


Exercise price = $50

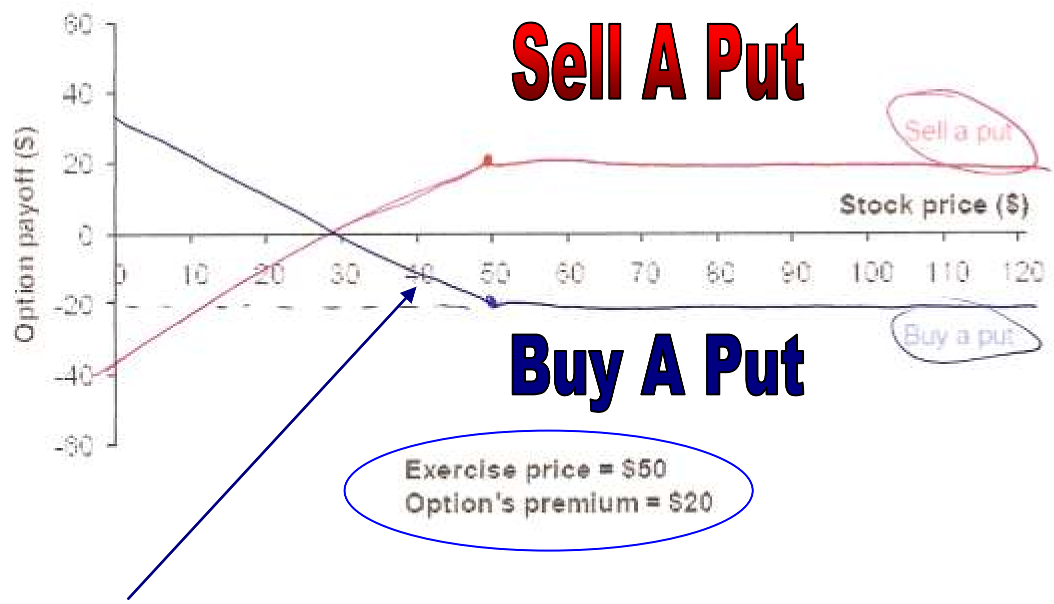
If the stock price is $30 and you can sell it at $50 your profit will be $20. When the stock price moves above $50 do not exercise (say S_T = 60 then profit would be 50 – 60 = -10).

The utility of options is to give the financial manager a tool for speculation and hedging.

Put option payoffs



Will not sell the put when the market price is above 50, the buyer would just turn around an resell for a gain. Below $50 we will sell, for example, selling something which has a market value of $40 for $50, making $10.



I hold the put option, looking to sell to someone. The Put Option cost me $20. If the stock > $50 I will not sell. When the stock is < $50 I will sell.

When you buy a put option you are hoping the market price of the stock will go down as much as possible.

Option pricing reporting

Call is in the money (buy)
Put is out of the money (sell)

			--Call--		--Put--	
Option/Strike		Exp.	Vol.	Last	Vol.	Last
IBM	130	Oct	364	15¼	107	5¼
138¼	130	Jan	112	19½	420	9¼
138¼	135	Jul	2365	4¾	2431	13/16
138¼	135	Aug	1231	9¼	94	5½
138¼	140	Jul	1826	1¾	427	2¾
138¼	140	Aug	2193	6½	58	7½

Current Stock Price

Strike Price (exercise)

Particular day of month by convention

Option Premium

Put Premium

Time is value, more time = more value.

"Premium higher than difference because of intrinsic and speculative value"

Valuing an Option

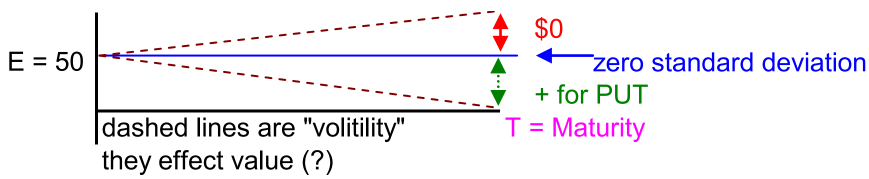
- As long as the company does not begin to pay a dividend or begin some other corporate event there is no difference between the value of an American Option and a European Option. Reason: there is no incentive to exercise before maturity. Doing so would give up the time value of the money.

