Chapter 20: Financial Options

I. Options Basics

A. Understanding Option Contracts

1. Quick overview

Option: **an option gives the holder the right to buy or sell some asset at a fixed price until the option expires**

Note: It is a two-step process involving at least two people.

1) One investor buys an option from another investor
2) The buyer of the option gets to decide whether to buy or sell the asset controlled by the option at the agreed-upon fixed price

Basic Terms:

call option: right to buy the asset
put option: right to sell the asset
strike or exercise price: the agreed-upon fixed price
exercising option: owner of option uses the option to buy or sell the asset
expiration date: last date on which option can be exercised
option writer: person who takes the opposite side of contract
European option: can only be exercised on expiration date
American option: can be exercised on any date until the expiration date
at-the-money: zero net payoff if exercise
in-the-money: positive net payoff if exercise
out-of-the-money: negative net payoff if exercise
hedging: using options to reduce risk
speculation: using options to bet on whether asset price will rise or fall

Note: It is important to differentiate between the following:
a) buy to open: buy an option
b) sell to open: write an option contract
c) sell to close: sell an option on which you are currently long
=> closes out long position
d) buy to close: buy an option on which you are currently short
=> closes out short position

B. Interpreting Stock Option Quotations

Note: We will look at option quotes for General Mills on Yahoo Finance:
http://finance.yahoo.com

Column headings for option quotes at Yahoo Finance:

Last Trade Date: date and time of most recent trade for a particular option contract
Strike: strike (exercise) price
Last Price: price of most recent trade
Bid: highest price that anyone has offered to pay
Ask: lowest price at which anyone has offered to sell
Change: difference between last price and close for previous day
% Change: percent change between last price and close from previous day
Volume: number of contracts traded today
Open Interest: number of contracts that have not been settled
Implied Volatility: volatility of underlying stock over the life of the option implied by the last price for the option and an option pricing model

Note: volatility of the underlying stock over the life of the contract is the only variable in the Black-Scholes Option pricing model that can't be observed.

Note: each traded contract is on 100 shares, but the prices listed are per share

=> <u>all numbers, calculations, and graphs are on a per-share basis unless I state otherwise</u>

Notes on Yahoo Finance example:

1) Calls with higher strike prices have lower market prices
=> right to buy at lower price more valuable

2) Puts with higher strike prices have higher market prices
=> right to sell at higher price more valuable

3) Puts and calls with longer time to expiration have higher market prices
=> having right to buy or sell for longer time more valuable

C. Buying and Selling Options

Key: anyone can buy an option or can create and sell an option
=> unrelated to any positions (long or short) might have in stock

Notes: see General Mills examples on website

1. Calls

Ex. Assume that at 3:47 PM (Eastern) on 7/5/2024, Greg submits a market order to buy one call contract (from Sharon who has submitted a limit order to sell one call contract) on General Mills that expires on Friday, 12/20/2024, with a strike price of $65 per share.

On 7/5:

1) **Sharon creates and sells the call contract to Greg**
2) **Greg pays $245 to Sharon to buy the call contract from Sharon.**

=> Greg now has the right to buy 100 shares of General Mills stock at $65 per share through 12/20/2024

Q: Why would Greg buy the call?
Q: Why would Sharon sell the call?

2. Puts

Ex. Assume that at 3:47 PM (Eastern) on 7/5/2024, Phil submits a market order to sell one put contract (from Carol who has submitted a limit order to buy one put contract) on General Mills that expires on Friday, 12/20/2024, with a strike price of $65.

On 7/5:

1) **Carol pays $430 to buy one put contract from Phil**
2) **Phil creates and sells one put contract to Carol**

=> Carol now has the right to sell 100 shares of General Mills to Phil at $65 per share through 12/20/2024

Q: Why would Carol buy the put?
Q: Why would Phil sell the put?

Notes:

1) Sharon and Phil are option writers
2) Sharon and Phil are creating contracts not selling existing ones

II. Payoffs on Options at Expiration

Key issues:

1) assumption in payoff calculation and graphs: don't have position in stock now and won't when finished
2) the payoff on the option at expiration depends on the stock price at expiration
3) the payoff on a short option equals the negative of the payoff on a long position
   => reason: the seller of the option is taking opposite side of each action of the buyer

1. Payoff on Long Call

=> right to buy stock for K if want to

a. Long call on General Mills

Note: Greg bought one call contract on General Mills with strike price of $65 that expires on 12/20/2024

1) Assume that on 12/20/2024, Greg is still long one call contract and the price of General Mills stock is $67.

=> **Greg buys 100 shares for $65 per share using the call and sells them in the market for $67 per share.**

=> Greg's payoff = **+$200**

2) Assume that on 12/20/2024, the price of General Mills stock is $63.

=> **Greg does nothing and the call expires**

=> Greg's payoff = **$0**

b. General equation for calculating payoff on long call: C = max(S – K,0) (20.1)

where:

C = value of call at expiration = payoff on call at expiration
S = market price of stock at expiration of call
K = exercise price = the price at which can buy stock if want to

If S > K:

Q: will holder of call want to buy the stock for K? **Yes**

=> **positive payoff**

If S < K:

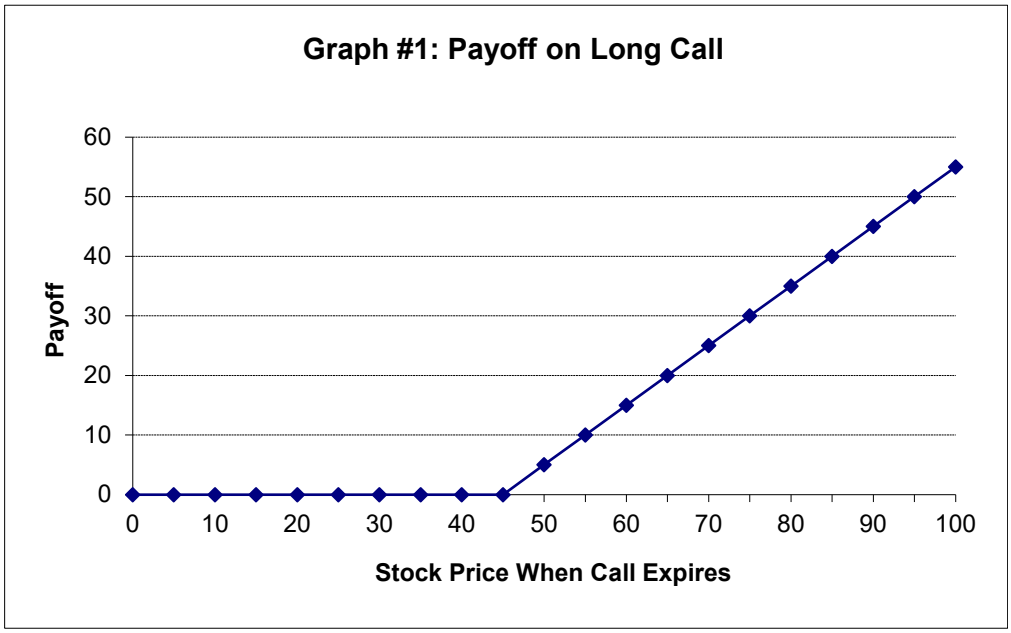
Q: will holder of call want to buy the stock for K? **No**
=> payoff = **0**

