FE 621- HW1 M.Furkan Isik

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[1]:
```python
import numpy as np
import datetime as dt
import pandas as pd
import yfinance as yf
from scipy.stats import norm
from datetime import datetime
import time
import matplotlib.pyplot as plt
import math as math
```

0.1 Part1

Creating a function to import both option data and equity data

- Finding the type of option from the option name
- Creating organized data frame

[2]:
```python
# Importing option chain from yahoo finance, and organizing the dataframe

def get_optionchain(inpt,exprdt):

# expiration date format should be like this "2020-03-12"


    stock=yf.Ticker(inpt)


    opt=stock.option_chain(exprdt)


    call=opt.calls

    put=opt.puts

    option_chain=call.append(put)
```

```
    a=option_chain.drop(["lastTradeDate","change","percentChange","volume","openInterest","inTheMoney","contra

    a["Expiration Date"]=exprdt

    #a.columns(["Option Name",])


    a.columns=['Option Name', 'Strike',"Last Price","Bid","Ask","Implied Volatility","Expiration Date"]

    a.reset_index(drop=True,inplace=True)



    # Loop to assign P or C values depending on the type of the option
    for i,j in a.iterrows():

        if j["Option Name"][-9]=="P":


            a.loc[i,"Type"]="P"




        elif j["Option Name"][-9]=="C":


            a.loc[i,"Type"]="C"






    a = a[['Option Name',"Expiration Date","Type",'Strike',"Bid","Ask","Last Price","Implied Volatility"]]

    #a=a.drop(["index"],axis=1)


    #a=a.reset_index()
```

```python
    a.sort_values(by=['Strike'], inplace=True, ascending=True)



    return a
```

AMZN option chain with different maturities

[4]:
```python
# AMZN option and stock data


a1=get_optionchain("AMZN",exprdt="2021-03-05")
a2=get_optionchain("AMZN",exprdt="2021-03-26")
a3=get_optionchain("AMZN",exprdt="2021-04-16")


AMZN_opt1=a1.append(a2).append(a3)

AMZN_opt1=AMZN_opt1.reset_index()

AMZN_opt1


# AMZN Stock price 3112
```

[4]:
```
      index          Option Name Expiration Date Type  Strike      Bid  \
0         0  AMZN210305C01910000      2021-03-05    C  1910.0  1197.00
1       236  AMZN210305P01910000      2021-03-05    P  1910.0     0.00
2         1  AMZN210305C01920000      2021-03-05    C  1920.0  1182.65
3       237  AMZN210305P01920000      2021-03-05    P  1920.0     0.01
4       238  AMZN210305P01930000      2021-03-05    P  1930.0     0.01
…      …                   …              …   …    …       …
1149    338  AMZN210416P05200000      2021-04-16    P  5200.0  2088.80
1150    339  AMZN210416P05250000      2021-04-16    P  5250.0  2136.25
1151    163  AMZN210416C05250000      2021-04-16    C  5250.0     0.06
1152    164  AMZN210416C05300000      2021-04-16    C  5300.0     0.10
1153    340  AMZN210416P05300000      2021-04-16    P  5300.0  2189.25

          Ask  Last Price  Implied Volatility
0     1203.60     1187.12            1.908936
1        0.01        0.06            1.093755
2     1186.65     1165.07            0.000010
3        0.24        0.06            1.353519
4        0.24        0.33            1.339847
…        …          …                 …
1149  2095.20     2113.00            0.629063
```

```
1150  2145.40     1995.50           0.607365
1151     0.80        0.66           0.506841
1152     0.34        0.59           0.504155
1153  2197.35     1945.20           0.676242

[1154 rows x 9 columns]
```

SPY option chain with different maturities

[6]:
```python
# SPY option and stock data


s1=get_optionchain("SPY",exprdt="2021-03-05")
s2=get_optionchain("SPY",exprdt="2021-03-26")
s3=get_optionchain("SPY",exprdt="2021-04-16")


SPY_opt1=s1.append(s2).append(s3)

SPY_opt1=SPY_opt1.reset_index()

SPY_opt1


# SPY  price 388.01
```

[6]:
```
     index         Option Name Expiration Date Type  Strike     Bid     Ask  \
0        0  SPY210305C00190000      2021-03-05    C   190.0  196.90  197.65
1      131  SPY210305P00190000      2021-03-05    P   190.0    0.00    0.01
2      132  SPY210305P00195000      2021-03-05    P   195.0    0.00    0.01
3        1  SPY210305C00195000      2021-03-05    C   195.0  191.88  192.59
4      133  SPY210305P00200000      2021-03-05    P   200.0    0.00    0.01
..     …                  …             …   …      …     …
853    381  SPY210416P00500000      2021-04-16    P   500.0  117.65  118.42
854    185  SPY210416C00505000      2021-04-16    C   505.0    0.01    0.02
855    186  SPY210416C00510000      2021-04-16    C   510.0    0.00    0.00
856    187  SPY210416C00515000      2021-04-16    C   515.0    0.01    0.02
857    382  SPY210416P00515000      2021-04-16    P   515.0  128.47  129.33

     Last Price  Implied Volatility
0        201.28            0.000010
1          0.01            1.812501
2          0.01            1.750001
3        186.84            0.000010
4          0.01            1.687502
..         …                 …
853      132.88            0.616093
```

```
854         0.02             0.251961
855         0.01             0.125009
856         0.02             0.267585
857       126.33             0.520635

[858 rows x 9 columns]
```

VIX option chain with different maturities

[8]:

```python
# VIX option and stock data


v1=get_optionchain("^VIX",exprdt="2021-03-10")
v2=get_optionchain("^VIX",exprdt="2021-03-24")
v3=get_optionchain("^VIX",exprdt="2021-04-21")


VIX_opt1=v1.append(v2).append(v3)

VIX_opt1=VIX_opt1.reset_index()

VIX_opt1


# VIX value is 23.76
```

