FE 621-HW2 Report

March 14, 2021

1 Part1

FE 621 Assignment 2 Author: Muhammet Furkan Isik Date: 03/14/2021

1.0.1 Importing and Organising Data

[1]:
```
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 math
import matplotlib.pyplot as plt
```

[2]:
```
# 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
```

```python
    a["Expiration Date"]=exprdt


    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"]="put"




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


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




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

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



    return a
```

[3]:
```python
# example for the function above


a1=get_optionchain("AMZN",exprdt="2021-03-19")
a2=get_optionchain("AMZN",exprdt="2021-04-16")
a3=get_optionchain("AMZN",exprdt="2021-05-21")


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

```
AMZN_opt1=AMZN_opt1.reset_index(drop=True)

AMZN_opt1
```

[3]:

```
              Option Name Expiration Date  Type  Strike      Bid      Ask  \
0     AMZN210319C01460000      2021-03-19  call  1460.0  1624.20  1636.55
1     AMZN210319P01460000      2021-03-19   put  1460.0     0.01     0.02
2     AMZN210319P01480000      2021-03-19   put  1480.0     0.00     0.05
3     AMZN210319C01480000      2021-03-19  call  1480.0  1604.15  1616.55
4     AMZN210319P01500000      2021-03-19   put  1500.0     0.00     0.05
…                     …             …    …     …       …        …
997   AMZN210521C04700000      2021-05-21  call  4700.0     2.60     3.15
998   AMZN210521C04800000      2021-05-21  call  4800.0     2.08     2.60
999   AMZN210521C04900000      2021-05-21  call  4900.0     1.82     2.68
1000  AMZN210521C05000000      2021-05-21  call  5000.0     1.90     2.19
1001  AMZN210521P05000000      2021-05-21   put  5000.0  1901.20  1919.50

      Last Price  Implied Volatility
0        1676.15            2.247075
1           0.02            1.609377
2           0.07            1.632814
3        1604.39            2.202153
4           0.01            1.609377
…            …                 …
997         2.74            0.431707
998         2.60            0.438635
999         2.23            0.457678
1000        2.00            0.462774
1001     1996.50            0.565114

[1002 rows x 8 columns]
```

Subsetting only call options

[4]:

```
# Subsetting only call options

AMZN_calls=AMZN_opt1.loc[AMZN_opt1["Type"]=="call"].reset_index(drop=True)
AMZN_calls
```

[4]:

```
             Option Name Expiration Date  Type  Strike      Bid      Ask  \
0    AMZN210319C01460000      2021-03-19  call  1460.0  1624.20  1636.55
1    AMZN210319C01480000      2021-03-19  call  1480.0  1604.15  1616.55
2    AMZN210319C01500000      2021-03-19  call  1500.0  1588.00  1593.30
3    AMZN210319C01520000      2021-03-19  call  1520.0  1564.35  1576.70
4    AMZN210319C01540000      2021-03-19  call  1540.0  1770.70  1778.10
..                    …             …    …     …       …        …
```

```
484  AMZN210521C04600000      2021-05-21  call  4600.0     2.97     3.55
485  AMZN210521C04700000      2021-05-21  call  4700.0     2.60     3.15
486  AMZN210521C04800000      2021-05-21  call  4800.0     2.08     2.60
487  AMZN210521C04900000      2021-05-21  call  4900.0     1.82     2.68
488  AMZN210521C05000000      2021-05-21  call  5000.0     1.90     2.19

     Last Price  Implied Volatility
0       1676.15            2.247075
1       1604.39            2.202153
2       1617.10            2.237309
3       1597.30            2.171391
4       1682.65            6.910249
..          …                   …
484        3.05            0.419958
485        2.74            0.431707
486        2.60            0.438635
487        2.23            0.457678
488        2.00            0.462774

[489 rows x 8 columns]
```

Subsettin AMZN at the money calls for 3 different expiration date

[5]:
```python
# AMZN at the money calls for 3 different expiration date
AMZN_ATM_calls=AMZN_calls[(AMZN_calls["Strike"]>3000) &␣
↪(AMZN_calls["Strike"]<3180)].reset_index(drop=True)
#AMZN_ATM_calls