Ex. Assume K = $45

Q: What is the payoff (per share) on a call if the stock price ends up at:

$40: C = 0 = **max (40-45,0)**
$50: C = 5 = **max (50-45,0)**
$60: C = 15 = **max (60-45,0)**
Q: What are the transactions?

Q: What are all possible payoffs on a long call with a strike price of $45?



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2. Payoff on Long Put

=> right to sell stock for K if want to

a. Long put on General Mills

Note: Carol bought one put contract on General Mills with a $65 strike price that expires on 12/20/2024.

1) Assume that on 12/20, Carol is still long one put contract and the price of General Mills stock is $67 per share.

=> **Carol does nothing and the put expires**
=> payoff = **$0**

2) Assume that on 12/20, the price of General Mills is $63

=> **Carol buys 100 shares for $63 per share in the market and sells them for $65 per share using the put**
=> payoff = **+$200**

b. General equation for calculating payoff on long put: $P = \max(K - S, 0)$ (20.2)

P = value of put at expiration = payoff on put at expiration
S = stock price at expiration of put
K = exercise price = the price at which can sell stock if want to

If S < K:

Q: will holder of put want to sell stock for K? **Yes**
=> **positive payoff**

If S > K:

Q: Will holder of put want to sell stock for K? **No**

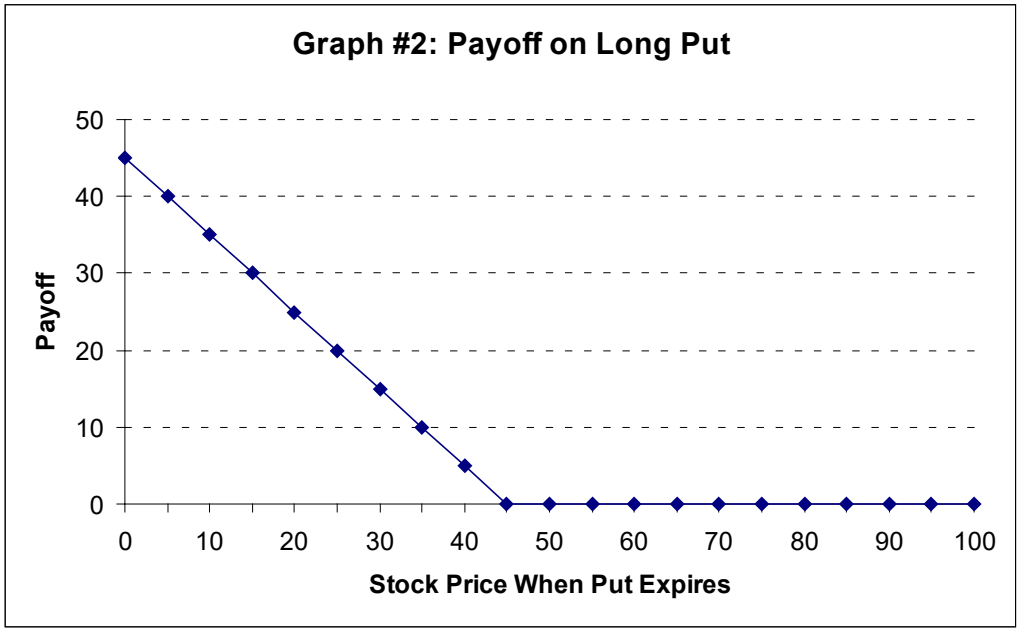
=> **would have loss**

Ex. Assume K = $45

Q: What is the payoff per share on a put if the stock price ends up at:

$30: P = 15 = **max (45-30,0)**
$40: P = 5 = **max (45-40,0)**
$50: P = 0 = **max (45-50,0)**
Q: What are the transactions?

Q: What are the possible payoffs per share on a long put with a strike price of $45?



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3. Payoff on short call:

1) have sold someone the right to buy the stock from you for K
2) buyer of call will only exercise if S > K
3) if they exercise, you must buy the stock at S (market price) and sell it for K (<S)

a. Short call on General Mills

Note: Sharon sold one call contract on General Mills with strike price of $65 that expires on 12/20 to Greg

1) Assume that on 12/20 Sharon is still short one call contract and the price of General Mills stock is $67.

=> **Greg will exercise the call**
=> **Sharon has to buy 100 shares in the market for $67 per share and sell them to Greg for $65 per share.**
=> payoff = **– $200**

Q: Why would Sharon do this?

2) Assume that on 12/20, the price of General Mills stock is $63.

=> **call expires since Greg does not exercise them**

b. General equation for calculating payoff on short call: $-C = -\max(S - K, 0)$

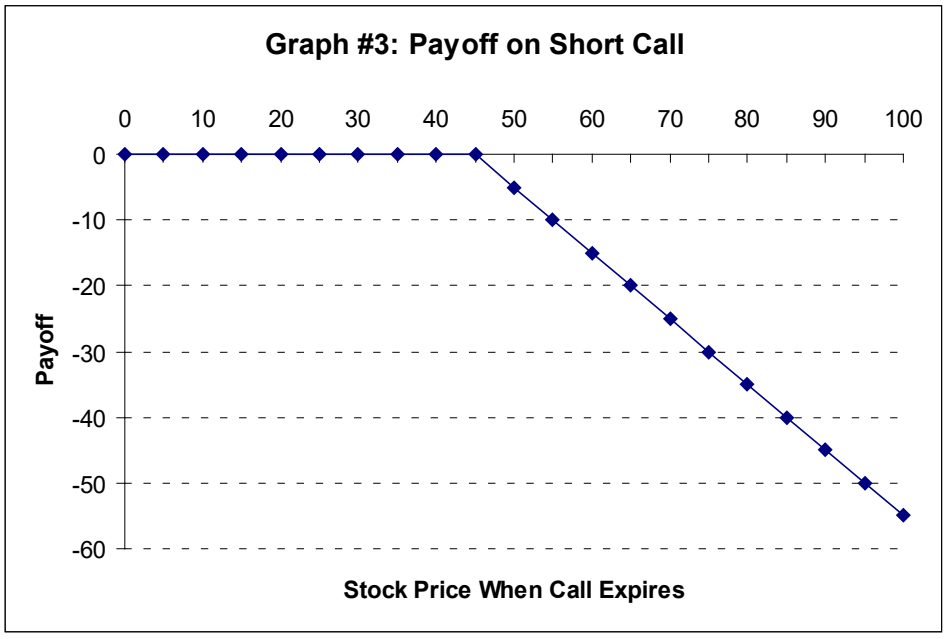
Ex. Assume the strike price on a call is $45 and that the market price for the stock is $60. What is the payoff (per share) on a short call?

