Chapter 20: Financial Options

I. Options Basics

A. Understanding Option Contracts

   Basic Terms:
   - financial option: contract that gives the owner the right to buy or sell an asset at a fixed price in the future
   - call option: right to buy
   - put option: right to sell
   - strike or exercise price: the 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 opposite side of contract
   - European option: option that can only be exercised on expiration date
   - American option: option that 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

B. Interpreting Stock Option Quotations

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

   Column headings for option quotes at Yahoo Finance:
   - Last: price of most recent trade
   - Change: difference between current price and close for previous day
   - Bid: highest price that anyone has offered to pay
   - Ask: lowest price at which anyone has offered to sell
   - Vol: number of contracts traded today

   Note: each traded contract is on 100 shares

   Notes on Yahoo Finance example:
   1) Calls with lower strike prices have higher 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. Examples (from Option Quotes for Ch 20 notes on website)

Ex. Assume that at 11:49 AM (Eastern) on 10/31/2011, Greg submits a market order to buy a call (from Sharon who has submitted a limit order to sell a call) on General Mills that expires on Friday, 12/16/2011, with a strike price of $40 per share.

On 10/31:

1) Sharon creates and sells the call to Greg
2) Greg pays $55 to Sharon to buy the call contract from Sharon.

Assume that on 12/16, Greg still holds the call and the price of General Mills stock is $42.

1) Sharon buys 100 shares in the market for $42 per share and sells it to Greg for $40 per share.
2) Greg buys 100 shares from Sharon for $40 per share using the call and sells the stock in the market for $42 per share.

Assume that on 12/16, the price of General Mills stock is $38.

=> Greg does nothing and call expires

Ex. Assume that at 11:49 AM (Eastern) on 10/31/2011, Phil submits a market order to sell a put (from Carol who has submitted a limit order to buy a put) on General Mills that expires on Friday, 12/16/2011, with a strike price of $40.

On 10/31:

1) Carol pays $145 to buy a put contract from Phil
2) Phil creates and sells the put to Carol

Assume that on 12/16, Carol still holds the put and the price of General Mills stock is $42 per share.

=> Carol does nothing and the put expires

Assume that on 12/16, the price of General Mills is $38

1) Carol buys 100 shares for $38 per share in the market and sells it for $40 per share using the put
2) Phil buys 100 shares from Carol for $40 per share and sells it in the market for $38 per share

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

Important:
1) the payoff on the option at expiration depends on the stock price at expiration
2) assumption in payoff calculation and graphs: don’t have position in stock now and won’t when finished

A. Long Positions in Option Contracts

=> payoff if own option

1. Payoff on Call

=> right to buy stock for K if want to

\[ C = \max(S - K, 0) \]  \hspace{1cm} (20.1)

\( C \) = value of call at expiration = payoff on call at expiration
\( S \) = stock price 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 on a call if the stock price ends up at:

\( \$40: C = \max(40-45,0) = 0 \)
\( \$50: C = \max(50-45,0) = 5 \)
\( \$60: C = \max(60-45,0) = 15 \)

Q: What are the transactions?

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

=> right to sell stock for K if want to

\[ P = \max(K - S, 0) \] (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 on a put if the stock price ends up at:

- $30: P = \max (45-30,0) = 15$
- $40: P = \max (45-40,0) = 5$
- $50: P = \max (45-50,0) = 0$

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

B. Short Position in an Option Contract

=> sell (write) an option contract

Basic idea: cash flows from a short position equal the negative of a long position

Reason: the seller of the option is taking opposite side of each action of the buyer

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

=> payoff = – \( C = - \max(S - K, 0) = - \max(60 - 45, 0) = -15 \)

**Q: What are transactions?**

=> you must buy for $60 and sell for $45

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

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**Graph #3: Payoff on Short Call**

Stock Price When Call Expires

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**Compare to graph #1**

2. 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 \( S < K \)

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

=> payoff = – \( P = - \max(K - S, 0) = - \max(45 - 35,0) = -10 \)

**Q: What are transactions?**

=> you must buy for $45 and sell for $35

Q: What are the possible payoffs on a short put with a strike of $45?
C. Profits for Holding an Option to Expiration

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

1. Calls

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 = 0 – 4.9 = -$4.90
$35: Profit = 10 – 4.9 = $5.10
$40: Profit = 15 – 4.9 = $10.10
Ex. What are the possible profits from buying the following calls?

<table>
<thead>
<tr>
<th>Strike</th>
<th>Price of Call Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>4.90</td>
</tr>
<tr>
<td>30</td>
<td>1.22</td>
</tr>
<tr>
<td>35</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**Q: Why is the call with \( K = 25 \) most valuable?**

Notes:

1) If \( S < K \), don’t exercise

   \[ \Rightarrow \text{loss} = \text{cost of call} \]

2) If \( S > K \):

   \[ \Rightarrow \text{for each } \$1 \text{ the stock price rises above } K, \text{ profit rises } \$1 \]

2. Puts

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

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

- **\$10:** Profit = \( 25 - 5.65 = $19.35 \)
- **\$20:** Profit = \( 15 - 5.65 = $9.35 \)
- **\$40:** Profit = \( 0 - 5.65 = -$5.65 \)
Ex. What are the possible profits from buying the following puts?