AMZN_ATM_calls=AMZN_ATM_calls.sort_values("Strike",ascending=True).
↪reset_index(drop=True)
AMZN_ATM_calls
```

[5]:
```
            Option Name Expiration Date  Type  Strike     Bid     Ask  \
0   AMZN210319C03010000      2021-03-19  call  3010.0  100.20  104.05
1   AMZN210521C03010000      2021-05-21  call  3010.0  223.35  226.80
2   AMZN210416C03010000      2021-04-16  call  3010.0  157.70  161.05
3   AMZN210416C03020000      2021-04-16  call  3020.0  151.30  154.85
4   AMZN210521C03020000      2021-05-21  call  3020.0  217.50  220.80
..                  …             …   …     …     …     …
62  AMZN210319C03165000      2021-03-19  call  3165.0   18.45   19.55
63  AMZN210416C03170000      2021-04-16  call  3170.0   73.95   76.20
64  AMZN210319C03170000      2021-03-19  call  3170.0   17.20   18.55
65  AMZN210521C03170000      2021-05-21  call  3170.0  141.20  143.70
66  AMZN210319C03175000      2021-03-19  call  3175.0   16.00   17.45

    Last Price  Implied Volatility
0       102.52            0.355689
```

```
1       208.45           0.348758
2       162.55           0.315269
3       153.35           0.314201
4       215.50           0.347491
..         …                …
62       19.60           0.301246
63       75.65           0.293662
64       17.70           0.303321
65      138.20           0.333892
66       16.65           0.304176

[67 rows x 8 columns]
```

1.0.2 Blackscholes

[6]:

```
## Blackscholes function to calulate option price

# S= Stock Price

# K= Strike Price

# t= Expiration Date

# sig= Volatility

# optype= Type

# r= risk free interest rate



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== "call":

        return call_price

    elif optype=="put":

```

```
        return put_price
```

1.0.3 Bisection

[8]:
```
# bisection function compatible with apply function

def bisection(row):

    S=3049
    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=f_b
            f_a=f_a


            #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
```

Applyin bisection method on ATM calls to find implied volatilities

[9]:
```
# example using bisection with apply function on ATM calls

AMZN_vol=AMZN_ATM_calls.apply(lambda row: bisection(row),axis=1)
AMZN_ATM_calls["bisection_implied"]=AMZN_vol
AMZN_ATM_calls
```

[9]:
```
            Option Name Expiration Date  Type  Strike     Bid     Ask  \
0   AMZN210319C03010000      2021-03-19  call  3010.0  100.20  104.05
1   AMZN210521C03010000      2021-05-21  call  3010.0  223.35  226.80
2   AMZN210416C03010000      2021-04-16  call  3010.0  157.70  161.05
3   AMZN210416C03020000      2021-04-16  call  3020.0  151.30  154.85
4   AMZN210521C03020000      2021-05-21  call  3020.0  217.50  220.80
..                  …             …   …     …      …      …
62  AMZN210319C03165000      2021-03-19  call  3165.0   18.45   19.55
63  AMZN210416C03170000      2021-04-16  call  3170.0   73.95   76.20
64  AMZN210319C03170000      2021-03-19  call  3170.0   17.20   18.55
65  AMZN210521C03170000      2021-05-21  call  3170.0  141.20  143.70
```

```
66   AMZN210319C03175000      2021-03-19  call  3175.0   16.00   17.45

    Last Price  Implied Volatility  bisection_implied
0       102.52            0.355689           0.027656
1       208.45            0.348758           0.020000
2       162.55            0.315269           0.020000
3       153.35            0.314201           0.020000
4       215.50            0.347491           0.020000
..         …                 …                 …
62       19.60            0.301246           0.021914
63       75.65            0.293662           0.020000
64       17.70            0.303321           0.021914
65      138.20            0.333892           0.020000
66       16.65            0.304176           0.021914

[67 rows x 9 columns]
```

1.1 Binomial General Additive European Call

[10]:
```
# Binomial General Additive European Call

def AdditiveEC(row):

    S=3000
    K= row["Strike"]
    r=0.0008
    N=200

    sig=row["Implied Volatility"]

    today = datetime.today()

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




    dt=T/(N-1)                                      # Dividing time into N␣
↪periods

    nu=r- 0.5*(sig**2)                             # risk neutral drift

    dxu=np.sqrt((sig**2)*dt + (nu*dt)**2)         # Small increment in x

    dxd= -dxu
```

```
pu= 0.5+ 0.5*((nu*dt)/dxu)                        # Prob up

pd=1-pu                                           # Prob down

disc=np.exp(-r*dt)                                # continuous discount



#St=S* np.exp(N*dxd)