=> payoff $= -15 =$ **$-\max(60 - 45, 0)$**

Q: What are transactions?

=> **must buy for $60 in the market and sell for $45 as call exercised**

Q: What are the possible payoffs on a short call with a strike of $45?



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Q: How does this graph compare to graph #1?

4. Payoff on short put:

1) have sold someone the right to sell the stock to you for K
2) they will only exercise if K > S
3) if they exercise, you must buy at K and can sell for the market price S (<K)

a. Short put on General Mills

Note: Phil sold one put contract on General Mills with a $65 strike price that expires on 12/20 to Carol.

1) Assume that on 12/20, Phil is still short one put contract and the price of General Mills stock is $67 per share.

=> **put expires since Carol does not exercise them**
=> payoff = **$0**

2) Assume that on 12/20, the price of General Mills is $63

=> **Carol will exercise the put**
=> **Phil must buy 100 shares from Carol for $65 per share and sell them in the market for $63 per share**
=> Phil's payoff = **– $200**

b. General equation for calculating payoff on short put: $-P = -\max(K - S, 0)$

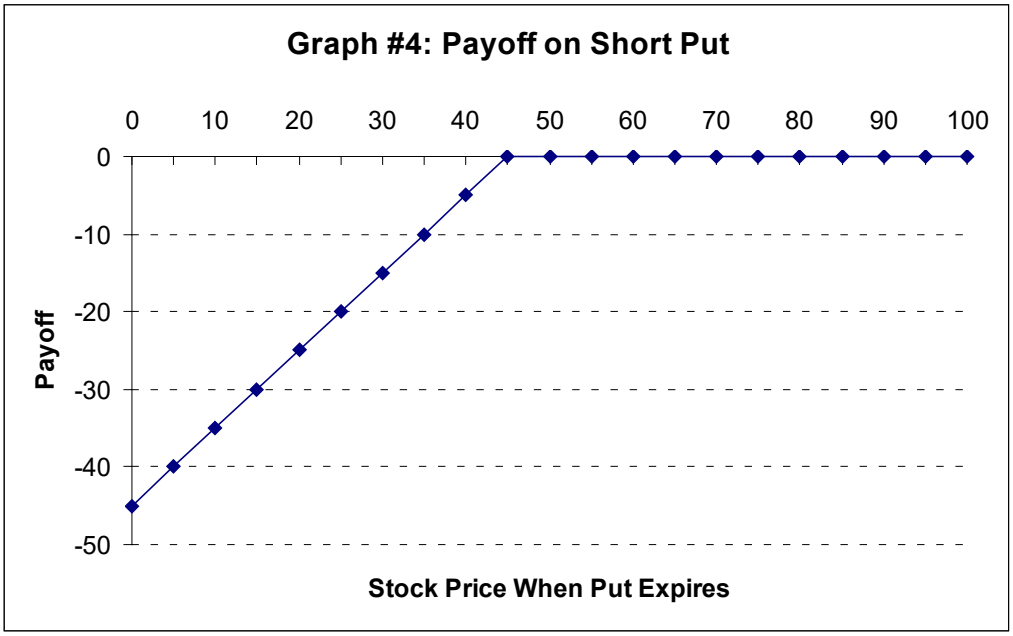
Ex. Assume S = 35, K = 45, what is the payoff on a short put?

=> payoff = -10 = **– max(45 – 35,0)**

Q: What are transactions?

=> **must buy for $45 as put exercised and sell for $35 in market**

Q: What are the possible payoffs on a short put with a strike of $45?



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Q: How does this graph compare to graph #2?

III. Profits for Holding an Option to Expiration

Profit = CF at expiration + CF when option first bought/sold

1. Long Calls

Ex. General Mills:

Note: Greg bought one call contract on General Mills with strike price of $65 for $245

1) If stock price ends up at $67 at expiration, payoff = $200, profit = -$45 = **200 – 245**

2) If stock price ends up at $63 at expiration, payoff = $0, profit = –$245 = **0 - 245**

Ex. Assume you can buy a call for $4.90 with an exercise price of $25. What is profit (per share) if the stock price equals $20, $35, or $40 at expiration?

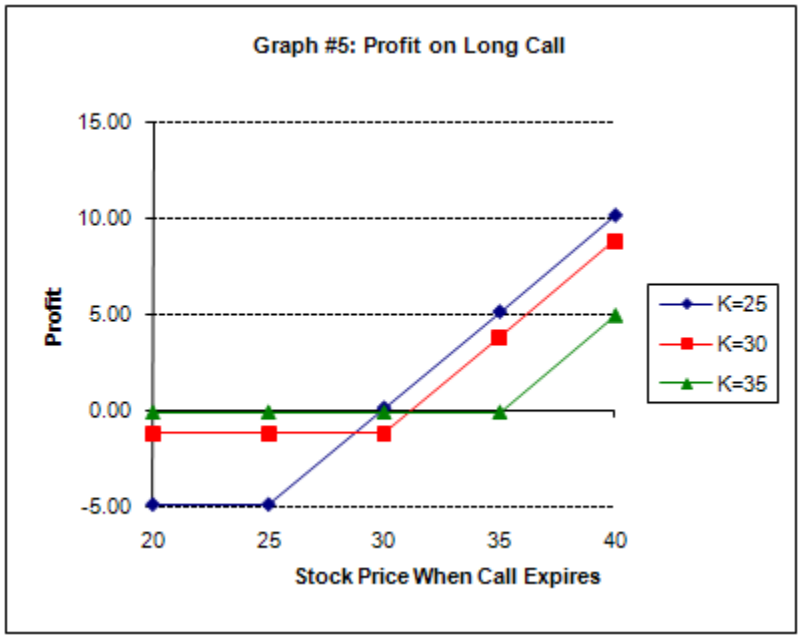
Q (for each of the following): What are sequence of transactions?