[8]:

```
     index         Option Name Expiration Date Type  Strike  Bid   Ask  \
0       29  VIXW210310P00012000      2021-03-10    P    12.0  NaN  0.00
1       30  VIXW210310P00014000      2021-03-10    P    14.0  0.0  0.03
2        0  VIXW210310C00015000      2021-03-10    C    15.0  8.6 10.37
3       31  VIXW210310P00015000      2021-03-10    P    15.0  0.0  0.05
4        1  VIXW210310C00016000      2021-03-10    C    16.0  7.5  9.28
..     …                   …            …   …     …   …     …
179     80   VIX210421P00130000      2021-04-21    P   130.0  0.0  0.00
180     43   VIX210421C00140000      2021-04-21    C   140.0  0.0  0.10
181     81   VIX210421P00140000      2021-04-21    P   140.0  0.0  0.00
182     44   VIX210421C00150000      2021-04-21    C   150.0  0.0  0.10
183     82   VIX210421P00150000      2021-04-21    P   150.0  0.0  0.00

     Last Price  Implied Volatility
0          0.02            0.500005
1          0.03            1.375003
2         11.14            2.796878
3          0.13            1.312503
4          9.80            2.382817
..          …                  …
179      103.70            0.000010
```

```
180        0.10             1.789064
181      113.69             0.000010
182        0.05             1.843751
183      124.60             0.000010

[184 rows x 9 columns]
```

0.1.1 Part1.3

AMZN is the ticker name of Amazon.Inc traded on Nasdaq.

SPY is well diversified basket of assets. it is consisted of the stocks in S&P 500 stocks The aim is to produce an investment vehicle that replicates S&P500 index's return

VIX is CBOE volatility index, real time market index representing the markets expectation for upcoming 30days

Option symbol is created by ticker of the equity, last two digit of the expiration date

two digits of the expiration month and two digits of expiration date, then type of the Call C or P

and lastly strike price of the option. Hence, we can determine the option expiration from the symbol.

For example, AMZN210226C01800000, This is a option of Amazon, expiration date: 2021-02-26. It is a call option and the strike price is 1800

AMZN Stock price 3112

SPY price 388.01

VIX value is 23.76

risk free rate=0.0008

0.2 Part 2

0.2.1 Blackscholes

[ ]:
```
## Blackscholes function to calulate option price

# S= Stock Price

# K= Strike Price

# t= Expiration Date

# sig= Volatility

# optype= Type

# r= risk free interest rate
```

```python
def blackscholes(S,K,t,optype,sig,r=0.0008):

    d1= (np.log(S/K)+(r+sig**2/2)*t)/(sig*np.sqrt(t))

    d2= d1-sig*np.sqrt(t)

    call_price=norm.cdf(d1,0,1)*S-  norm.cdf(d2,0,1)*K*np.exp(-r*t)

    put_price = K* np.exp(-r*t)* norm.cdf(-d2,0,1) -  S* norm.cdf(-d1,0,1)

    if optype== "C":

        return call_price

    elif optype=="P":

        return put_price
```

Implementing blackscholes for Amazon

[11]:
```python
# Implementing blackscholes for Amazon

blackscholes(S=3112,K=5250,t=46/365,optype="C",sig=0.2)
```

[11]: 3.3532187533524453e-12

Implementing blackscholes for SPY

[12]:
```python
# Implementing blackscholes for SPY

blackscholes(S=388,K=515,t=46/365,optype="P",sig=0.2)
```

[12]: 126.94831967356708

0.2.2 Bisection Method

[87]:
```python
# another bisection function compatible with apply function


def bisection(row):

    S=3140
    K=row["Strike"]
    optype=row["Type"]
```

```
today = datetime.today()
exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
t=(exp-today).days



avr_price=(row["Bid"]+row["Ask"])/2



a= 0.01

b=1





f_b=blackscholes(S,K,t,optype,b)-avr_price

f_a=blackscholes(S,K,t,optype,a)-avr_price

count=0

while b-a>0.01:


        count+=1

        if count>1000:

            break





        c=a+b/2

        f_c=blackscholes(S,K,t,optype,c)-avr_price

        f_b=blackscholes(S,K,t,optype,b)-avr_price

        f_a=blackscholes(S,K,t,optype,a)-avr_price
```

```
            if f_c<0.01:

                break


            if f_c*f_b<0:

                a=c



            elif f_c*f_a<0:


                b=c





    return c
```

[190]:
```
# Creating a small dataframe of AMAZON

amzn=AMZN_opt1.loc[477:570]
amzn
```

[190]:
```
     index          Option Name Expiration Date Type  Strike     Bid     Ask  \
477    164  AMZN210326P01870000      2021-03-26    P  1870.0    0.40    1.29
478    165  AMZN210326P01890000      2021-03-26    P  1890.0    0.42    1.37
479    166  AMZN210326P01920000      2021-03-26    P  1920.0    0.56    1.48
480    167  AMZN210326P01950000      2021-03-26    P  1950.0    0.69    1.60
481    168  AMZN210326P01970000      2021-03-26    P  1970.0    0.70    1.48
..     …                   …             …   …       …      …       …
566     25  AMZN210326C02780000      2021-03-26    C  2780.0  341.50  351.50
567    228  AMZN210326P02790000      2021-03-26    P  2790.0   17.80   18.45
568     26  AMZN210326C02790000      2021-03-26    C  2790.0  332.50  342.50
569    229  AMZN210326P02800000      2021-03-26    P  2800.0   18.65   19.40
570     27  AMZN210326C02800000      2021-03-26    C  2800.0  326.95  332.30

     Last Price  Implied Volatility
```

```
477        1.80            0.750491
478        1.70            0.740725
479        1.00            0.730227
480        1.55            0.718509
481        1.43            0.700076
..          …                …
566      326.88            0.379836
567       29.50            0.362128
568      318.20            0.377066
569       18.20            0.359259
570      317.30            0.367270

[94 rows x 9 columns]
```