# Creating stock and call matrices to hold values
stock_prices=np.zeros((N,N))

call_prices=np.zeros((N,N))



#stock_prices[0,0]=S

for j in range(0,N):

    M=j+1


    stock_prices[j,0]= S* math.exp(j*dxd)

    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)

    for i in range(1,M):

        stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)





call_prices[0,0]=0


for j in range(1,N):
```

```
        M=j+1

        call_prices[j,0]=max(0,stock_prices[j,0]-K)

        for i in range(1,M):

            call_prices[j,i]=max(0,stock_prices[j,i]-K)


    #return call_prices


    #return dxd
    #return stock_prices

    #return call_prices


    rcall_prices=np.zeros((N,N))

    for j in range(N-1,-1,-1):

        if j==N-1:

            for i in range(0,N):

                rcall_prices[j,i]=call_prices[j,i]

        else:



            for i in range(0,j+1):

                rcall_prices[j,i]=  disc* (pd*rcall_prices[j+1,i]  + 
 ↪pu*rcall_prices[j+1,i+1])

                #print(rcall_prices[j,i])


    return rcall_prices[0,0]
```

[11]:
```
Tree_Price=AMZN_ATM_calls.apply(lambda row: AdditiveEC(row),axis=1 )
Tree_Price
```

[11]:
```
0      835.042526
1     2633.717863
2     1908.901671
3     1902.062730
4     2627.369024
         …
62     653.792285
63    1773.665601
64     656.979409
65    2553.401826
66     657.326756
Length: 67, dtype: float64
```

Applying Binomial General Additive European Method

[12]:
```
AMZN_ATM_calls["Tree_Price"]=Tree_Price
AMZN_ATM_calls
```

[12]:
```
            Option Name Expiration Date  Type  Strike     Bid     Ask  \
0   AMZN210319C03010000      2021-03-19  call  3010.0  100.20  104.05
1   AMZN210521C03010000      2021-05-21  call  3010.0  223.35  226.80
2   AMZN210416C03010000      2021-04-16  call  3010.0  157.70  161.05
3   AMZN210416C03020000      2021-04-16  call  3020.0  151.30  154.85
4   AMZN210521C03020000      2021-05-21  call  3020.0  217.50  220.80
..                  …             …   …     …      …     …
62  AMZN210319C03165000      2021-03-19  call  3165.0   18.45   19.55
63  AMZN210416C03170000      2021-04-16  call  3170.0   73.95   76.20
64  AMZN210319C03170000      2021-03-19  call  3170.0   17.20   18.55
65  AMZN210521C03170000      2021-05-21  call  3170.0  141.20  143.70
66  AMZN210319C03175000      2021-03-19  call  3175.0   16.00   17.45

    Last Price  Implied Volatility  bisection_implied   Tree_Price
0       102.52            0.355689           0.027656   835.042526
1       208.45            0.348758           0.020000  2633.717863
2       162.55            0.315269           0.020000  1908.901671
3       153.35            0.314201           0.020000  1902.062730
4       215.50            0.347491           0.020000  2627.369024
..         …                 …                 …          …
62       19.60            0.301246           0.021914   653.792285
63       75.65            0.293662           0.020000  1773.665601
64       17.70            0.303321           0.021914   656.979409
65      138.20            0.333892           0.020000  2553.401826
66       16.65            0.304176           0.021914   657.326756
```

[67 rows x 10 columns]

1.2 Binomial General Additive European Put

[13]:
```
# Binomial General Additive European Put

def AdditiveEP(row):

    S=3000
    K= row["Strike"]
    r=0.0008
    N=200

    sig=row["Implied Volatility"]

    today = datetime.today()

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




    dt=T/(N-1)                                      # Dividing time into N␣
↪periods

    nu=r- 0.5*(sig**2)                             # risk neutral drift

    dxu=np.sqrt((sig**2)*dt + (nu*dt)**2)         # Small increment in x

    dxd= -dxu

    pu= 0.5+ 0.5*((nu*dt)/dxu)                    # Prob up

    pd=1-pu                                       # Prob down

    disc=np.exp(-r*dt)                            # continuous discount



    #St=S* np.exp(N*dxd)




    # Creating stock and call matrices to hold values
```

```
stock_prices=np.zeros((N,N))

put_prices=np.zeros((N,N))



#stock_prices[0,0]=S

for j in range(0,N):

