Risk Management: Exotic Options

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Option Pricing and Risk Management

- Remember the formula... EU call/put
- Remember the hedging strategies... delta hedge, gamma hedge, vega hedge, ...

Option Pricing and Risk Management

- Risk management = manage the likelihood and/or severity of risks to align with the appetite level
- Consider benefits and costs of the risk management strategy that you execute
- For financial risks, there are many other clever ways to do so...

Exotic Options

- Non-standard options
- Exotic options solve particular business problems that ordinary option do not
- They are often constructed by tweaking ordinary options in minor way

What You Should Know about Exotic Options

- What are the payoffs? Any different?
- Are they cheaper or more expensive? Why?
- When would you use them?
- Is it easy to hedge them?

Types of Exotic Options

TABLE 12.1   Intensity of Use of Option Structures in Various Markets

	Interest Rate Options		FX Options		Equity Options		Commodity Options	
	OTC	Exchanges	OTC	Exchanges	OTC	Exchanges	OTC	Exchanges
First-generation options								
European style	A	A	A	A	A	O	A	A
American style	A		A		R	A	A	A
Bermuda style	A		A		R		O	
Second-generation options								
Path-dependent options								
Average price (rate)	A		A		A		A	A
Barrier options	A		A		A		A	
Capped	O		O		A		O	
Lookback	R		R		O		R	
Ladder	O		O		A		O	
Ratchet	O		O		A		O	
Shout	R		R		R		O	
Correlation-dependent options								
Rainbow options	R		O		O		O	
Quanto options	A		A		A		A	
Basket options	R		A		A		A	R
Time-dependent options								
Chooser options	R		R		R		O	
Forward-start options	R		R		A		A	
Cliquet options	R		R		A		O	
Single-payout options								
Binary options	A		A		A		A	
Contingent premium options	A		A		A		A	

FX = foreign exchange; OTC = over the counter; A = actively used; O = occasionally used; R = rarely used; blank = not used.
Source: Smithson (2000).

Allen, S. (2012). Financial Risk Management: A Practitioner's Guide to Managing Market and Credit Risk

Types of Exotic Options

- Asian Options (Option of Average)
- Barrier Options
- Exchange Options
- All-or-Nothing Options
- All-or-Nothing Barrier Options
- Rebate Options
- Multivariate Options
- etc...

Agenda

1. Vanilla Option

2. Exotic Options
   - Asian Options
   - Barrier Options
   - Binary Options
   - Other Exotic Options

3. Mini Case

Why

- Use when business cares about average [prices] over time
- ... or when rices at a single point in time are subject to manipulation
- ... or when price swings are frequent due to thin markets

Example

- For an average strike call option using arithmetic averaging and a 30-day period for sampling the data.
- On November 1st, a trader purchased a 90-day arithmetic call option on stock XYZ with an exercise price of \$22, where the averaging is based on the value of the stock after each 30-day period. The stock price after 30, 60, and 90 days was $21.00, 22.00,$ and \$24.00.
- The arithmetic average (mean) is $(21.00 + 22.00 + 24.00) / 3 =$ 22.33.
- The profit is the average minus the strike price 22.33 - 22 = 0.33 or \$33.00 per 100 share contract.
- As with standard options, if the average price is below the strike price, the loss is limited to the premium paid for the call options.

Payoffs

- There are 2x2x2 combinations of Asian options:
    - Call or Put
    - Fixed strike & average past prices or spot price & strike = average past prices
    - Geometric or arithmetic average: G(T)
- For example:
    - Ave. Price Call = max[0,G(T) - K]
    - Ave. Price Put = max[0,K - G(T)]
    - Ave. Strike Call = max[0,S - G(T)]
    - Ave. Strike Put = max[0,G(T) - S]
    - where G(T) is the arith. average or geom. average.

Pricing

- If we can get a closed-form solution for pricing formula, it would be easy for pricing in practice (we can use Excel) and for hedging
- … but we often cannot, unfortunately
- In this case, we can get close-form formula for the geometric average options only:

Pricing Asian Option in R & Sensitivity Analysis

- Run the following codes in R:

  ```
  install.packages(c("fOptions","fExoticOptions"))
  library(fOptions)
  library(fExoticOptions) #Parameters Setting


  TypeFlag = "p"
  S = 80
  X = 85
  Time = 1
  r = 0.05
  b = 0.08
  sigma = 0.20


  #Geometric Average Rate Option:
  price1 = GeometricAverageRateOption(TypeFlag,S,X,Time,r,b,sigma)
  #Compare with the BS Option:
  price2 = GBSOption(TypeFlag,S,X,Time,r,b,sigma)
  ```

# Pricing Asian Option in R & Sensitivity Analysis

- Run the following codes in R:

  # Sensitivity Analyses on Stock Price

  ```
  x = c(-10:10) # You can adjust the range here
  CompareS = matrix(0, nrow = length(x), ncol = 2)

  for (i in 1:length(x)){
  CompareS[i,1] = GeometricAverageRateOption(TypeFlag,S+x[i],X,Time,r,b,sigma)@price
  CompareS[i,2] = GBSOption(TypeFlag,S+x[i],X,Time,r,b,sigma)@price
  }
  ```