$20: Profit = -$4.90 = **0 – 4.9**
$35: Profit = $5.10 = **10 – 4.9**
$40: Profit = $10.10 = **15 – 4.9**

Ex. What are the possible profits from buying the following calls?

Strike	Price of Call Today
25	4.90
30	1.22
35	0.13

Q: Why is the call with K = 25 most valuable?



Notes:

1) If S < K, **don't exercise**
   => loss = **cost of call**

2) If S > K:
   => **for each $1 the stock price rises above K, profit rises $1**

2. Long Puts

Ex. General Mills:

Note: Carol bought one put contract on General Mills with strike price of $65 for $430

1) If stock price ends up at $67 at expiration, payoff = $0, profit = **–$430**

2) If stock price ends up at $63 at expiration, payoff = $200, profit = **–$230**

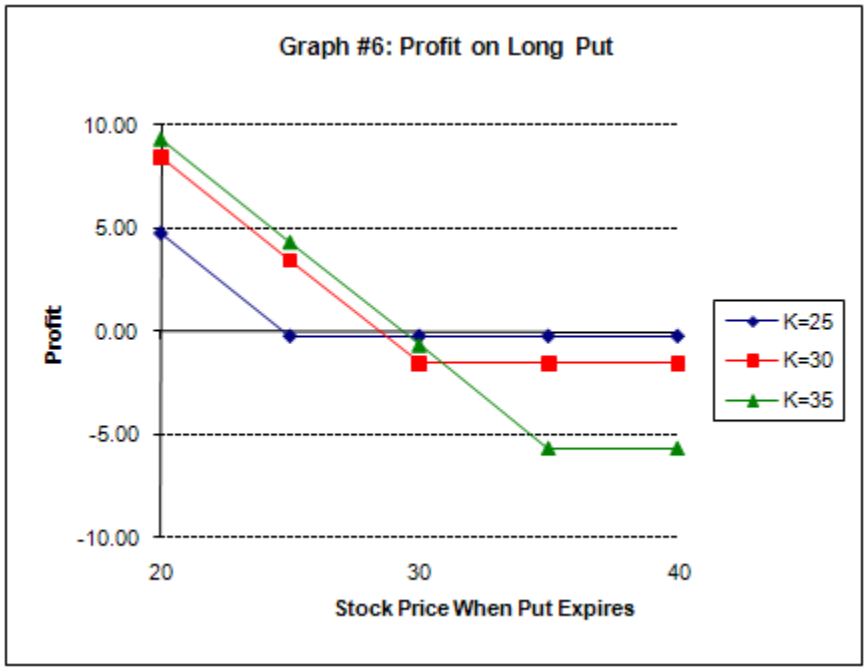
Ex. Assume that you can buy a put for $5.65 with an exercise price of $35. What is the profit if the stock price ends up at $10, $20, or $40?

Q (for each of the following): What are set of transactions?
$10: Profit = $19.35 = **25 – 5.65**
$20: Profit = $9.35 = **15 – 5.65**
$40: Profit = -$5.65 = **0 – 5.65**

Ex. What are the possible profits from buying the following puts?

Strike	Price of Put Today
25	0.21
30	1.55
35	5.65

Q: Why is the put with K = 35 most valuable?



Notes:

1) If S > K, **don't exercise**
   => loss = **cost of put**

2) If S < K :
   => **for each $1 the stock price drops below K, profit rises $1**

3. Short Calls

Ex. General Mills:

Note: Sharon sold one call contract on General Mills with strike price of $65 for $245 to Greg

1) If stock price ends up at $67 at expiration, payoff = –$200, profit = $45 = **245 – 200**

2) If stock price ends up at $63 at expiration, payoff = $0, profit = $245 = **245 – 0**

Ex. Assume you can sell a call for $4.90 with an exercise price of $25. What is profit if the stock price equals $20, $35, or $40 at expiration?

Q (for each of the following): What are sequence of transactions?

$20: Profit = $4.90 = **4.9 – 0**
$35: Profit = –$5.10 = **4.9 – 10**
$40: Profit = –$10.10 = **4.9 – 15**

2. Short Puts

Ex. General Mills:

Note: Phil sold one put contract on General Mills with strike price of $65 for $430

1) If stock price ends up at $67 at expiration, payoff = $0, profit = $430 = **430 – 0**

2) If stock price ends up at $63 at expiration, payoff = –$200, profit = $230 = **430 – 200**

Ex. Assume that you can sell a put for $5.65 with an exercise price of $35. What is the profit if the stock price ends up at $10, $20, or $40?

Q (for each of the following): What are set of transactions?

$10: Profit = –$19.35 = **5.65 – 25**
$20: Profit = –$9.35 = **5.65 – 15**
$40: Profit = $5.65 = **5.65 – 0**

IV. Returns for Holding an Option to Expiration

Note: rate of return only really makes sense on long options

1. Long Calls

Ex. Assume that you can buy a call for $4.90 that has an exercise price of $25. What is return on the call if the stock price ends up at $20, $35, or $40?

Note: profits (from previous section):

$20: -$4.90
$35: +$5.10
$40: +$10.10

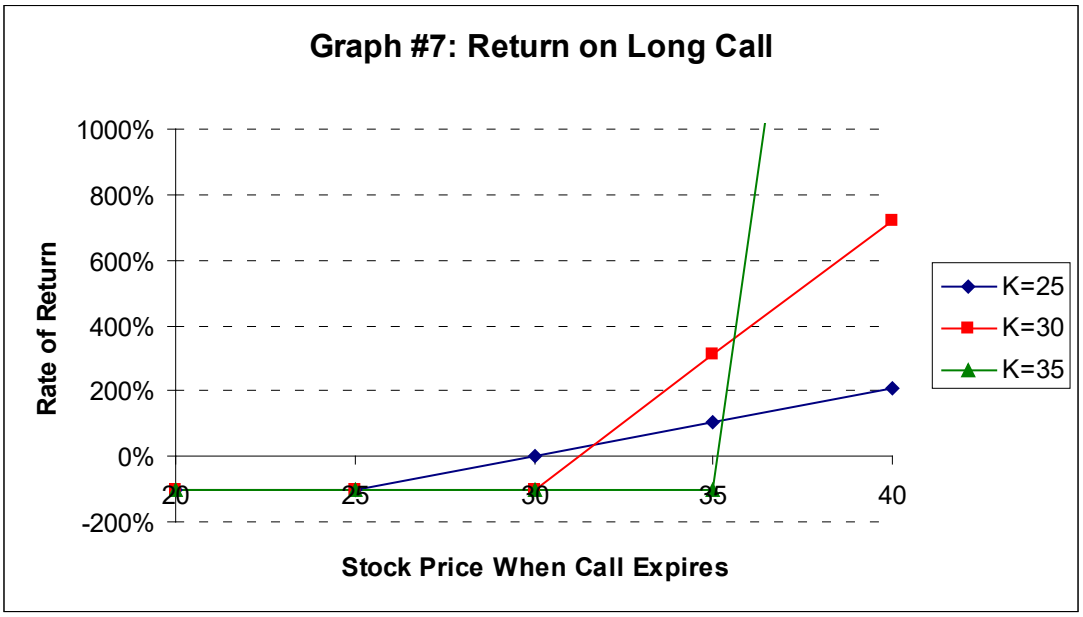
$20: Return $= -100\% = \frac{-4.90}{4.90}$