[191]:
```python
# example using bisection with apply function
amzn_vol=amzn.apply(lambda row: bisection(row),axis=1)
amzn_vol
```

[191]:
```
477    0.035313
478    0.035313
479    0.035313
480    0.035313
481    0.035313
         …
566    0.510000
567    0.021914
568    0.510000
569    0.021914
570    0.510000
Length: 94, dtype: float64
```

Bisection Method Implementation for AMZN

[192]:
```python
amzn_vol=amzn_vol.to_frame()

amzn_vol.columns=["Computed Implied Vol"]


amzn_vol
```

[192]:
```
     Computed Implied Vol
477              0.035313
478              0.035313
479              0.035313
480              0.035313
481              0.035313
..                    …
```

```
566             0.510000
567             0.021914
568             0.510000
569             0.021914
570             0.510000

[94 rows x 1 columns]
```

[146]:
```python
# Creating a small dataframe of SPY

spy=SPY_opt1.loc[477:570]
spy
```

[146]:
```
     index         Option Name Expiration Date Type  Strike     Bid     Ask  \
477    189  SPY210416P00170000      2021-04-16    P   170.0    0.05    0.06
478      1  SPY210416C00175000      2021-04-16    C   175.0  199.35  200.23
479    190  SPY210416P00175000      2021-04-16    P   175.0    0.06    0.07
480    191  SPY210416P00180000      2021-04-16    P   180.0    0.06    0.08
481      2  SPY210416C00180000      2021-04-16    C   180.0  206.74  207.63
..     …                   …             …   …       …      …
566     40  SPY210416C00300000      2021-04-16    C   300.0   87.44   87.89
567    239  SPY210416P00300000      2021-04-16    P   300.0    0.88    0.90
568     41  SPY210416C00301000      2021-04-16    C   301.0   86.74   87.19
569    240  SPY210416P00301000      2021-04-16    P   301.0    0.89    0.91
570     42  SPY210416C00302000      2021-04-16    C   302.0   85.62   86.50

     Last Price  Implied Volatility
477        0.10            0.818361
478      195.70            0.000010
479        0.07            0.804689
480        0.06            0.783205
481      194.00            0.000010
..          …                   …
566       85.84            0.000010
567        0.88            0.417975
568       82.74            0.315437
569        0.87            0.414435
570       86.72            0.364752

[94 rows x 9 columns]
```

[147]:
```python
spy_vol=spy.apply(lambda row: bisection(row),axis=1)
spy_vol
```

[147]:
```
477    0.08125
478    0.51000
479    0.08125
```

```
480    0.08125
481    0.51000
         …
566    0.51000
567    0.08125
568    0.51000
569    0.08125
570    0.51000
Length: 94, dtype: float64
```

Bisection Method Implementation for SPY

[148]:
```
spy_vol=spy_vol.to_frame()

spy_vol.columns=["Computed Implied Vol"]
spy_vol
```

[148]:
```
     Computed Implied Vol
477               0.08125
478               0.51000
479               0.08125
480               0.08125
481               0.51000
..                    …
566               0.51000
567               0.08125
568               0.51000
569               0.08125
570               0.51000

[94 rows x 1 columns]
```

0.2.3 Secant Method

[157]:
```
def secant(row):



    S=3140
    K=row["Strike"]
    optype=row["Type"]




    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days

```

```
avr_price=(row["Bid"]+row["Ask"])/2


a= 0.01

b=1



f_b=blackscholes(S,K,t,optype,b)-avr_price

f_a=blackscholes(S,K,t,optype,a)-avr_price

count=0


#if f_b*f_a<0:

while b-a>0.001:

        count+=1

        if count>800:

            break




        c=(a*f_b-b*f_a)/(f_b-f_a)

        f_c=blackscholes(S,K,t,optype,c)-avr_price

        f_b=blackscholes(S,K,t,optype,b)-avr_price

        f_a=blackscholes(S,K,t,optype,a)-avr_price
```

```
            if f_c<0.01:

                break


            if f_c*f_b<0:

                a=c


            elif f_c*f_a<0:


                b=c


    return c

```

Secant Method Implementation for AMZN

[ ]:
```
amzn_vol_secant=amzn.apply(lambda row: secant(row),axis=1)

amzn_vol_secant
```

[159]:
```
amzn_vol_secant=amzn_vol_secant.to_frame()
amzn_vol_secant.columns=["Computed Implied Vol"]
amzn_vol_secant
```

[159]:
```
     Computed Implied Vol
477              0.010465
478              0.010487
479              0.010546
480              0.010604
481              0.010569
..                    …
566             -0.014500
567              0.016619
568             -0.014123
569              0.016914
570             -0.013339

[94 rows x 1 columns]
```

Measuring the time difference between biscection method and secant method - As it can be seen below, it is obvious that secant method take much less time to find the root

[161]:

```python
# Measuring time spent on bisection method

start = time.time()

amzn_vol=amzn.apply(lambda row: bisection(row),axis=1)
#amzn_vol


end = time.time()

print(end-start)
```

```
32.12326979637146
```

[162]:

```python
# Measuring time spent on secant method

start = time.time()

amzn_vol=amzn.apply(lambda row: secant(row),axis=1)
#amzn_vol


end = time.time()

print(end-start)
```

```
0.4698491096496582
```

[ ]:

```python
amzn["Bisection vol"]=amzn_vol
amzn
```

[194]:

```python
amzn["Secant Vol"]=amzn_vol_secant
amzn
```

```
<ipython-input-194-47a7e7010b5f>:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-
docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy
  amzn["Secant Vol"]=amzn_vol_secant
```

