Week 6 Project

Peilin Luo

Problem 1

From the given information, the time to maturity is 0.0384 years. Using the general Black-Scholes option pricing model, I calculated the prices for both the call and put options for a range of implied volatilities between 10% and 80%. From **Figure 1**, we can conclude that when there are higher demand and lower supply, the price of options will increase, and the implied volatility will also increase. When there are lower demand and higher supply, the price of options will decrease, and the implied volatility will also decrease.

Additionally, to be more general, the supply and demand of options can affect implied volatility in a complex way, such as liquidity. To be specific, when there is a higher demand for options, the options market will be more liquid, which in turn decreases the implied volatility.

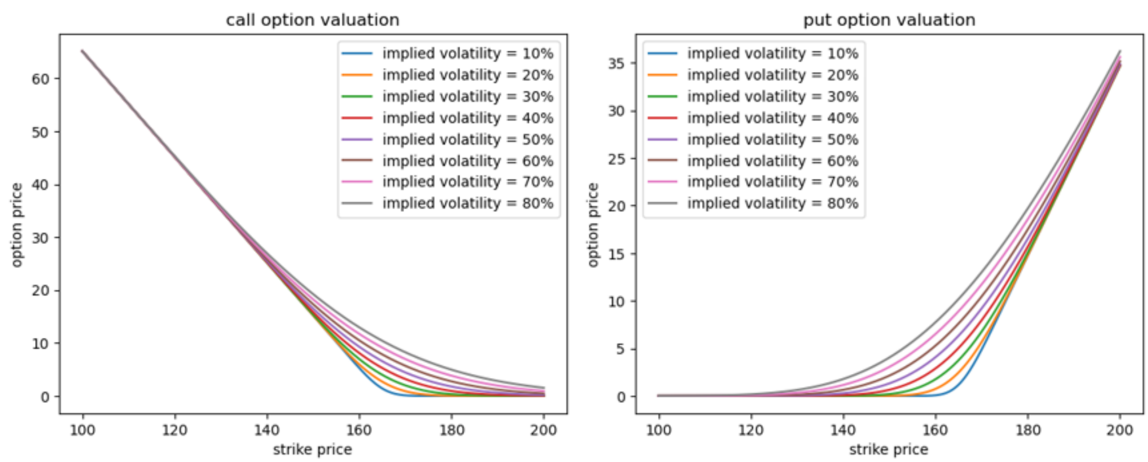

Figure 1 Option Price on different implied volatility

Problem 2

Using the general Black-Scholes model and solving the equations, I calculated the implied volatility for each AAPL option. From **Figure 2**, the AAPL **call option has a volatility "smirk"**, while the AAPL **put option has a volatility "smile"**.

Implied volatility is the market's forecast of a likely movement in a security's price. The higher the implied volatility is, the higher the option prices are. Because the probabilities are higher that the option will be in the money.

Theoretically, one security should only have one implied volatility in a specific time period. However, from **Figure 2**, we observed that not all options on the same underlying and expiration have the same implied volatility.

For the AAPL **call options**, the implied volatility is higher when options are in the money and lower when options are out of the money. This pattern is rational because **demand should be greater when options are in the money, increasing the implied volatility**. For the AAPL **put options**, the implied volatility is higher when options are in the money or out of the money, versus at the money. To illustrate, the demand for put options is greater when the options are in the money and out of the money. Investors may believe that **extreme events could occur, causing significant shifts in stock prices and making the options finish in the money**.

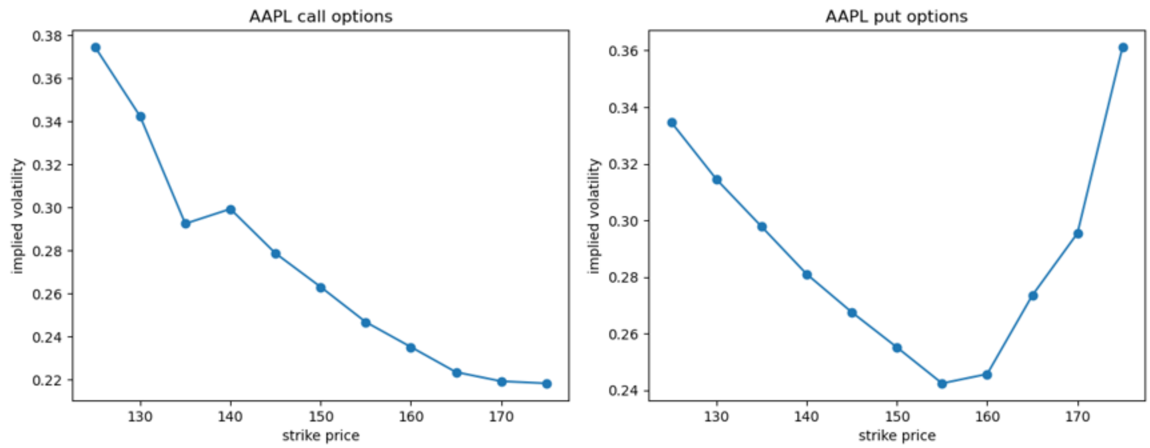

Figure 2 relationship between implied volatility and strike price

Problem 3

I used the general Black-Scholes model to calculate portfolio value over a range of underlying values from \$100 to \$200.