    M=j+1


    stock_prices[j,0]= S* math.exp(j*dxd)

    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)

    for i in range(1,M):

        stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)






put_prices[0,0]=0


for j in range(1,N):

    M=j+1


    put_prices[j,0]=max(0,K-stock_prices[j,0])


    for i in range(1,M):


        put_prices[j,i]=max(0,stock_prices[j,i]-K)



#return call_prices
```

```
    #return dxd
    #return stock_prices

    #return call_prices


    rput_prices=np.zeros((N,N))

    for j in range(N-1,-1,-1):

        if j==N-1:

            for i in range(0,N):

                rput_prices[j,i]=put_prices[j,i]

        else:



            for i in range(0,j+1):

                rput_prices[j,i]=  disc* (pd*rput_prices[j+1,i]  + ␣
↪pu*rput_prices[j+1,i+1])

                #print(rcall_prices[j,i])


    return rput_prices[0,0]
```

1.3 Binomial General Additive American Put

[14]:
```
# Binomial General Additive American Put

def AdditiveAP(row):

    S=3000
    K= row["Strike"]
    r=0.0008
    N=200

    sig=row["Implied Volatility"]

    today = datetime.today()
```

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




    dt=T/(N-1)                                              # Dividing time into N␣
↪periods

    nu=r- 0.5*(sig**2)                                     # risk neutral drift

    dxu=np.sqrt((sig**2)*dt + (nu*dt)**2)           # Small increment in x

    dxd= -dxu

    pu= 0.5+ 0.5*((nu*dt)/dxu)                            # Prob up

    pd=1-pu                                                # Prob down

    disc=np.exp(-r*dt)                                     # continuous discount



    #St=S* np.exp(N*dxd)




    # Creating stock and call matrices to hold values
    stock_prices=np.zeros((N,N))

    put_prices=np.zeros((N,N))



    #stock_prices[0,0]=S

    for j in range(0,N):

        M=j+1


        stock_prices[j,0]= S* np.exp(j*dxd)

        #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
        #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)
```

```
        for i in range(1,M):

            stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)




    put_prices[0,0]=0


    for j in range(1,N):

        M=j+1


        put_prices[j,0]=max(0,K-stock_prices[j,0])


        for i in range(1,M):


            put_prices[j,i]=max(0,K-stock_prices[j,i])



    #return call_prices


    #return dxd
    #return stock_prices

    #return call_prices


    C_stock_prices=np.zeros((N,N))
    rput_prices=np.zeros((N,N))




    for j in range(N-1,-1,-1):

        if j==N-1:
```

```
            for i in range(0,N):

                rput_prices[j,i]=put_prices[j,i]

        else:



            for i in range(0,j+1):

                rput_prices[j,i]=  disc* (pd*rput_prices[j+1,i]  + ␣
↪pu*rput_prices[j+1,i+1])

                C_stock_prices[j,i]=stock_prices[j,i]/ (np.exp(dxd))


                rput_prices[j,i]= max(rput_prices[j,i], K- C_stock_prices[j,i])

                #print(rcall_prices[j,i])


    #return rput_prices

    #return stock_prices

    return rput_prices[0,0]

    #return dxd

    #return dt
```

[15]:
```
# Subsetting only put options

AMZN_puts=AMZN_opt1.loc[AMZN_opt1["Type"]=="put"].reset_index(drop=True)
AMZN_puts
```

[15]:

	Option Name	Expiration Date	Type	Strike	Bid	Ask	\
0	AMZN210319P01460000	2021-03-19	put	1460.0	0.01	0.02	
1	AMZN210319P01480000	2021-03-19	put	1480.0	0.00	0.05	
2	AMZN210319P01500000	2021-03-19	put	1500.0	0.00	0.05	
3	AMZN210319P01520000	2021-03-19	put	1520.0	0.00	0.05	
4	AMZN210319P01540000	2021-03-19	put	1540.0	0.00	0.05	
..	…	…	…	…	…	…	
508	AMZN210521P04400000	2021-05-21	put	4400.0	1303.20	1318.15	
509	AMZN210521P04500000	2021-05-21	put	4500.0	1402.80	1417.90	
510	AMZN210521P04600000	2021-05-21	put	4600.0	1502.55	1517.50	

```
511  AMZN210521P04700000      2021-05-21  put  4700.0  1601.60  1620.00
512  AMZN210521P05000000      2021-05-21  put  5000.0  1901.20  1919.50

     Last Price  Implied Volatility
0          0.02            1.609377
1          0.07            1.632814
2          0.01            1.609377
3          0.05            1.578127
4          0.01            1.546877
..          …                  …
508     1338.05            0.429571
509     1447.10            0.448904
510     1507.70            0.465765
511     1575.75            0.510793
512     1996.50            0.565114

[513 rows x 8 columns]
```