[194]:

	index	Option Name	Expiration Date	Type	Strike	Bid	Ask	\
477	164	AMZN210326P01870000	2021-03-26	P	1870.0	0.40	1.29	
478	165	AMZN210326P01890000	2021-03-26	P	1890.0	0.42	1.37	
479	166	AMZN210326P01920000	2021-03-26	P	1920.0	0.56	1.48	
480	167	AMZN210326P01950000	2021-03-26	P	1950.0	0.69	1.60	
481	168	AMZN210326P01970000	2021-03-26	P	1970.0	0.70	1.48	

```
..      …                    …              …   …      …      …       …
566     25   AMZN210326C02780000      2021-03-26    C   2780.0  341.50  351.50
567    228   AMZN210326P02790000      2021-03-26    P   2790.0   17.80   18.45
568     26   AMZN210326C02790000      2021-03-26    C   2790.0  332.50  342.50
569    229   AMZN210326P02800000      2021-03-26    P   2800.0   18.65   19.40
570     27   AMZN210326C02800000      2021-03-26    C   2800.0  326.95  332.30

     Last Price  Implied Volatility  Bisection vol  Secant Vol
477        1.80            0.750491       0.035313    0.010465
478        1.70            0.740725       0.035313    0.010487
479        1.00            0.730227       0.035313    0.010546
480        1.55            0.718509       0.035313    0.010604
481        1.43            0.700076       0.035313    0.010569
..          …                 …             …           …
566      326.88            0.379836       0.510000   -0.014500
567       29.50            0.362128       0.021914    0.016619
568      318.20            0.377066       0.510000   -0.014123
569       18.20            0.359259       0.021914    0.016914
570      317.30            0.367270       0.510000   -0.013339

[94 rows x 11 columns]
```

0.2.4 Put Call parity

[197]:
```
def put_call_parity(row):

    S=3140
    K=row["Strike"]
    opttype=row["Type"]
    price=row["Last Price"]

    r=0.0008



    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days





    if opttype=="C":


        Calculated_Put= price-S+K*np.exp(-r*t)
```

```python
        row["Calculated Put"]=Calculated_Put


    elif opttype=="P":

        Calculated_Call=S+price- K*np.exp(-r*t)

        #print(Calculated_Call)

        row["Calculated Call"]=Calculated_Call






    return row
```

- From the table we can see that calculated price of the option using put call parity is vey close to the bid and ask given in the table

[199]:
```python
AMZN_opt1.apply(lambda row: put_call_parity(row),axis=1 )
```

[199]:

```
          Ask      Bid  Calculated Call  Calculated Put Expiration Date  \
0     1203.60  1197.00              NaN      -47.458504      2021-03-05
1        0.01     0.00      1234.638504             NaN      2021-03-05
2     1186.65  1182.65              NaN      -59.532475      2021-03-05
3        0.24     0.01      1224.662475             NaN      2021-03-05
4        0.24     0.01      1214.956446             NaN      2021-03-05
…         …        …                …               …              …
1149  2095.20  2088.80       236.870474             NaN      2021-04-16
1150  2145.40  2136.25        71.138459             NaN      2021-04-16
1151     0.80     0.06              NaN     1925.021541      2021-04-16
1152     0.34     0.10              NaN     1973.183555      2021-04-16
1153  2197.35  2189.25       -27.393555             NaN      2021-04-16

      Implied Volatility  Last Price         Option Name  Strike Type  index
0               1.908936     1187.12  AMZN210305C01910000  1910.0    C      0
1               1.093755        0.06  AMZN210305P01910000  1910.0    P    236
2               0.000010     1165.07  AMZN210305C01920000  1920.0    C      1
3               1.353519        0.06  AMZN210305P01920000  1920.0    P    237
4               1.339847        0.33  AMZN210305P01930000  1930.0    P    238
…                    …           …                   …      …    …      …
1149            0.629063     2113.00  AMZN210416P05200000  5200.0    P    338
```

```
1150              0.607365     1995.50  AMZN210416P05250000  5250.0    P    339
1151              0.506841        0.66  AMZN210416C05250000  5250.0    C    163
1152              0.504155        0.59  AMZN210416C05300000  5300.0    C    164
1153              0.676242     1945.20  AMZN210416P05300000  5300.0    P    340

[1154 rows x 11 columns]
```

[200]:
```
AMZN_calls=AMZN_opt1[AMZN_opt1["Type"]=="C"]
```

[201]:
```
cal_call=AMZN_opt1.apply(lambda row: put_call_parity(row),axis=1 )[["Option␣
 ↪Name","Expiration Date","Calculated Call"]].dropna()
cal_call
```

[201]:
```
              Option Name Expiration Date  Calculated Call
1     AMZN210305P01910000      2021-03-05      1234.638504
3     AMZN210305P01920000      2021-03-05      1224.662475
4     AMZN210305P01930000      2021-03-05      1214.956446
5     AMZN210305P01950000      2021-03-05      1194.864388
7     AMZN210305P01960000      2021-03-05      1184.748360
…                     …             …              …
1145  AMZN210416P05100000      2021-04-16         6.734503
1147  AMZN210416P05150000      2021-04-16        52.752489
1149  AMZN210416P05200000      2021-04-16       236.870474
1150  AMZN210416P05250000      2021-04-16        71.138459
1153  AMZN210416P05300000      2021-04-16       -27.393555

[589 rows x 3 columns]
```

[202]:
```
AMZN_calls=AMZN_opt1[AMZN_opt1["Type"]=="C"]
AMZN_calls[["Expiration Date","Last Price"]]
```