For Straddle, the strike price for both the call and put options is \$150. So when the underlying price is below \$150, the put option is in the money. When the underlying price is above \$150, the call option is in the money. Therefore, **Straddle decreases the risk**.

For SynLong, we will make a profit when the underlying price is above \$150 and get losses when the underlying price is below \$150. Because the buyer of the put option will gain money from us when the underlying price is less than \$150. Hence, **SynLong increases the risk**.

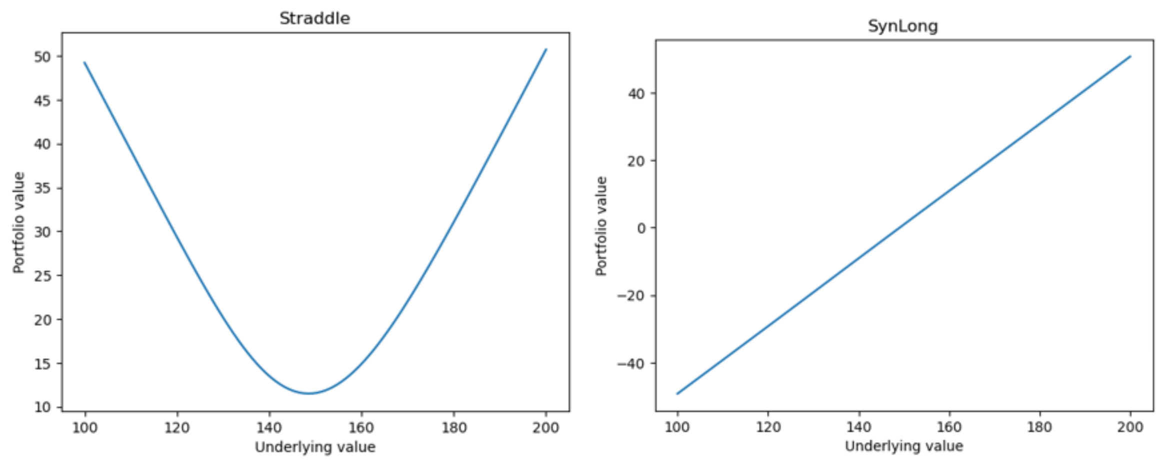

Figure 3 Straddle & SynLong: portfolio value

For CallSpread, when the underlying price is below \$150, both call options are out of the money and will not be executed. When the underlying price is between \$150 and \$160, the option we long is in the money, so we can make a profit. When the underlying price is above \$160, both options are in the money, so our **profit will have a limit of \$10**.

For PutSpread, which is similar to CallSpread, when the underlying price is above \$150, none of the put options will be executed. When the underlying price is between \$140 and \$150, the put option we long is in the money, so we can make a profit. When the underlying price is below \$140, both options are in the money, so our **profit has a limit of \$10**.