[16]:

```
# AMZN at the money putss for 3 different expiration date
AMZN_ATM_puts=AMZN_puts[(AMZN_puts["Strike"]>2800) &␣
↪(AMZN_puts["Strike"]<3090)].reset_index(drop=True)


AMZN_ATM_puts=AMZN_ATM_puts.sort_values("Strike",ascending=True).
↪reset_index(drop=True)
AMZN_ATM_puts
```

[16]:

```
            Option Name Expiration Date Type  Strike     Bid     Ask  \
0   AMZN210319P02850000      2021-03-19  put  2850.0    5.05    6.00
1   AMZN210319P02900000      2021-03-19  put  2900.0    7.15    7.95
2   AMZN210521P02900000      2021-05-21  put  2900.0  100.30  102.75
3   AMZN210416P02900000      2021-04-16  put  2900.0   45.65   47.65
4   AMZN210319P02910000      2021-03-19  put  2910.0    7.75    9.00
..                  …             …   …      …      …       …
62  AMZN210319P03075000      2021-03-19  put  3075.0   40.55   43.00
63  AMZN210319P03080000      2021-03-19  put  3080.0   42.65   45.35
64  AMZN210416P03080000      2021-04-16  put  3080.0  104.10  106.90
65  AMZN210521P03080000      2021-05-21  put  3080.0  170.65  173.60
66  AMZN210319P03085000      2021-03-19  put  3085.0   44.70   47.45

    Last Price  Implied Volatility
0         5.40            0.444738
1         7.75            0.398962
2       104.22            0.350901
3        46.62            0.327155
4         8.72            0.397101
..         …                  …
```

```
62       42.14            0.316619
63       43.70            0.316627
64      103.20            0.297218
65      170.81            0.333587
66       46.55            0.314536

[67 rows x 8 columns]
```

[17]:
```
Tree_AmPut_Price=AMZN_ATM_puts.apply(lambda row: AdditiveAP(row),axis=1 )
Tree_AmPut_Price
```

[17]:
```
0      925.120066
1      860.025237
2     2345.309553
3     1797.890826
4      862.488544
         …
62     786.939674
63     790.059576
64    1803.833721
65    2439.611441
66     788.333960
Length: 67, dtype: float64
```

Applying Binomial General Additive American Put on AMZN OptionChain

[18]:
```
AMZN_ATM_puts["Tree_Price"]=Tree_AmPut_Price
AMZN_ATM_puts
```

[18]:
```
             Option Name Expiration Date Type  Strike     Bid     Ask  \
0   AMZN210319P02850000      2021-03-19  put  2850.0    5.05    6.00
1   AMZN210319P02900000      2021-03-19  put  2900.0    7.15    7.95
2   AMZN210521P02900000      2021-05-21  put  2900.0  100.30  102.75
3   AMZN210416P02900000      2021-04-16  put  2900.0   45.65   47.65
4   AMZN210319P02910000      2021-03-19  put  2910.0    7.75    9.00
..                  …              …   …    …      …      …
62  AMZN210319P03075000      2021-03-19  put  3075.0   40.55   43.00
63  AMZN210319P03080000      2021-03-19  put  3080.0   42.65   45.35
64  AMZN210416P03080000      2021-04-16  put  3080.0  104.10  106.90
65  AMZN210521P03080000      2021-05-21  put  3080.0  170.65  173.60
66  AMZN210319P03085000      2021-03-19  put  3085.0   44.70   47.45

    Last Price  Implied Volatility   Tree_Price
0         5.40            0.444738   925.120066
1         7.75            0.398962   860.025237
2       104.22            0.350901  2345.309553
3        46.62            0.327155  1797.890826
```

```
4          8.72            0.397101   862.488544
..          …                 …           …
62        42.14            0.316619   786.939674
63        43.70            0.316627   790.059576
64       103.20            0.297218  1803.833721
65       170.81            0.333587  2439.611441
66        46.55            0.314536   788.333960

[67 rows x 9 columns]
```