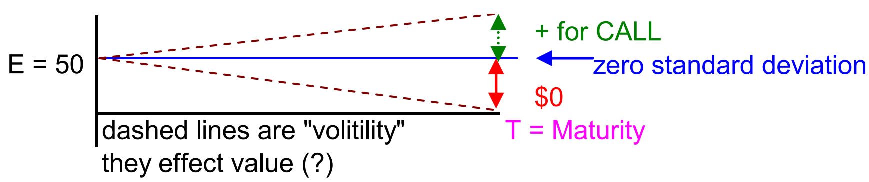
-Option value determinants: how are each of these effected by increasing, Positive or negative?

	Call	Put
1. Stock Price	+	-
2. Exercise Price	-	+
3. Interest Rate	+	-
4. Volatility of the Stock Price	+	+
5. Time to Expiration	+	+

EXAM

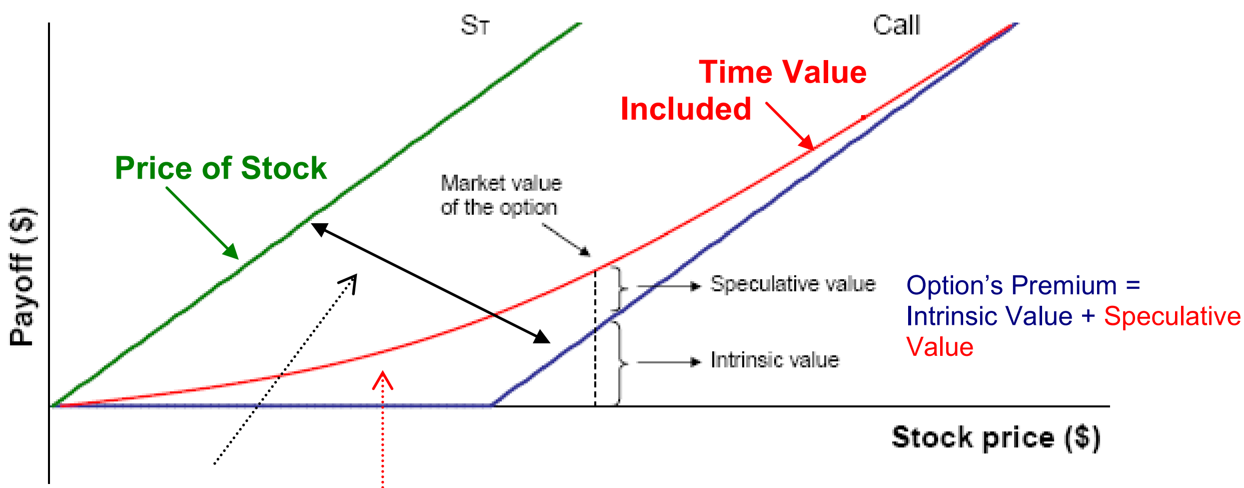
Must know the proper meanings of volatility line directions





[losses are limited to 0]

The value of the options will depend on these factors (the range in which the price of the option must fall).



These are the bounds. Actual price.