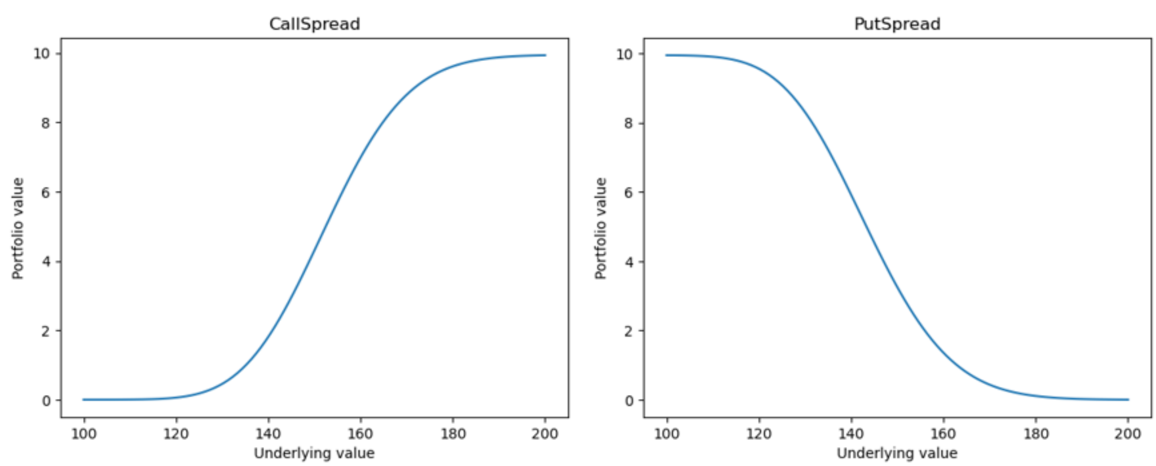

Figure 4 CallSpread & PutSpread: portfolio value

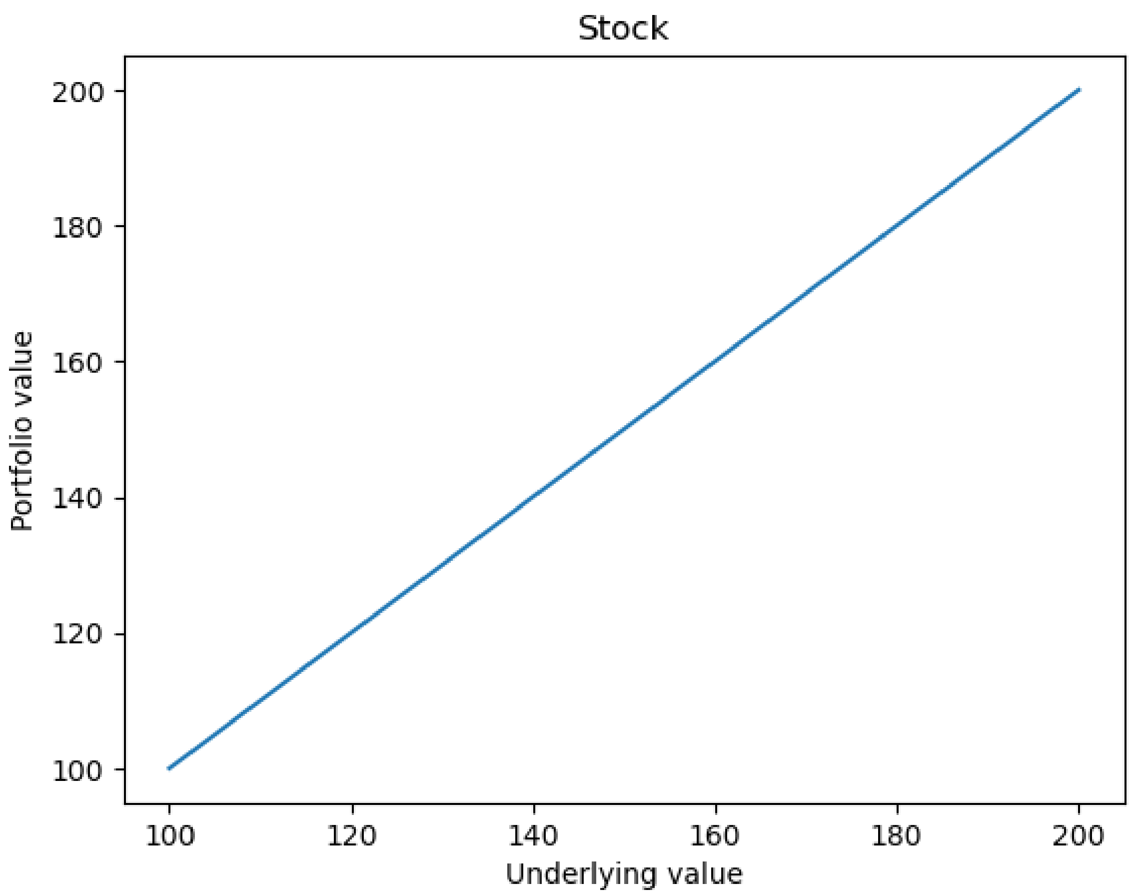

Figure 5 Stock AAPL: portfolio value

For Call, it is in the money when the underlying price is above $150. For Put, it is in the money when the underlying price is below $150. For options, the loss has a limit while the profit does not.