1.3.1 Blackscholes on dataframe

[19]:
```
## Blackscholes function to calulate option price

# S= Stock Price

# K= Strike Price

# t= Expiration Date

# sig= Volatility

# optype= Type

# r= risk free interest rate



def blackscholes(row):

    S=3000

    K=row["Strike"]

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

    optype=row["Type"]

    sig=row["Implied Volatility"]

    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== "call":

        return call_price

    elif optype=="put":

        return put_price
```

Applying Blackscholes on AMZN calls

[20]:
```
Blackscholes_callprice=AMZN_ATM_calls.apply(lambda row:␣
↪blackscholes(row),axis=1)
```

[21]:
```
AMZN_ATM_calls["Black_Price"]=Blackscholes_callprice
AMZN_ATM_calls
```

[21]:
```
           Option Name Expiration Date  Type  Strike     Bid     Ask  \
0   AMZN210319C03010000      2021-03-19  call  3010.0  100.20  104.05
1   AMZN210521C03010000      2021-05-21  call  3010.0  223.35  226.80
2   AMZN210416C03010000      2021-04-16  call  3010.0  157.70  161.05
3   AMZN210416C03020000      2021-04-16  call  3020.0  151.30  154.85
4   AMZN210521C03020000      2021-05-21  call  3020.0  217.50  220.80
..                  …             …   …     …      …      …
62  AMZN210319C03165000      2021-03-19  call  3165.0   18.45   19.55
63  AMZN210416C03170000      2021-04-16  call  3170.0   73.95   76.20
64  AMZN210319C03170000      2021-03-19  call  3170.0   17.20   18.55
65  AMZN210521C03170000      2021-05-21  call  3170.0  141.20  143.70
66  AMZN210319C03175000      2021-03-19  call  3175.0   16.00   17.45

    Last Price  Implied Volatility  bisection_implied   Tree_Price  \
0       102.52            0.355689           0.027656   835.042526
1       208.45            0.348758           0.020000  2633.717863
2       162.55            0.315269           0.020000  1908.901671
3       153.35            0.314201           0.020000  1902.062730
4       215.50            0.347491           0.020000  2627.369024
..         …                 …                …          …
62       19.60            0.301246           0.021914   653.792285
63       75.65            0.293662           0.020000  1773.665601
```

```
64       17.70            0.303321           0.021914   656.979409
65      138.20            0.333892           0.020000  2553.401826
66       16.65            0.304176           0.021914   657.326756

    Black_Price
0    833.640729
1   2551.038551
2   1894.781235
3   1888.115773
4   2545.896188
..          …
62   653.677230
63  1763.377456
64   656.786568
65  2484.272823
66   657.049478

[67 rows x 11 columns]
```

[ ]:
```
Applying Blackscholes on AMZN puts
```

[22]:
```
Blackscholes_putprice=AMZN_ATM_puts.apply(lambda row: blackscholes(row),axis=1)
```

[24]:
```
AMZN_ATM_puts["Black_Price"]=Blackscholes_putprice
AMZN_ATM_puts
```

[24]:
```
            Option Name Expiration Date Type  Strike     Bid     Ask  \
0   AMZN210319P02850000      2021-03-19  put  2850.0    5.05    6.00
1   AMZN210319P02900000      2021-03-19  put  2900.0    7.15    7.95
2   AMZN210521P02900000      2021-05-21  put  2900.0  100.30  102.75
3   AMZN210416P02900000      2021-04-16  put  2900.0   45.65   47.65
4   AMZN210319P02910000      2021-03-19  put  2910.0    7.75    9.00
..                  …             …  …      …     …      …
62  AMZN210319P03075000      2021-03-19  put  3075.0   40.55   43.00
63  AMZN210319P03080000      2021-03-19  put  3080.0   42.65   45.35
64  AMZN210416P03080000      2021-04-16  put  3080.0  104.10  106.90
65  AMZN210521P03080000      2021-05-21  put  3080.0  170.65  173.60
66  AMZN210319P03085000      2021-03-19  put  3085.0   44.70   47.45

    Last Price  Implied Volatility   Tree_Price  Black_Price
0         5.40            0.444738   925.120066   925.355405
1         7.75            0.398962   860.025237   859.599771
2       104.22            0.350901  2345.309553  2315.269862
3        46.62            0.327155  1797.890826  1793.793020
4         8.72            0.397101   862.488544   861.920767
..         …                 …           …            …
62       42.14            0.316619   786.939674   786.506546
```