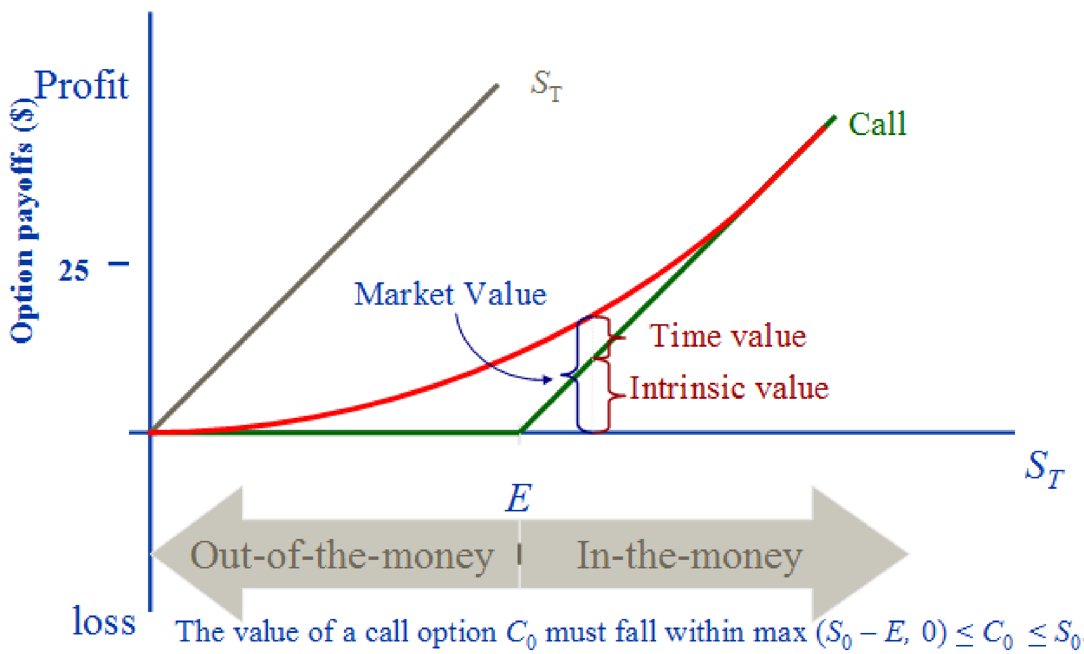
The market value of the option, C_0 , must fall within Max[S_T - E, 0] <= C0 <= S_T

Example:
E = 50   S = 60   T (time to maturity) = 1 month C_0 = 12 (sale price of option)
Incentive is to wait right up to the end of maturity.
Generally never exercise before maturity unless the company begins to pay an offsetting dividend (which is unlikely).

Seller of the option has the stock, owns it. This is the same as an option with an exercise price of $0, you already own it.

Stock Price = Price of Option with E=0 > Price of Option E > 50

The value of a call option C_0 must fall within: max $(S_0 - E, 0) \le C_0 \le S_0$.