$35: Return$= +104.1\% = \frac{5.10}{4.90}$

$40: Return$= +206.1\% = \frac{10.10}{4.90}$

Ex. What are the possible returns from buying the following calls?

Strike	Price of Call Today
25	4.90
30	1.22
35	0.13



Notes on call return graph:

1) if S < K:
   => **don't exercise**
   => return = **-100%**

2) **volatility of returns is higher for calls with higher strike prices**

2. Long Puts

Ex. Assume that you can buy a put for $5.65 that has an exercise price of $35. What is the return on the put if the stock price ends up at $40, $20, or $10?

Note: profits (from previous section):

$10: +$19.35
$20: +$9.35
$40: -$5.65

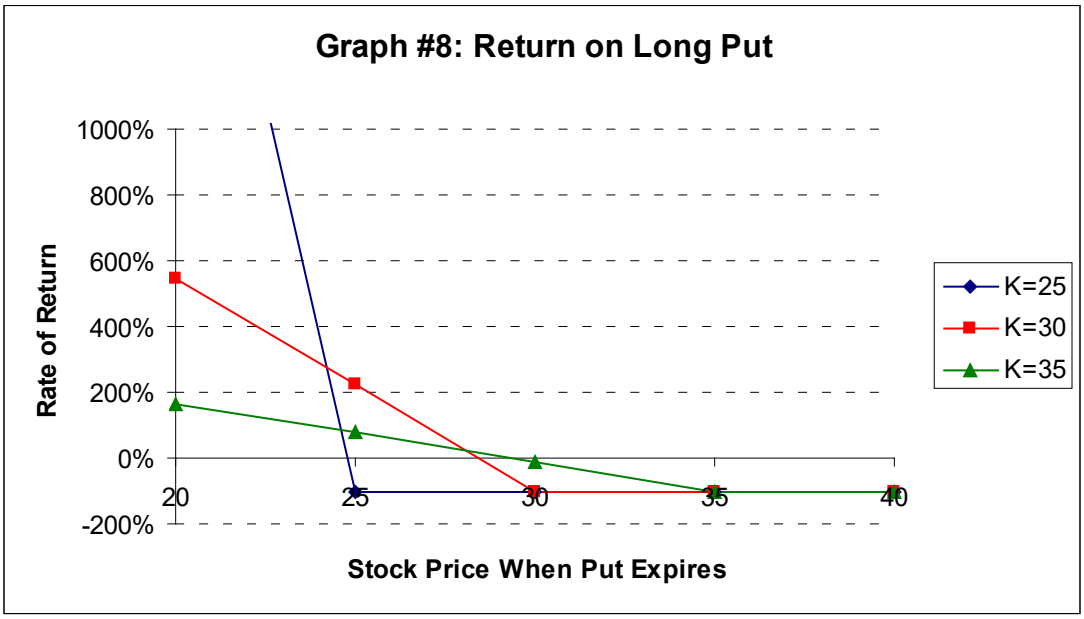
$10: Return$= +342.5\% = \frac{\mathbf{19.35}}{\mathbf{5.65}}$

$20: Return$= +165.5\% = \frac{\mathbf{9.35}}{\mathbf{5.65}}$

$40: Return$= -100\% = \frac{\mathbf{-5.65}}{\mathbf{5.65}}$

Ex. What are the possible returns from buying the following puts?

Strike	Price of Put Today
25	0.21
30	1.55
35	5.65



Notes on put return graph:

1) if S>K:
   => **don't exercise**
   => return = **-100%**

2) **volatility of returns is higher for puts with low strike prices**

3. Option betas:

Note: we will prove all of the following in Chapter 21

If a stock has a positive beta:

1) **a call will have a positive beta that is higher than the stock beta**

Q: Why? **The risk of the stock is magnified in the call.**

Stock = **call with zero strike price**
=> **as strike increases, call volatility increases and beta increases for the same reason**
=> **beta of call > beta of stock**

2) the deeper out-of-the-money a call, the higher its beta

Q: Why? **As call goes out of money, value drops**
=> **impact of any change in price of stock is magnified**
=> **beta rises**

3) a put will have negative beta

Q: Why? **Stocks and puts move in opposite directions**

4) the deeper out-of-the-money a put, the more negative its beta

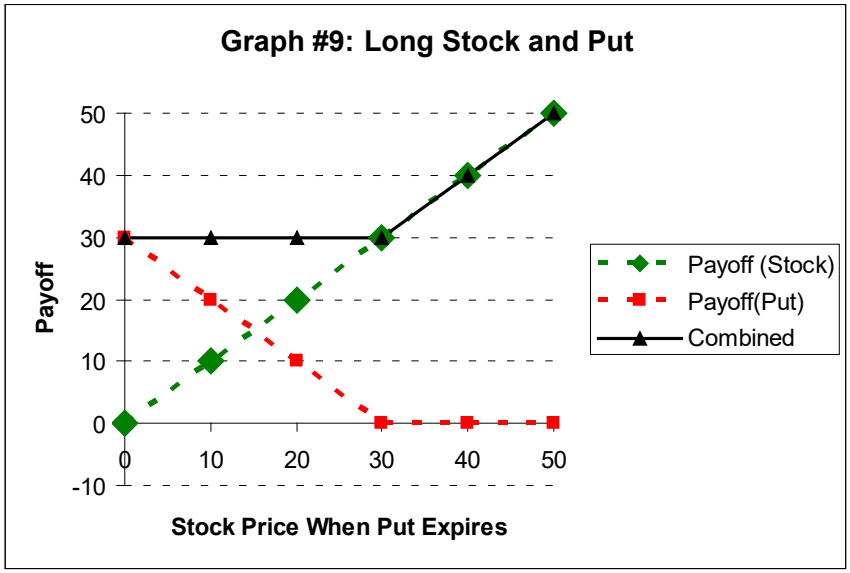
Q: Why?
=> **As goes deeper out of money, value drops**
=> **impact of any change in stock price is magnified**
=> **magnitude of beta rises**
=> **more negative**