63	43.70	0.316627	790.059576	789.701531
64	103.20	0.297218	1803.833721	1800.104155
65	170.81	0.333587	2439.611441	2409.760554
66	46.55	0.314536	788.333960	788.067498

[67 rows x 10 columns]

1.4 Plots

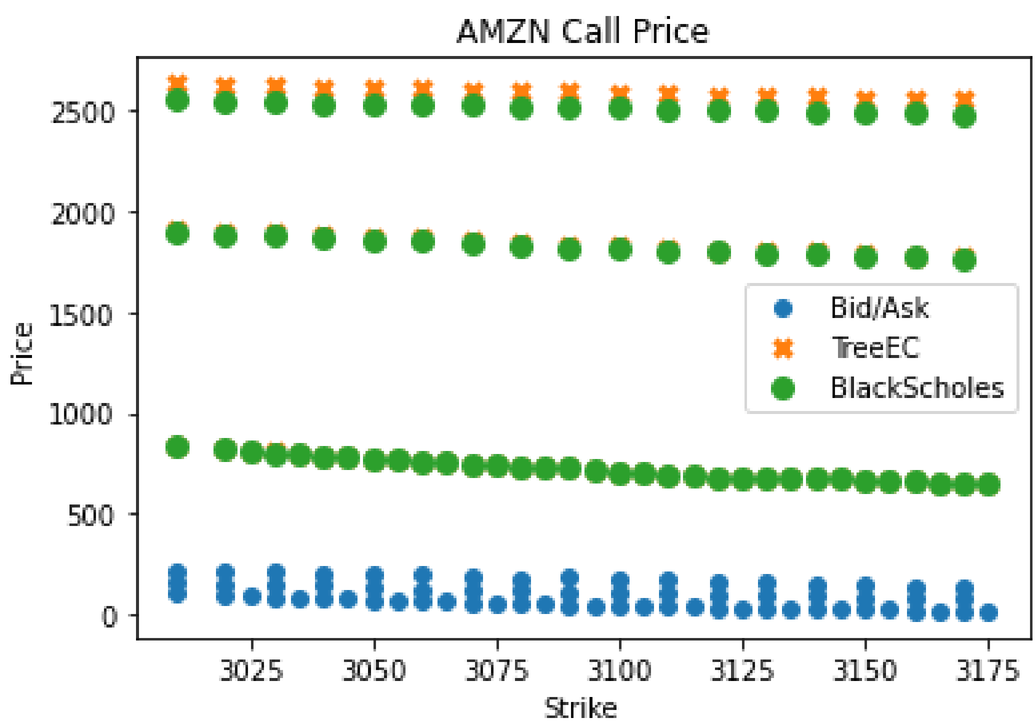
AMZN Calls' plot

[25]:
```
plt.scatter(AMZN_ATM_calls["Strike"],AMZN_ATM_calls["Last Price"],label="Bid/
↪Ask")
plt.
↪scatter(AMZN_ATM_calls["Strike"],AMZN_ATM_calls["Tree_Price"],label="TreeEC",marker="x",lin
plt.
↪scatter(AMZN_ATM_calls["Strike"],AMZN_ATM_calls["Black_Price"],label="BlackScholes",linewid

plt.legend()

plt.title("AMZN Call Price")
plt.xlabel("Strike")
plt.ylabel("Price")
```