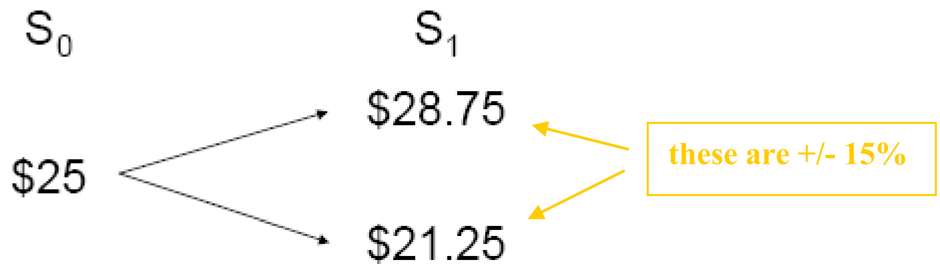


Binomial option pricing model

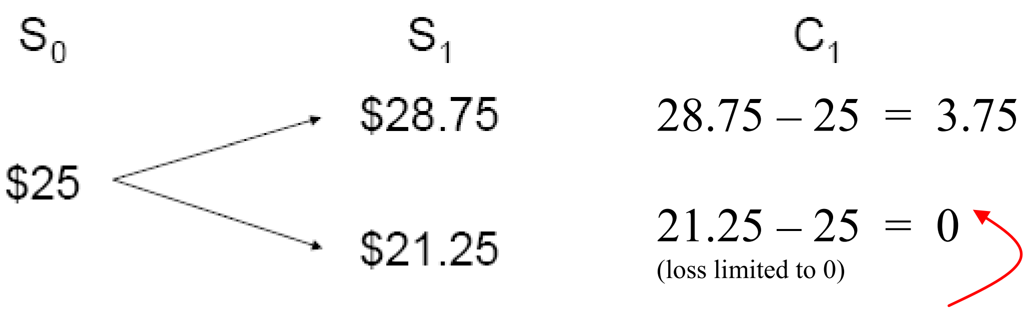
Assuming stock price is a binominal random variable, only two possible outcomes. Can also be extended to other distributions (below).

-Suppose a stock is worth $25 today and in one period will either be worth 15% more or 15% less. S_0 = $25 (so that E = S) today and in one year S_1 is either $28.75 or $21.25.

What is the value of an **at-the-money** call option?
What is the value of an option with E = 25?



First we write the payoffs of the option in each of the cases. Write the value of the payoff in each case. -A call option on this stock with exercise price of $25 will have the following payoffs.



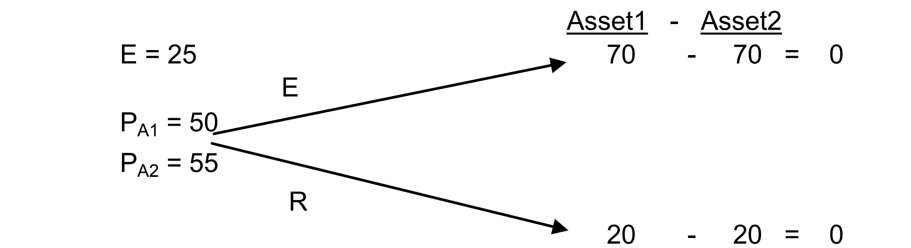
The payoffs are 0 and $3.75 ay time C_1.

-We can replicate the payoffs of the call option with a levered position in the stock

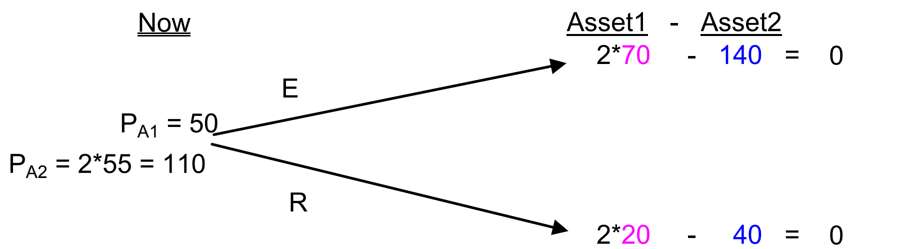
Now we are asked to find another portfolio which will mimic this payoff structure, will generate the same cash in each of the cases (price down 15% and price up 15%). When we have this we can say the prices are related. This means there is an arbitrage opportunity.

(continued next page)

Sidebar overview:



Buy P_1 and sell P_2, earn \$5, zero cash flow in future



Buy 2 of P_1 and sell 1 of P_2, earn \$10

So we have found a way to arbitrage

Asset2 has a known 2-to-1 relation to Asset1 (which doubles it's price)

If you find a portfolio which has the same relation in (each case) of earnings, they must have the same relation in prices because of arbitrage opportunities. This can be extended to 3 times, four times, …

The practice of the construction of a riskless hedge is called *delta hedging*.

The delta of a call option is positive.