[202]:
```
     Expiration Date  Last Price
0         2021-03-05     1187.12
2         2021-03-05     1165.07
6         2021-03-05     1091.07
8         2021-03-05     1149.16
9         2021-03-05     1086.35
…                …          …
1144      2021-04-16        0.74
1146      2021-04-16        0.64
1148      2021-04-16        0.63
1151      2021-04-16        0.66
1152      2021-04-16        0.59

[565 rows x 2 columns]
```

[204]:
```
cal_put=AMZN_opt1.apply(lambda row: put_call_parity(row),axis=1 )[["Option␣
↪Name","Expiration Date","Calculated Put"]].dropna()
cal_put
```

[204]:
```
              Option Name Expiration Date  Calculated Put
0     AMZN210305C01910000      2021-03-05      -47.458504
2     AMZN210305C01920000      2021-03-05      -59.532475
6     AMZN210305C01950000      2021-03-05     -103.604388
8     AMZN210305C01960000      2021-03-05      -35.538360
9     AMZN210305C01980000      2021-03-05      -78.396302
…                     …             …             …
1144  AMZN210416C05100000      2021-04-16     1780.405497
1146  AMZN210416C05150000      2021-04-16     1828.537511
1148  AMZN210416C05200000      2021-04-16     1876.759526
1151  AMZN210416C05250000      2021-04-16     1925.021541
1152  AMZN210416C05300000      2021-04-16     1973.183555

[565 rows x 3 columns]
```

[205]:
```
AMZN_puts=AMZN_opt1[AMZN_opt1["Type"]=="P"]
az=AMZN_puts[["Expiration Date","Last Price"]]
az
```

[205]:
```
     Expiration Date  Last Price
1         2021-03-05        0.06
3         2021-03-05        0.06
4         2021-03-05        0.33
5         2021-03-05        0.19
7         2021-03-05        0.05
…              …          …
1145      2021-04-16     1786.40
1147      2021-04-16     1880.65
1149      2021-04-16     2113.00
1150      2021-04-16     1995.50
1153      2021-04-16     1945.20

[589 rows x 2 columns]
```

0.2.5 Plotting

[207]:
```
AMZN_opt1.loc[(AMZN_opt1["Type"]=="C")&(AMZN_opt1["Expiration␣
↪Date"]=="2021-03-05")]
```

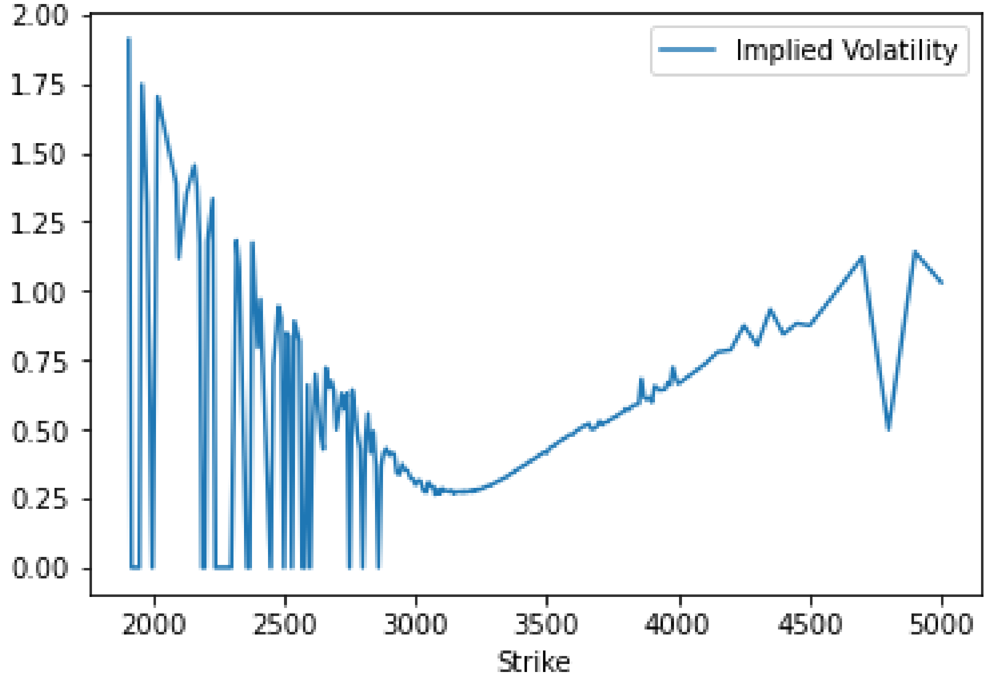
[207]:
```
     index          Option Name Expiration Date Type  Strike      Bid  \
0        0  AMZN210305C01910000      2021-03-05    C  1910.0  1197.00
2        1  AMZN210305C01920000      2021-03-05    C  1920.0  1182.65
6        2  AMZN210305C01950000      2021-03-05    C  1950.0  1154.20
```