<table>
<thead>
<tr>
<th>Strike</th>
<th>Price of Put Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.21</td>
</tr>
<tr>
<td>30</td>
<td>1.55</td>
</tr>
<tr>
<td>35</td>
<td>5.65</td>
</tr>
</tbody>
</table>

*Q: Why is the put with \( K = 35 \) most valuable?*

Notes:

1) If \( S > K \), don’t exercise
   
   \[
   \Rightarrow \text{loss} = \text{cost of put}
   \]

2) If \( S < K \):
   
   \[
   \Rightarrow \text{for each \$1 the stock price drops below K, profit rises \$1}
   \]
D. Returns for Holding an Option to Expiration

1. 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: \text{Return} = \frac{-4.90}{4.90} = -100\%

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

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

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

<table>
<thead>
<tr>
<th>Strike</th>
<th>Price of Call Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>4.90</td>
</tr>
<tr>
<td>30</td>
<td>1.22</td>
</tr>
<tr>
<td>35</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Graph #7: Return on Long Call
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. 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

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

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

$40: Return = \frac{-5.65}{5.65} = -100\%$
Ex. What are the possible returns from buying the following puts?

<table>
<thead>
<tr>
<th>Strike</th>
<th>Price of Put Today</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.21</td>
</tr>
<tr>
<td>30</td>
<td>1.55</td>
</tr>
<tr>
<td>35</td>
<td>5.65</td>
</tr>
</tbody>
</table>

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. 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

E. Combinations of 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

Graph #9: Long Stock and Put

Payoff (Stock)  Payoff (Put)  Combined

2. Buy riskless bond that matures for $30 (K) and a long call with K = $30
III. Put-Call Parity

A. 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

$$S + P = PV(K) + C \quad \text{(20.A)}$$

$$C = P + S - PV(K) \quad \text{(20.3)}$$

$\Rightarrow$ can solve for the value of a call if know the other 3 variables

$$P = C - S + PV(K) \quad \text{(20.B)}$$

$\Rightarrow$ 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?

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

B. 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

\[
S + P = PV(K) + C + PV(Div)
\]

\[
C = P + S - PV(K) - PV(Div)
\]

\[
P = C - S + PV(K) + PV(Div)
\]

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

\[
P = 4.90 - 29.33 + 25\left(\frac{1}{1.0483}\right)^{\frac{99}{365}} + .20\left(\frac{1}{1.07}\right)^{\frac{35}{365}} = .4509
\]

**Q: Why is the put worth more than if there is no dividend?**

IV. Factors Affecting Option Prices

1. Calls are more valuable if:
   1) stock price 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
   \( Q: \text{Why?} \)

4. American option can’t be worth less than European option that otherwise same
   \( Q: \text{Why?} \)
   \( \Rightarrow \text{being able to exercise before expiration may be worth something} \)

5. The price of a put can never exceed the strike price
   \( \Rightarrow \) as the stock price falls, the payoff on a put rises
   \( \Rightarrow \) lowest possible stock price is $0
   \( \Rightarrow \text{maximum payoff on a put} = K \)

6. The price of a call can never exceed the stock’s price
   \( \Rightarrow \) as the strike price falls, the payoff on a call rises
   \( \Rightarrow \) the lowest possible strike price is $0
   \( \Rightarrow \text{maximum payoff on call} = S \)

7. If two American options are otherwise identical, the one with the earlier expiration date
   can’t be worth more
   \( \Rightarrow \text{right to delay exercising is probably worth something} \)

   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
      
      \( Q: \text{What happens to the payoff on a long call as } S \text{ rises further above } K? \)
      \( \Rightarrow \text{increases} \)
      
      \( Q: \text{What happens to the payoff on a long call as } S \text{ falls further below } K? \)
      \( \Rightarrow \text{nothing…stays at zero} \)

   2) Volatility and calls

   \( \Rightarrow \) as the volatility of the stock increases:

      \( \Rightarrow \) there is a greater chance of very high and very low stock values
      \( \Rightarrow \text{upside benefits while downside has no impact} \)
      \( \Rightarrow \text{the value of an option rises as the stock becomes more volatile} \)

   Note: Same basic idea holds for puts
V. Options and Corporate Finance

A. Equity as an Option

Ex. Assume that $100,000 is owed to bondholders in two years. What is the payoff to stockholders when the debt matures if the firm’s assets are worth $75,000? How about if the firm’s assets are worth $150,000?

*Show payoffs for $75,000 and $150,000 firm values*

![Graph #11: Payoff to Stockholders](image)

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 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 really a call on the firm’s assets
B. Debt as a Portfolio of Options

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?

![Graph #12: Payoff on Risky Bond](image)

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.
Do numbers then show on graph

Graph #13: Own Firm and Short Call

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

If firm value = $150,000:

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

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

If firm value = $150,000:

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