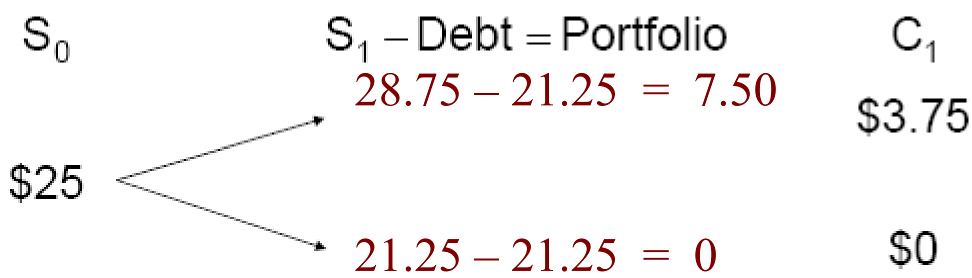
The delta of a put option is negative.

$$\Delta = \frac{\text{Swing of call}}{\text{Swing of stock}} = \frac{\$3.75 - 0}{\$28.75 - \$21.25} = \frac{\$3.75}{\$7.5} = \frac{1}{2}$$

Back to example:

-Borrow \$21.25 today and buy 1 share (\$21.25 is the present value of \$25 at r=15%)
-The net payoff for this levered equity portfolio in one period is either \$7.50 or \$0

-The levered equity portfolio has twice the option's payoff so the portfolio is worth twice the call option value (we barrowed **21.25** to buy which we pay back at time 1). We choose the 21.25 as the amount to barrow because it is the lower expected earning and we will not be out of pocket if the lower earning is realized.



So 7.50 and 0 are the payoffs of this portfolio. How can we relate these two payoff structures? **If we choose this portfolio we get, in each case, twice as much as generated in the call option, C_1. So if we know the price of the portfolio how should we relate it to the price of the option? By $\frac{1}{2}$, the price of the option ($C_{1)}$ should be exactly half of the price of the portfolio.** If we know the price of the portfolio then we can find the price of the option by dividing it by two.

Now what has it cost us to get to this position?

The price of the stock is \$25. What about the barrowing? We barrowed 21.25 so our cost would be the present value = 21.25/(1+r).

Price of Portfolio (1 period) = $25 - \frac{21.25}{1+r}$ = Cash Outflow at Time 0

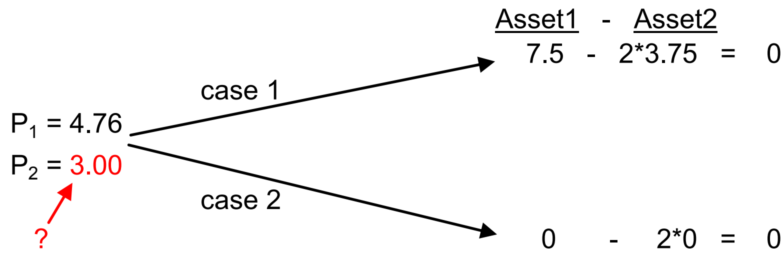
½ of this portfolio price is the price of the option …

$$C0 = \frac{1}{2}[25 - \frac{21.25}{1+r}] \quad \text{at r=5\% we have} \quad C0 = \frac{1}{2}(4.76) = 2.38$$

Portfolio Price (4.76)

Option Price (2.38)

Example:



Structure says buy 1 of P_1 and buy 2 of P_2

Cash Flow @ Time 0 = CF_0 = -4.76 + 2*3 = $1.24
Cash Flow @ Time 1 = 0

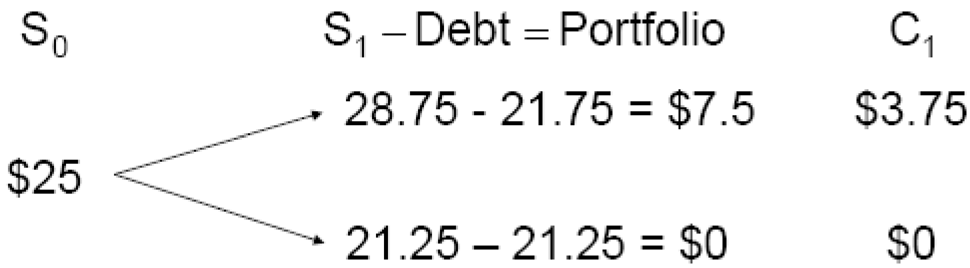
This is an arbitrage, free money, money machine.