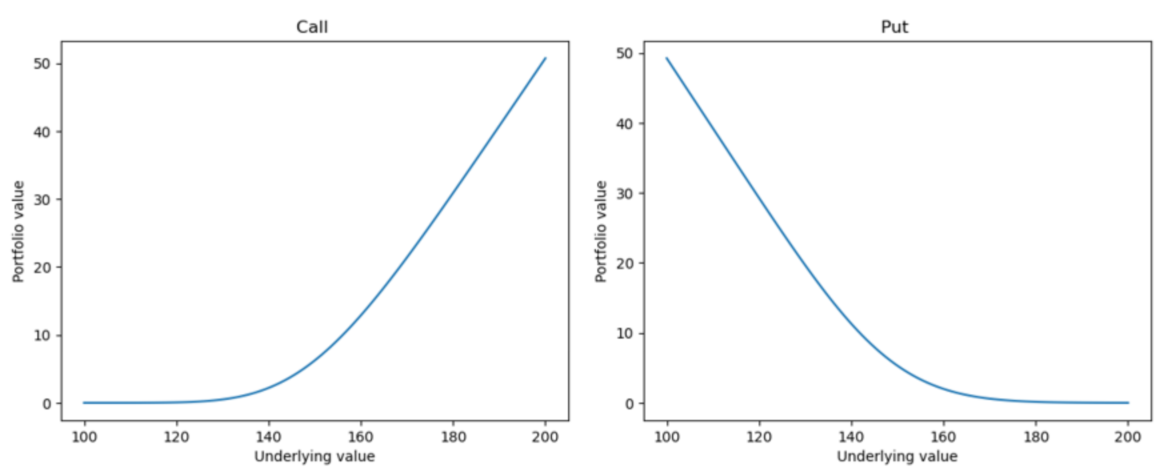

Figure 6 Call & Put: portfolio value

For CoveredCall, according to **Put Call Parity**, longing a stock and shorting a call is equivalent to shorting a put. So, the portfolio value of CoveredCall is the reverse of Put (from Figure 6). The sum of CoveredCall and Put will always be the present value of the strike price. For ProtectedPut, longing a stock and a put is equivalent to longing a call. So, the portfolio value of ProtectedPut has the same shape as Call (from Figure 6). The difference between ProtectedPut and Call will always be the present value of the strike price.

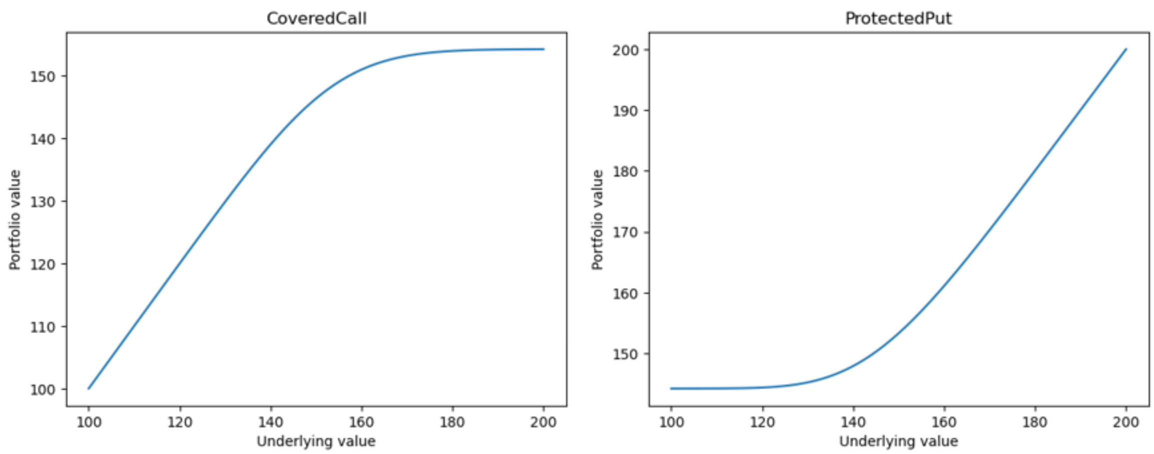

Figure 7 CoveredCall & ProtectedPut: portfolio value

To calculate the average PL, VaR and ES, I fitted the AAPL returns with AR(1) model and simulated the AAPL underlying prices 10 days ahead. From Table 1, the results align with the analysis above.

For Straddle, VaR and ES are small, meaning a small risk. For SynLong, VaR and ES are large, showing a greater risk.

The average profit or loss of CoveredCall is approximately the opposite of that of Put, since buying a CoveredCall equals selling a Put. Also, the average profit or loss of ProtectedPut is similar to that of Call, because buying a ProtectedPut equals buying a Call.

Table 1 PL mean, VaR, and ES for portfolios

Portfolio	PL mean	VaR	ES
Straddle	1.5399	1.3797	1.3877
SynLong	-0.0292	16.1957	20.0312
CallSpread	-0.1029	3.8852	4.1873
PutSpread	0.3060	2.6282	2.8017
Stock	0.1742	15.9536	19.7661
Call	0.7554	6.0319	6.3690
Put	0.7845	4.3645	4.5891
CoveredCall	-0.7139	12.1403	15.8338
ProtectedPut	0.8338	8.0618	8.6943