V. Put-Call Parity

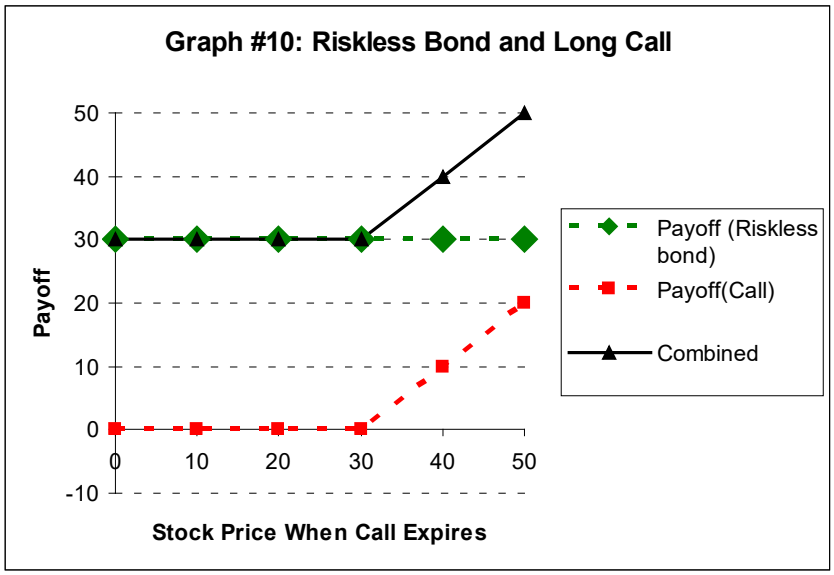
A. Payoffs on Portfolios Involving Options

Key: add up the payoffs of the individual securities

1. Portfolio insurance: **own stock and a long put with K = $30**
   => **protected against downside but retain upside potential**



2. Buy riskless bond that matures for $30 (K) and a long call with K = $30



Note: combined payoffs from 1) and 2) are the same!

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B. Options on stock that doesn't pay dividends

Payoff same if:

1) **own stock and a long put**
2) **have a long call and a riskless zero-coupon bond that matures for K**

Law of One Price: **cost to set up the two portfolios must be the same**

Let:

S = current stock price
P = current put price
PV(K) = present value of K = current price of zero-coupon bond
C = current call price

$S + P = PV(K) + C$ (20.A)

$C = P + S - PV(K)$ (20.3)
=> can solve for the value of a call if know the other 3 variables

$P = C - S + PV(K)$ (20.B)
=> can solve for the value of a put if know the other 3 variables

Ex. Assume that a stock's current price is \$29.33 per share. Assume also that you can buy a call on this stock for \$4.90 that expires in 99 days with an exercise price of \$25. What is the value of an equivalent put if the risk-free rate equals 4.83% per year?

$$P = .2522 = 4.9 - 29.33 + 24.68 = \mathbf{4.90 - 29.33 + 25\left(\frac{1}{1.0483}\right)^{99/365}}$$

C. Options on stock that pays a dividend over the life of the option

=> if a stock doesn't pay a dividend, the cash flow at expiration on a stock and put equals the cash flow on a bond and a call at expiration
=> **if stock pays a dividend, stock and put has more cash flow than the bond and call**
=> **must add PV(Divs) paid on the stock over the life of the option to the right side of equation 20.A**

=> $S + P = PV(K) + C + PV(Div)$ (20.C)

$C = P + S - PV(K) - PV(Div)$ (20.4)

$P = C - S + PV(K) + PV(Div)$ (20.D)

Ex. Assume that in the stock in the previous example is expected to pay a dividend of $0.20 per share 35 days from today. What is the value of the put if the expected return on the stock is 7%?

Note: discount dividends at stock's cost of capital

$$P = .4509 = 4.9 - 29.3 + 24.68 + .1987$$
$$= \mathbf{4.90 - 29.33 + 25\left(\frac{1}{1.0483}\right)^{99/365} + .20\left(\frac{1}{1.07}\right)^{35/365}}$$

Q: Why is the put worth more if a dividend is paid?

VI. Factors Affecting Option Prices

1. Calls are more valuable if:
   1) market price for stock is: **higher**
      Q: Why?
   2) strike price is: **lower**
      Q: Why?

2. Puts are more valuable if:
   1) stock price is: **lower**
      Q: Why?
   2) strike price is: **higher**
      Q: Why?

3. **Option prices can't be negative**
   Q: Why?

4. American option can't be worth less than European option that otherwise same
   Q: Why?
   => **being able to exercise before expiration may be worth something**

5. The price of a put can never exceed the strike price
   => as the stock price falls , the payoff on a put rises
   => lowest possible stock price is $0

   => maximum payoff on a put = **K**

6. The price of a call can never exceed the stock's price
   => as the strike price falls, the payoff on a call rises
   => the lowest possible strike price is $0

   => maximum payoff on call = **S**

7. If two American options are otherwise identical, the one with the earlier expiration date can't be worth more
   => **right to delay exercising is probably worth something**

   Note: not necessarily true for European option

8. As the volatility of the stock increases, the value of an option increases

   Reason:

   1) Stock prices and payoffs on a call

      Q: What happens to the payoff on a long call as S rises further above K?
      => **increases**

      Q: What happens to the payoff on a long call as S falls further below K?
      => **nothing…stays at zero**

   2) volatility and calls

      => as the volatility of the stock increases:

      => **there is a greater chance of very high and very low stock values**
      => **upside benefits while downside has no impact**
      => the value of an option rises as the stock becomes more volatile

   Note: Same basic idea holds for puts

VII. Options and Corporate Finance

A. Equity as an Option

E = min (0, V – D)

Where:

E = payoff to equity holders
V = value of firm's assets when debt matures
D = maturity value of debt

=> **stockholders get whatever is left after debtholders are paid**

=> **but stockholders never have a payoff below 0 due to limited liability**

Ex. Assume that $100,000 is owed to bondholders in two years.