This example shows that the price of asset 2 cannot be 3.00 because that price would generate an arbitrage opportunity. If the price of asset 2 were $2 then we would lose money at time 0 (-.76) and still have zero cash flow at time 1.

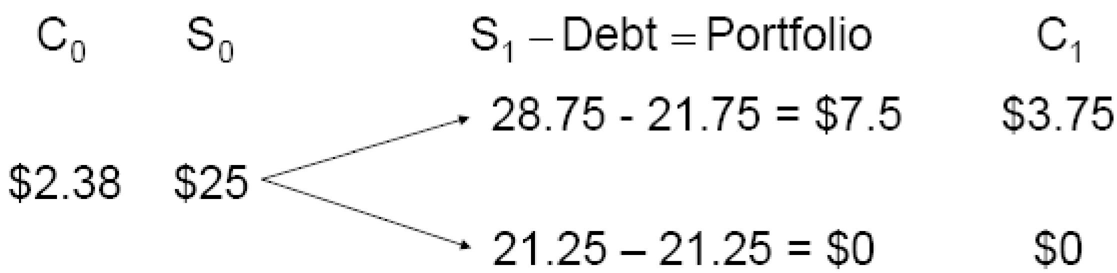
This replication is very important. Using this technique we do not need the exact probabilities of each outcome. We just mimic the portfolio.

Binomial option pricing model

-We can value the call option today as half of the value of the levered equity portfolio:



-If the interest rate is 5%, the call is worth:



BINOMIAL OPTION PRICING MODEL

-The most important lesson (so far) from the binomial option pricing model is:

the replicating portfolio intuition (used for the binomial case)

-Many derivative securities can be valued by valuing portfolios of primitive securities when those portfolios have the same payoffs as the derivative securities (by using replication of the portfolio).

If we can replicate the cash flow then. Because of arbitrage consideration, the value of the portfolio must be the value of the call option.

This technique can be generalized to the normal distribution.

AN OPTION-PRICING FORMULA

-We started with a binomial option pricing formula to build our intuition

-We will graduate to the normal approximation to the binomial for some real-world option valuation

-The **Black-Scholes Model** allows us to value options in the real world just as we have done in the 2-state world **[NOT ON EXAM]**

This technique continues replicating the portfolio using the normal distribution. Probably the most cited paper in finance literature.

The Black-Scholes Model

Not on Exam

-The Black-Scholes Model is

$$C_0 = SN(d_1) - Ee^{-rT}N(d_2)$$

Where
r = risk-free rate, S = stock price, E = exercise price

(?) S or σ = volatility of the stock return

$$d_1 = \frac{\ln(S/E) + (r + \sigma^2/2)T}{\sigma\sqrt{T}} \; ; \qquad d_2 = d_1 - \sigma\sqrt{T}$$

N(d) = probability that a standardized, normally distributed, random variable will be less than or equal to d

Example:

- Find the value of a six-month call option on the Microsoft with an exercise price of $150
- The current value of a share of Microsoft is $160
- The interest rate available in the US is r = 5%
- The option maturity is 6 months (half of a year)
- The volatility of the underlying asset is 30% per annum

Before we start, note that the ***intrinsic value*** of the option is $10 --our answer must be at least that amount