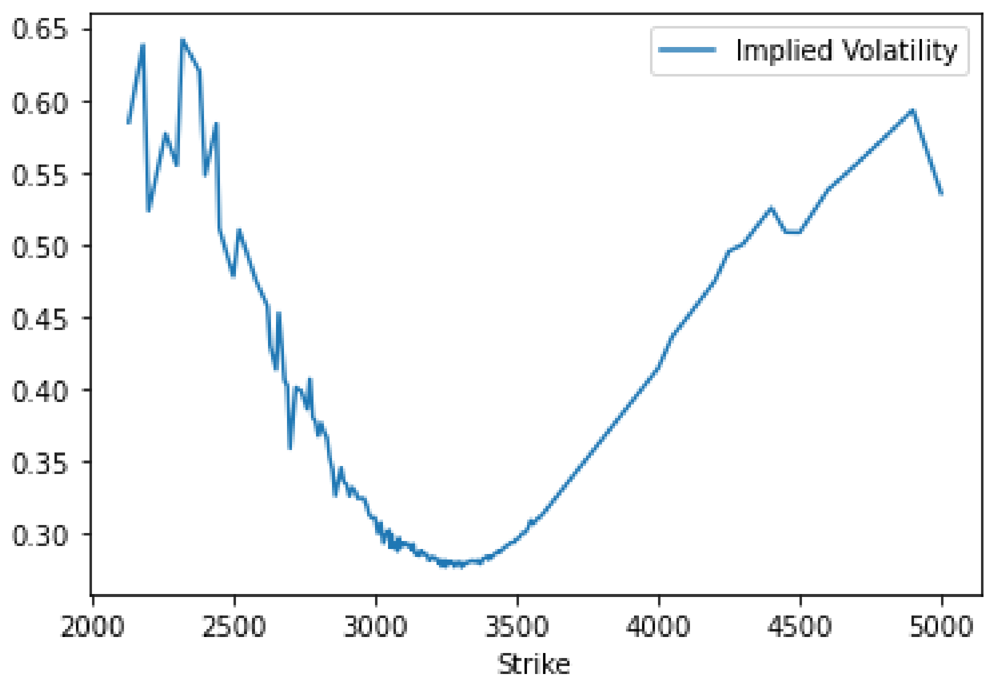
```
8        3  AMZN210305C01960000      2021-03-05    C  1960.0  1147.00
9        4  AMZN210305C01980000      2021-03-05    C  1980.0  1127.80
..     …                  …              …   …      …       …
469    231  AMZN210305C04600000      2021-03-05    C  4600.0     0.00
470    232  AMZN210305C04700000      2021-03-05    C  4700.0     0.00
472    233  AMZN210305C04800000      2021-03-05    C  4800.0     0.00
475    234  AMZN210305C04900000      2021-03-05    C  4900.0     0.00
476    235  AMZN210305C05000000      2021-03-05    C  5000.0     0.01

         Ask  Last Price  Implied Volatility
0    1203.60     1187.12            1.908936
2    1186.65     1165.07            0.000010
6    1159.10     1091.07            0.000010
8    1152.90     1149.16            1.747560
9    1131.00     1086.35            1.312503
..       …          …                  …
469     0.09        0.40            0.996094
470     0.23        0.01            1.122075
472     0.00        0.01            0.500005
475     0.09        0.01            1.140629
476     0.00        0.01            1.031255

[236 rows x 9 columns]
```

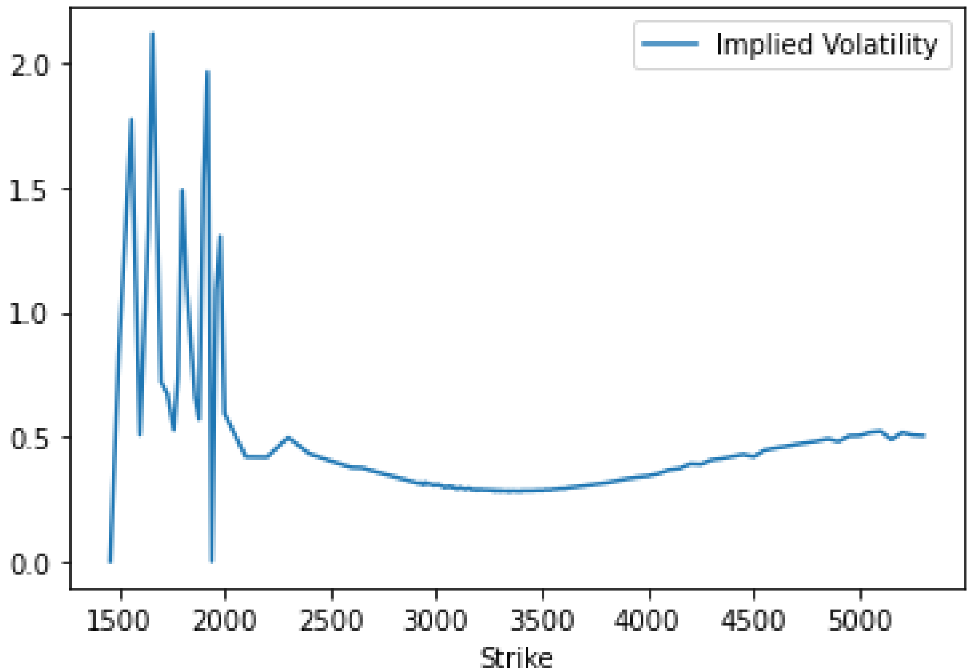
- According to plots below, it could be say that there is a smile shape in the plot.
- In some place of the graph data is randomly scatter, it might be due to missing data issues

[211]:
```
## Plotting


#plt.plot(AMZN_opt1.loc[(AMZN_opt1["Type"]=="C")&(AMZN_opt1["Expiration␣
 ↪Date"]=="2021-03-26")])
a=AMZN_opt1.loc[(AMZN_opt1["Type"]=="C")&(AMZN_opt1["Expiration␣
 ↪Date"]=="2021-03-05")]
b=AMZN_opt1.loc[(AMZN_opt1["Type"]=="C")&(AMZN_opt1["Expiration␣
 ↪Date"]=="2021-03-26")]
c=AMZN_opt1.loc[(AMZN_opt1["Type"]=="C")&(AMZN_opt1["Expiration␣
 ↪Date"]=="2021-04-16")]
#plt.plot(a[["Computed Vol","Strike"]],x="Strike",y="Computed Vol")

a.plot(x="Strike", y="Implied Volatility")

b.plot(x="Strike", y="Implied Volatility")

c.plot(x="Strike", y="Implied Volatility")
```

[211]: <matplotlib.axes._subplots.AxesSubplot at 0x7fedb9a7db80>


Implied Volatility
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
2000
2500
3000
3500
4000
4500
5000
Strike


Implied Volatility
0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
2000
2500
3000
3500
4000
4500
5000
Strike