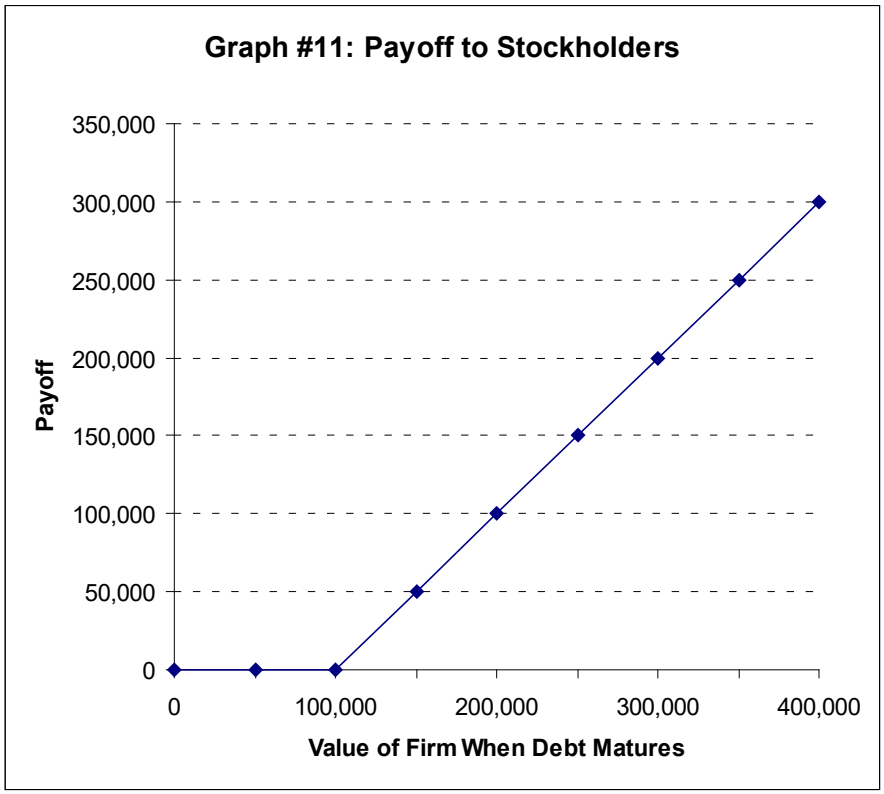
Q: What is the payoff to stockholders when the debt matures if the firm's assets are worth $75,000?

=> 0 = **min(0; 75,000 – 100,000)**

Q: How about if the firm's assets are worth $150,000?

= 50,000 = **min(0; 150,000 – 100,000)**

Q: What does a graph of all possible payoffs as a function of the value of the firm's assets look like?



Note: looks exactly like the payoff on a long call!
Basic idea: Stock can be viewed as a long call on the firm's assets
=> **strike price equals the amount owed the bondholders at maturity**
=> only exercise a call if it is "in-the-money"
=> **only pay off bondholders in full if firm value exceeds what is owed bondholders**

Note: the same things that affect a call's value affects stock values

Ex. The higher the value of the underlying asset, the higher the value of a call

=> **the higher the value of a firm's assets, the higher the value of the firm's stock**

Reason: **stock is essentially a call on the firm's assets**

B. Debt as a Portfolio of Options

=> DM = min (V, D)

Where:

DM = payoff to debt holders when the debt matures
V = value of firm's assets when debt matures
D = maturity value of debt

=> **bondholders are paid the lower of what owed or the firm value**

1. Payoff on Debt as a Function of the Value of the Firm's Assets when the Debt Matures

Ex. Assume that $100,000 is owed to bondholders in two years. What is the payoff to bondholders when the debt matures?

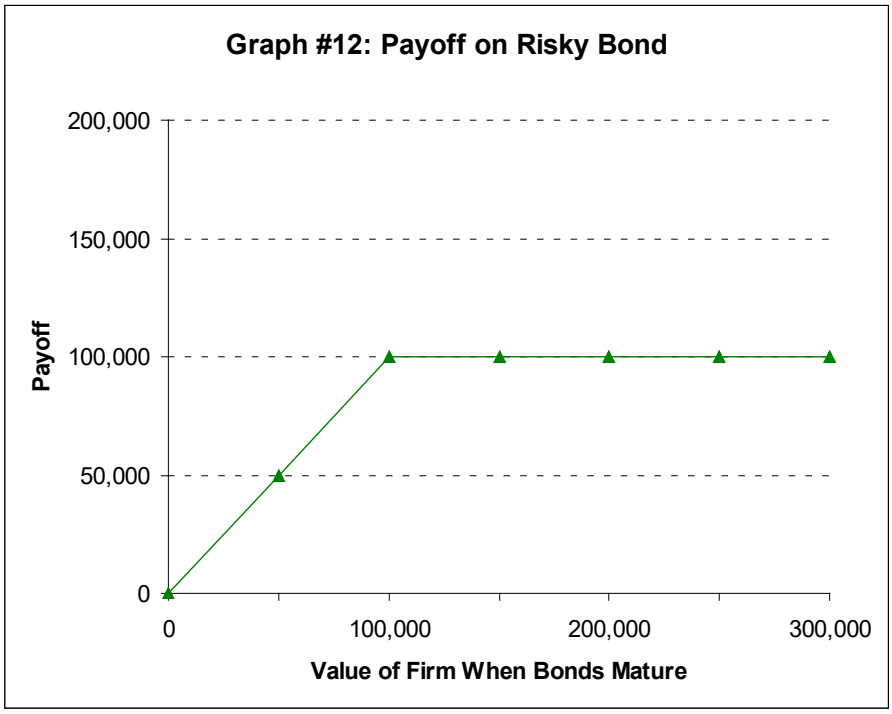
Q: What are payoffs on bond if value of firm equals $75,000 or $150,000 in two years?

75,000: 75,000 = **min(75,000; 100,000)**

150,000 = 100,000 = **min(150,000; 100,000)**

Q: Explain logic?

Q: What does a graph of all possible payoffs as a function of the value of the firm's assets look like?



2. Owning a firm's risky bond can be viewed as owning the firm but having a short call on the firm's assets with a strike price equal to the amount owed to the bondholders at maturity.