Sensitivity Analysis: Comparing Put Options
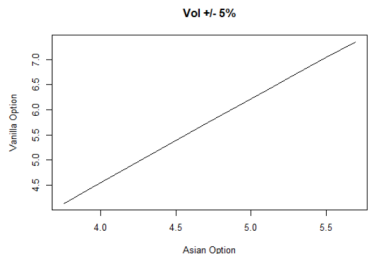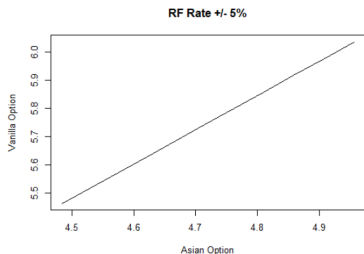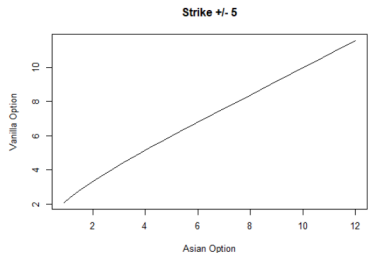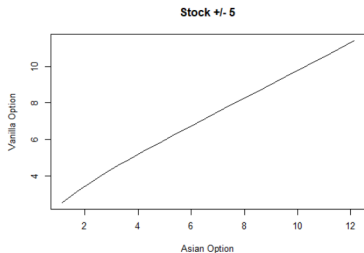
Asian Options: Key Takeaways

- Relatively cheaper than vanilla options due to lower payoff volatility
- Multiple use i business... good for hedging over a period of time
- Pricing can be complicated and might involve [a little bit of] programming

Agenda

Barrier Options

- Barrier options are options which its value depending on whether the price of the underlying asset reaches a specified level, called the *barrier*
- ... it's a path-dependent option

Types of Barrier Options

- Knock-out options - deactivate when reaches the barrier e.g. down-and-out & up-and-out
- Knock-in options - activate when reaches the barrier e.g. down-and-in & up-and-in
- Rebate options - pay fixed amount when reaches the barrier e.g. up rebates & down rebates

Barrier Options: Illustration

FIGURE 14.1

Illustration of a price path where the initial stock price is $100 and the barrier is $75. At $t = 0.5$, the stock hits the barrier.
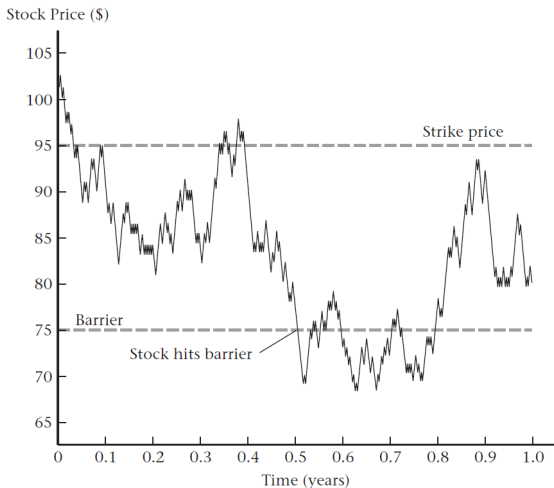
Pricing

- Question: Do you think barrier (knock-out & knock-in) options are more or less expensive than the vanilla options?
- Consider the following identity:
  Knock-in + Knock-out = Ordinary Option

Pricing Barrier Option in R & Sensitivity Analysis

- Run the following codes in R:

```
install.packages(c("fOptions","fExoticOptions"))
library(fOptions)
library(fExoticOptions) #Parameters Setting


TypeFlag = "p"
S = 80
X = 85
Time = 1
r = 0.05
b = 0.08
sigma = 0.20


#Geometric Average Rate Option:
price1 = GeometricAverageRateOption(TypeFlag,S,X,Time,r,b,sigma)
#Compare with the BS Option:
price2 = GBSOption(TypeFlag,S,X,Time,r,b,sigma)
```

Pricing Barrier Option in R & Sensitivity Analysis

- Run the following codes in R:
  ?BarrierOptions

  #Standard Barrier Options
  # Barrier = H
  # Barrier must comply with the initial stock price
  # K = Cash Rebate... if K = 0 then investors receive no cash value once knocked-out or knocked-in.