0.2.6 Greeks

[212]:
```
### Greeks


def d(row):


    S=3140

    K=row["Strike"]

    r=0.0008

    sig=row["Implied Volatility"]


    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days


    d1= 1/(sig*np.sqrt(t))  * (np.log(S/K) + (r+ sig**2/2)*t)
```

```
    d2= d1- sig*np.sqrt(t)

    return d1,d2
```

[222]:
```
#delta calculation

def delta(row):



    S=3140

    K=row["Strike"]

    r=0.0008

    sig=row["Implied Volatility"]


    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days


    d1= 1/(sig*np.sqrt(t))  * (np.log(S/K) + (r+ sig**2/2)*t)



    if row["Type"]=="C":

        delta_call=norm.cdf(d1)

        return delta_call

    elif row["Type"]=="P":

        delta_put=norm.cdf(-d1)

        return delta_put
```

[ ]:
```
az=AMZN_opt1.iloc[700:710]
az
```

[270]:
```
amzn_delta=AMZN_opt1.apply(lambda row: delta(row),axis=1)



amzn_delta=amzn_delta.to_frame()

amzn_delta.columns=["delta"]

amzn_delta
```

[270]:

	delta
0	0.964405
1	0.112968
2	1.000000
3	0.083328
4	0.085172
…	…
1149	0.022808
1150	0.027439
1151	0.940550
1152	0.939050
1153	0.015358

[1154 rows x 1 columns]

[230]:
```
## Gamma

def gamma(row):



    S=3140

    K=row["Strike"]

    r=0.0008
```

```
    sig=row["Implied Volatility"]


    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days


    d1= 1/(sig*np.sqrt(t))  * (np.log(S/K) + (r+ sig**2/2)*t)

    d2= d1- sig*np.sqrt(t)



    gamma= K*np.exp(-r*t)*norm.pdf(d2)/(S**2*sig*np.sqrt(t))


    return(gamma)
```

[269]:

```
amzn_gamma=AMZN_opt1.apply(lambda row: gamma(row),axis=1)


amzn_gamma=amzn_gamma.to_frame()

amzn_gamma.columns=["gamma"]

amzn_gamma
```

[269]:

	gamma
0	0.000008
1	0.000032
2	0.000000
3	0.000021
4	0.000021
…	…
1149	0.000004
1150	0.000005
1151	0.000011
1152	0.000011
1153	0.000003

[1154 rows x 1 columns]

[239]:

```
## Theta


def theta(row):


    S=3140

    K=row["Strike"]

    r=0.0008

    sig=row["Implied Volatility"]


    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days


    d1= 1/(sig*np.sqrt(t))  * (np.log(S/K) + (r+ sig**2/2)*t)

    d2= d1- sig*np.sqrt(t)




    if row["Type"]=="C":

        theta_call= -S*sig*norm.pdf(d1)/(2*np.sqrt(t)) - r*K*np.exp(-r*t)*norm.
 ↪cdf(d2)

        return theta_call*100/365



    elif row["Type"]=="P":

        theta_put= - S*sig*norm.pdf(-d1)/(2*np.sqrt(t)) - r*K* np.
 ↪exp(-r*t)*norm.cdf(-d2)

        return theta_put*100/365
```

```
```

[240]:
```
amzn_theta=AMZN_opt1.apply(lambda row: theta(row),axis=1)


amzn_theta=amzn_theta.to_frame()

amzn_theta.columns=["theta"]

amzn_theta
```

[240]:
```
          theta
0    -37.168706
1    -52.371493
2     -0.419813
3    -51.880288
4    -52.205079
…           …
1149  -3.267377
1150  -3.553049
1151  -3.880027
1152  -3.935766
1153  -2.786511

[1154 rows x 1 columns]
```

[242]:
```
def vega(row):


    S=3140

    K=row["Strike"]

    r=0.0008



    sig=row["Implied Volatility"]


    today = datetime.today()
    exp=datetime.strptime(row["Expiration Date"],"%Y-%m-%d")
    t=(exp-today).days
```

```
    d1= 1/(sig*np.sqrt(t))  * (np.log(S/K) + (r+ sig**2/2)*t)


    vega= S*norm.pdf(d1)*np.sqrt(t)

    return vega/100
```

[271]:
```
amzn_vega=AMZN_opt1.apply(lambda row: vega(row),axis=1)


amzn_vega=amzn_vega.to_frame()

amzn_vega.columns=["vega"]

amzn_vega
```

[271]:

	vega
0	4.260940
1	10.423271
2	0.000000
3	8.337754
4	8.475828
…	…
1149	11.396816
1150	13.307181
1151	24.911445
1152	25.402135
1153	8.140373

[1154 rows x 1 columns]

[272]:
```
horizontal_stack = pd.concat([amzn_delta,amzn_gamma,amzn_vega, amzn_theta],␣
 ↪axis=1)
horizontal_stack
```

[272]:

	delta	gamma	vega	theta
0	0.964405	0.000008	4.260940	-37.168706
1	0.112968	0.000032	10.423271	-52.371493
2	1.000000	0.000000	0.000000	-0.419813
3	0.083328	0.000021	8.337754	-51.880288

```
4     0.085172  0.000021   8.475828 -52.205079
…         …         …          …          …
1149  0.022808  0.000004  11.396816  -3.267377
1150  0.027439  0.000005  13.307181  -3.553049
1151  0.940550  0.000011  24.911445  -3.880027
1152  0.939050  0.000011  25.402135  -3.935766
1153  0.015358  0.000003   8.140373  -2.786511

[1154 rows x 4 columns]
```

0.3 Part3

[244]:
```python
def f(x):

    if x==0:

        return 1

    else:

        return np.sin(x)/x




def trapezoidal(f,a,b,n):


    h=float(b-a)/n

    result=0.5*f(a)+0.5*f(b)



    for i in range(1,n):

        result+=f(a+i*h)


    result*=h

    return result
```