Ex. Amount owed bondholders = $100,000 = K on short call

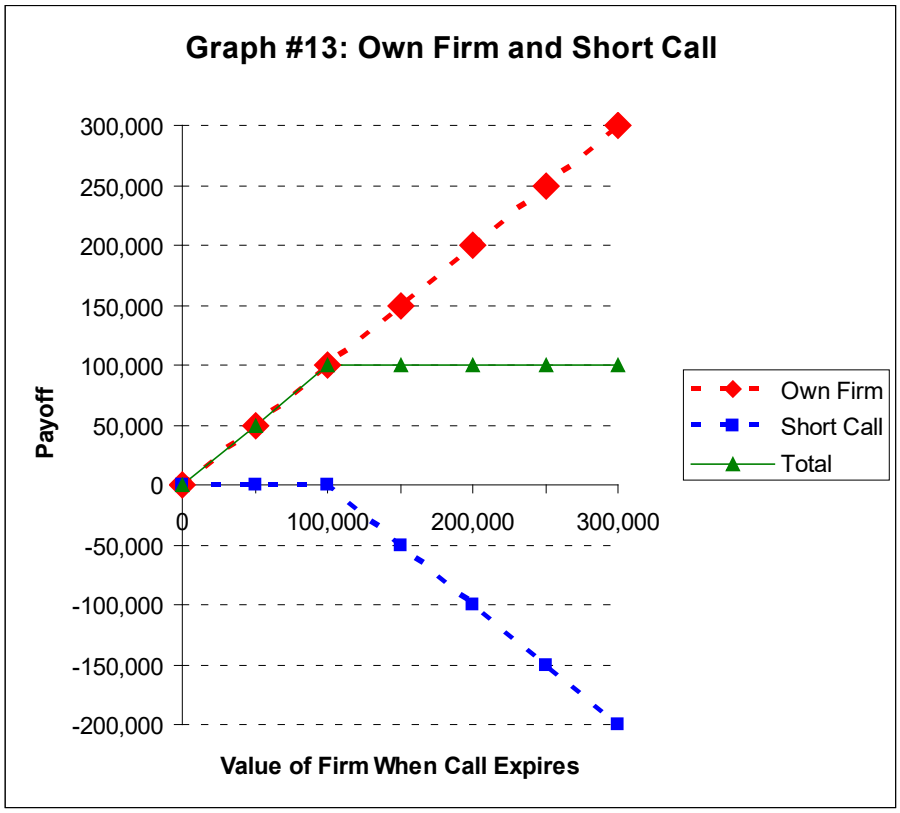
If firm value = $75,000:

Payoff on firm = **$75,000**
Payoff on short call = **$0**
Net = $75,000 = **75,000 – 0**

If firm value = $150,000:

Payoff on firm = **$150,000**
Payoff on short call = **-$50,000**
Net = $100,000 **= 150,000 – 50,000**

Q: What does a graph of all possible payoffs as a function of the value of the firm's assets look like?



Video

3. Owning a firm's risky bond can be viewed as owning a portfolio of riskless debt with a maturity value equal to the promised payment on the firm's bond and a short put on the firm's assets with an exercise price equal to the promised payment on the firm's bond.

Ex. Amount owed bondholders = $100,000 = K on short put

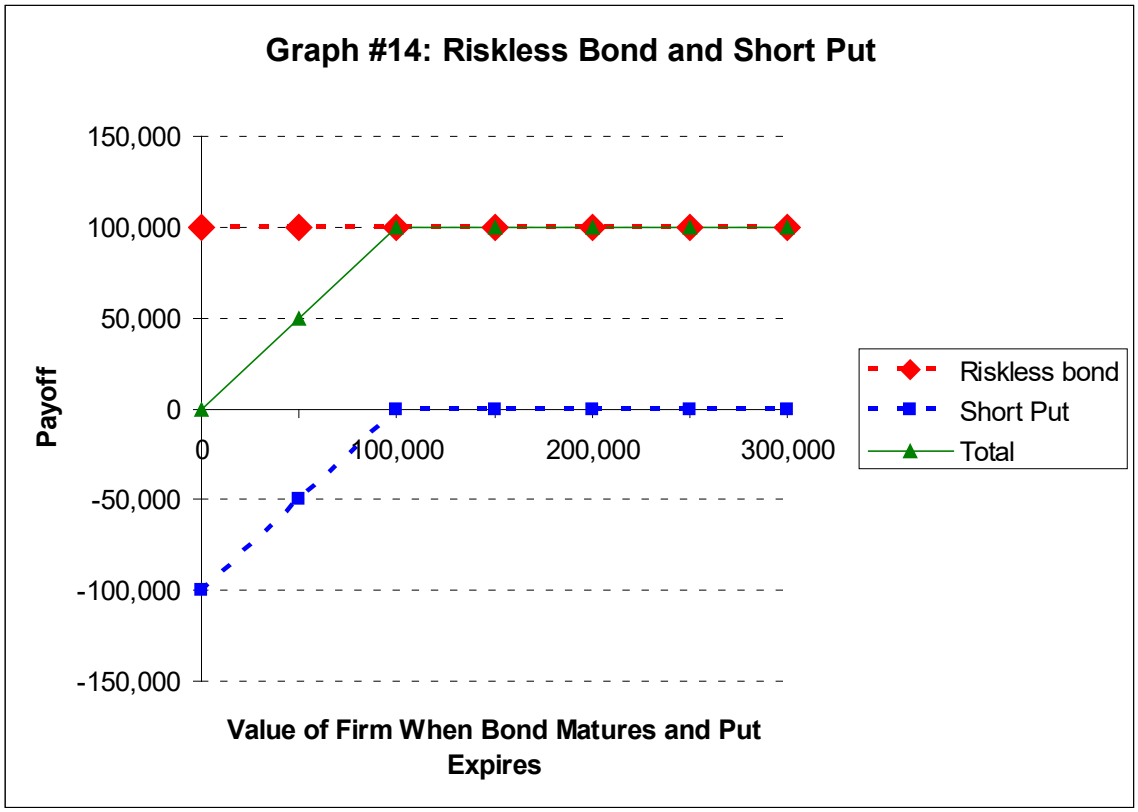
If firm value = $75,000:

Payoff on riskless bond = **$100,000**
Payoff on short put = **-$25,000**
Net = $75,000= **100,000 – 25,000**

If firm value = $150,000:

Payoff on riskless bond = **$100,000**
Payoff on short put = **$0**
Net = $100,000 **= 100,000 - 0**

Q: What does a graph of all possible payoffs as a function of the value of the firm's assets look like?



Video

C. Options and Agency Conflicts

Key: if view stocks and bonds in terms of options, we can draw many of the same conclusions as in Chapter 16

1) Stockholders gain at the expense of bondholders if the firm overinvests in risky projects

=> **stock is a call on the firm's assets**
=> **calls increase in value if the risk of the underlying asset increases**

2) Stockholders may prefer the firm reject positive NPV projects

=> bondholders essentially have a risk-free bond and a short put on the firm's assets
=> value of bond = value of risk-free bond – value of put

=> as value of firm rises, the value of a put falls
=> value of short put becomes less negative

=> **shareholders don't get all of the benefit if the firm's value rises**
=> **reduces incentive to invest in positive NPV projects**

Note: same idea applies (in reverse) to payouts by firm
=> stockholders gain at bondholder expense when firm pays out cash