-First, calculate $d_1$and d_2:

r=.05   sigma = .3   E = 150   S = 160   T = .5 (annum)

solve for d_1 = .5282 and d_2 = .31602

-Then, find the normal distribution cumulative probabilities for $d_1$and d_2

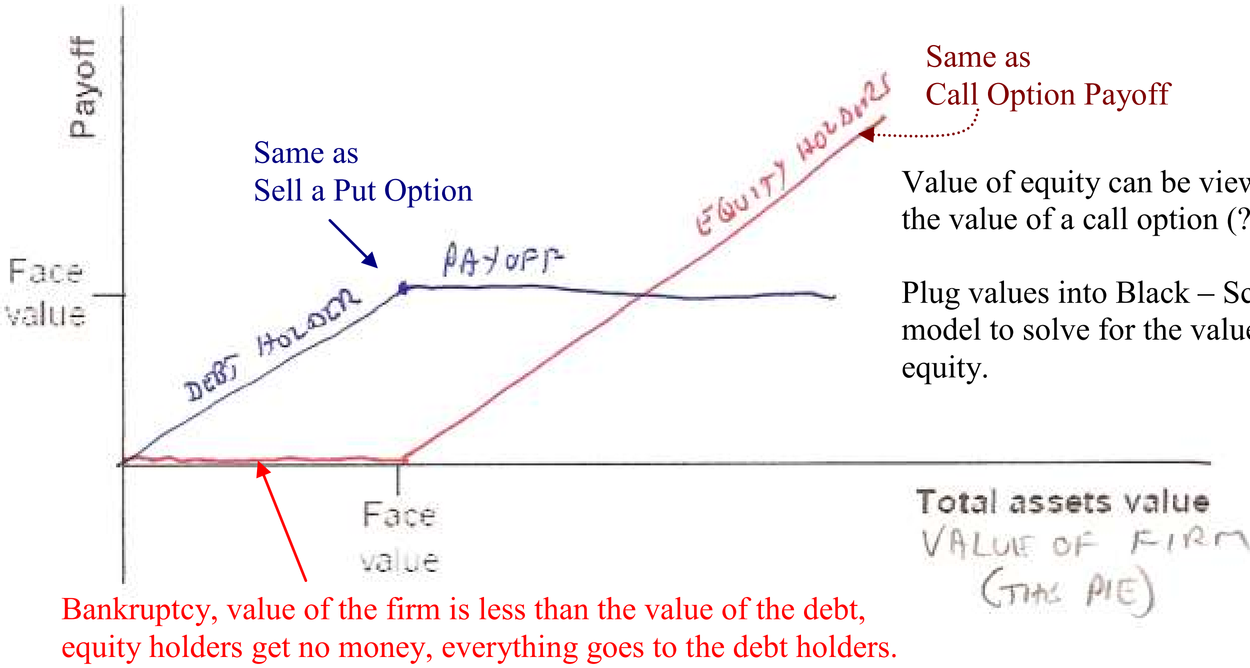
N(.5282) = .7013   N(.31602) = .62401

-The value of the option is:

$$C_0 = SN(d_1) - Ee^{-rT}N(d_2) \quad = \$20.92$$

EQUITY AND DEBT AS OPTIONS

How options are related to capital structure. We are comparing to the value of the firm (the pie, equity plus debt), total asset value. Below Face Value is the face value of the debt. What we see is the cash value varying above and below this.



Value of equity can be viewed as the value of a call option (?).

Plug values into Black – Scholes model to solve for the value of the equity.

Red Line: models return to equity holders as cash value of the firm increases. We see that this is similar to the payoff on a Call Option. The value of the equity can be viewed as the value of a call option on the firms total assets. Option pricing is sometimes used to estimate the value of a firms equity. Can even use Black-Scholes formula because the payoffs are the same. The value of the equity can be viewed as the value of the call option on the firms assets.

Blue Line: models return to debt holders, similar to the payoff of a Put Option. The debt holders only get repaid what they are owed, thus the straight line above "face value". Buying a firms debt is like selling a Put option on the firms total assets where the exercise price is the face value.

We see that both equity and debt can be viewed as some form of options.

Practice questions

22.5 22.11 22.12 22.19