[254]:
```
trapezoidal(f,-1000000,1000000,n=130000)
```

[254]: 15.70796091749369

[247]:
```
def simpson(f,a,b,n):


    x=np.linspace(a,b,n+1)


    integral=0


    for i in range(len(x)-1):

        x1=x[i]

        x2=x[i+1]

        h=(x2-x1)/2

        summ= (h/3)*(f(x1)+4*f((x1+x2)/2)+f(x2))


        integral+=summ

        continue

    return integral
```

[255]:
```
simpson(f,-1000000,1000000,n=130000)
```

[255]: 7.330372340238341

- From the table below, it is obvious that error would become to small as n increases
- Trapezoidal is better for large numbers whereas Simpson's rule is much better in small numbers

[250]:
```
## Truncation error

def trunctrap_error(trapezoidal,a,b,n):
```

```
    df_func=[]

    df_error=[]

    n_steps=[]

    a=a

    b=b


    i=0
    while 2**i<n:

        func_result=trapezoidal(f,a,b,n=2**i)

        error_result=func_result- np.pi

        n_steps.append(2**i)

        df_func.append(func_result)

        df_error.append(error_result)

        i+=1


    df=pd.DataFrame({"n":n_steps,"result":df_func,"error":df_error})


    return df
```

[251]:

```
## Truncation for trapezoidal

trunctrap_error(trapezoidal,-10**6,10**6,2**21)
```

[251]:

	n	result	error
0	1	-0.699987	-3.841580
1	2	999999.650006	999996.508414
2	4	500000.180666	499997.039073
3	8	249998.741156	249995.599563
4	16	125000.782187	124997.640595
5	32	62501.898891	62498.757298
6	64	31249.431008	31246.289416

```
7       128   15623.160000   15620.018407
8       256    7813.138512    7809.996920
9       512    3905.002313    3901.860721
10     1024    1950.932618    1947.791025
11     2048     977.035095     973.893502
12     4096     486.947222     483.805629
13     8192     241.903106     238.761513
14    16384     122.522087     119.380495
15    32768      59.690306      56.548713
16    65536      28.274393      25.132801
17   131072      15.707960      12.566367
18   262144       9.424769       6.283176
19   524288       3.141594       0.000001
20  1048576       3.141591      -0.000001
```

[252]:

```
## Truncation for simpson

def truncsim_error(simpson,a,b,n):

    df_func=[]

    df_error=[]

    n_steps=[]

    a=a

    b=b


    i=0
    while 2**i<n:

        func_result=simpson(f,a,b,n=2**i)

        error_result=func_result- np.pi

        n_steps.append(2**i)

        df_func.append(func_result)

        df_error.append(error_result)

        i+=1


    df=pd.DataFrame({"n":n_steps,"result":df_func,"error":df_error})
```

```
    return df
```

[253]:
```
truncsim_error(simpson,-10**6,10**6,2**21)
```

[253]:

	n	result	error
0	1	1.333333e+06	1.333330e+06
1	2	3.333337e+05	3.333305e+05
2	4	1.666649e+05	1.666618e+05
3	8	8.333480e+04	8.333165e+04
4	16	4.166894e+04	4.166580e+04
5	32	2.083194e+04	2.082880e+04
6	64	1.041440e+04	1.041126e+04
7	128	5.209798e+03	5.206656e+03
8	256	2.602290e+03	2.599149e+03
9	512	1.299576e+03	1.296434e+03
10	1024	6.524026e+02	6.492610e+02
11	2048	3.235846e+02	3.204430e+02
12	4096	1.602217e+02	1.570801e+02
13	8192	8.272841e+01	7.958682e+01
14	16384	3.874638e+01	3.560479e+01
15	32768	1.780242e+01	1.466083e+01
16	65536	1.151915e+01	8.377556e+00
17	131072	7.330372e+00	4.188779e+00
18	262144	1.047202e+00	-2.094390e+00
19	524288	3.141591e+00	-2.107140e-06
20	1048576	3.141591e+00	-1.883143e-06

- Trapezoidal converges more faster than simpson rule, 15 and 20 respectively

[256]:
```
def convergence_trap(trapezoidal,a,b,n, epsilon = 10**-4):
    k=2

    a=a
    b=b

    while True:
        I_k = trapezoidal(f,a,b,n=(2**k)+1)
        I_k_1 = trapezoidal(f,a,b,n=(2**(k+1)) +1)
        error = abs(I_k_1 - I_k)
        if error<epsilon:
            df1 = pd.DataFrame({"Iterations":[k+1],"Ik":[I_k],"Ik+1":[I_k_1],␣
↪"Error":[error]})
            return df1
```

```
        k+=1
```

[257]:
```
convergence_trap(trapezoidal,-10**6,10**6,2**10, epsilon = 10**-4)
```

[257]:
```
   Iterations        Ik      Ik+1     Error
0          15 -3.141619 -3.141547  0.000072
```

[260]:
```
def convergence_simp(trapezoidal,a,b,n, epsilon = 10**-4):
    k=2

    a=a
    b=b

    while True:
        I_k = simpson(f,a,b,n=(2**k)+1)
        I_k_1 = simpson(f,a,b,n=(2**(k+1)) +1)
        error = abs(I_k_1 - I_k)
        if error<epsilon:
            df1 = pd.DataFrame({"Iterations":[k+1],"Ik":[I_k],"Ik+1":[I_k_1],␣
 ↪"Error":[error]})
            return df1
        k+=1
```

[261]:
```
convergence_simp(simpson,-10**6,10**6,2**10, epsilon = 10**-4)
```

[261]:
```
   Iterations        Ik      Ik+1         Error
0          20  3.141591  3.141591  2.239926e-07
```