  # EX1) down-and-out Barrier Call
  StandardBarrierOption(TypeFlag = "cdo", S = 100, X = 90, H = 95, K = 0, Time = 0.5, r = 0.08, b = 0.04, sigma = 0.25)@price
  GBSOption(TypeFlag = "c",S = 100,X = 90,Time = 0.5,r = 0.08,b = 0.04,sigma = 0.25)@price

  # EX2) up-and-out Barrier Call
  StandardBarrierOption(TypeFlag = "cuo", S = 100, X = 90, H = 120, K = 0, Time = 0.5, r = 0.08, b = 0.04, sigma = 0.25)@price
  GBSOption(TypeFlag = "c",S = 100,X = 90,Time = 0.5,r = 0.08,b = 0.04,sigma = 0.25)@price

Pricing

- More variations on barrier options:
    - Double Barrier Options... impose both upper & lower barriers
    - Two Asset Barrier Options... Asset A determines how much the option is in- or out-of-the-money; Asset B determines if the price hits the barrier
    - Discrete Barrier Options... Barrier hitting is considered at multiple points in time.
    - Soft Barrier Options... multiple up or down barriers (soft and hard barriers)... if hit the soft barrier, options will be knocked-in or out proportionately

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   - Barrier Options
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   - Other Exotic Options

3. Mini Case

Binary Options

- ... or digital options
- Think of a lottery... pay fixed amount doesn't matter how much the option is in-the-money

Variations of Binary Options

- Cash-or-nothing options... pay fixed amount of cash if in-the-money
- Asset-or-nothing options... predetermined asset value is paid if in-the-money
- Binary-barrier options... put a barrier in a binary!

Pricing the Binary Options

- It's Simple!!
- Cash-or-nothing:
  - CashCall $= e^{-r(T-t)}N(d_2)$
  - CashPut $= e^{-r(T-t)}N(-d_2)$
- Asset-or-nothing:
  - AssetCall $= Se^{-\delta(T-t)}N(d_1)$
  - AssetPut $= Se^{-\delta(T-t)}N(-d_1)$
- Looks familiar?

Binary Options Payoffs
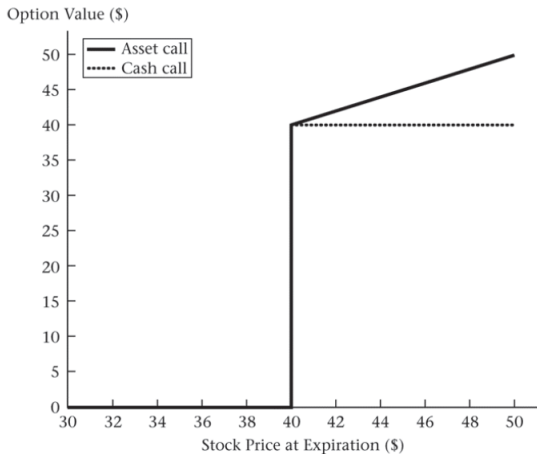
What about R?

- Try this:

  ?BinaryOptions

  CashOrNothingOption(TypeFlag = "p", S = 100, X = 80, K = 10,
  Time = 9/12,r = 0.06, b = 0, sigma = 0.35)@price
  AssetOrNothingOption(TypeFlag = "p", S = 70, X = 65, Time = 0.5,
  r = 0.07, b = 0.07 - 0.05, sigma = 0.27)@price

  There are 28 types of binary-barrier options!

  BinaryBarrierOption(TypeFlag = "6", S = 95, X=102, H = 100, K = 15,
  Time = 0.5, r = 0.1, b = 0.1, sigma = 0.20)@price
  BinaryBarrierOption(TypeFlag = "12", S = 95, X = 98, H = 100, K = 15,
  Time = 0.5, r = 0.1, b = 0.1, sigma = 0.20)@price

'Financial Engineer' using binary options

- Binary options are simple to price and highly liquid
- You can construct more complicated/ structured exotic options using binary options... you can now think of something like this:
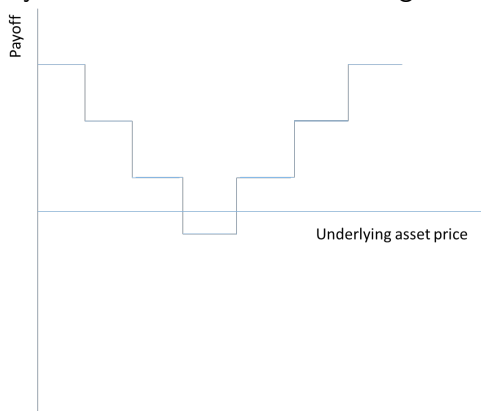
Agenda

Lookback Options

- Strike call (put) is set at the past minimum (maximum) price given a certain period.
- This will allow investors to buy (sell) stock at the lowest (highest) price
- Types... Floating strike, fixed strike, partial time, extreme spread
- See ?LookBackOptions in R

Options on Multiple Assets

- Two-asset correlation option
- Exchange option
- Options on min/max of two risky assets
- Consult ?MultipleAssetOptions in R

Mini Case

- You can work in a group up to 3 people
- Install and study R
- Study library(fOptions) and library(fExoticOptions)
- Record and post a 5-10 min video clip teaching undergrad finance students on "how to price an option in R using Black-Scholes model". In the same clip, explain and teach them how to price 3 other exotic options of your interest by using R.
- Post the video clip on YouTube and submit the YouTube link using this Google form: `https://tinyurl.com/ex-option-clip`
- Part of the score will be graded by an actual undergrad students!

Coming Up

- Volatility.. a key ingredient of risk management
- Volatility modelling... GARCH and its variations
- Intraday volatility, realized volatility... more advanced stuff
- Bring a laptop if you can