[25]:
```
Text(0, 0.5, 'Price')
```



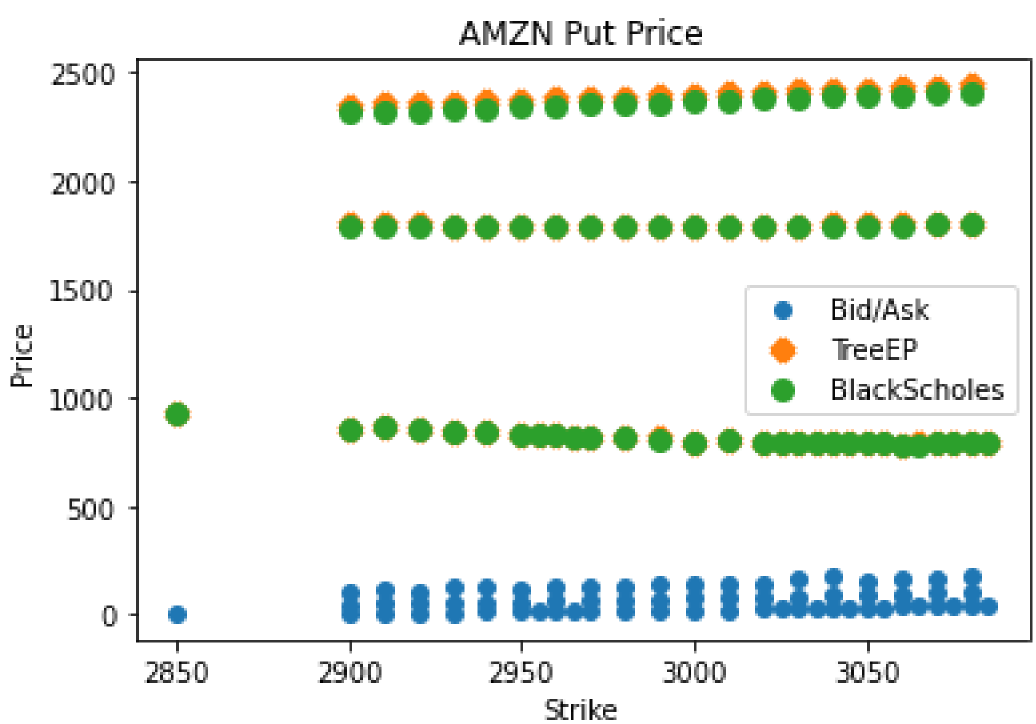
AMZN Puts' plot

```
[30]: plt.scatter(AMZN_ATM_puts["Strike"],AMZN_ATM_puts["Last Price"],label="Bid/Ask")
plt.
 ↪scatter(AMZN_ATM_puts["Strike"],AMZN_ATM_puts["Tree_Price"],label="TreeEP",marker="x",linew
plt.
 ↪scatter(AMZN_ATM_puts["Strike"],AMZN_ATM_puts["Black_Price"],label="BlackScholes",linewidth

plt.legend()

plt.title("AMZN Put Price")
plt.xlabel("Strike")
plt.ylabel("Price")
```

```
[30]: Text(0, 0.5, 'Price')
```



- According to graph, we can say that Tree Prices and Blackscholes Prices our moving in a harmony.
- For Call Option, as Strike price increases price of the option decreases
- For Put Option, as Strike price increases price of the decreases

1.5 Absolute Error Calculation

[32]:
```
## Blackscholes function to calulate Put option price

# S= Stock Price

# K= Strike Price

# t= Expiration Date

# sig= Volatility

# optype= Type

# r= risk free interest rate



def blackscholes_P(S,K,t,sig,r=0.0008):

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

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

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

    return put_price
```

[33]:
```
# Binomial General Additive European Put

def sing_AdditiveEP(S,K,T,r,sig,N,):




    dt=T/(N-1)                                          # Dividing time into N␣
↪periods

    nu=r- 0.5*(sig**2)                                 # risk neutral drift

    dxu=np.sqrt((sig**2)*dt + (nu*dt)**2)          # Small increment in x

    dxd= -dxu

    pu= 0.5+ 0.5*((nu*dt)/dxu)                      # Prob up

    pd=1-pu                                         # Prob down
```

```
disc=np.exp(-r*dt)                              # continuous discount


#St=S* np.exp(N*dxd)



# Creating stock and call matrices to hold values
stock_prices=np.zeros((N,N))

put_prices=np.zeros((N,N))


#stock_prices[0,0]=S

for j in range(0,N):

    M=j+1


    stock_prices[j,0]= S* math.exp(j*dxd)

    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)

    for i in range(1,M):

        stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)





put_prices[0,0]=0


for j in range(1,N):

    M=j+1


    put_prices[j,0]=max(0,K-stock_prices[j,0])
```

```
        for i in range(1,M):

            put_prices[j,i]=max(0,stock_prices[j,i]-K)


    #return call_prices


    #return dxd
    #return stock_prices

    #return call_prices


    rput_prices=np.zeros((N,N))

    for j in range(N-1,-1,-1):

        if j==N-1:

            for i in range(0,N):

                rput_prices[j,i]=put_prices[j,i]

        else:



            for i in range(0,j+1):

                rput_prices[j,i]=  disc* (pd*rput_prices[j+1,i]  + ␣
↪pu*rput_prices[j+1,i+1])

                #print(rcall_prices[j,i])


    return rput_prices[0,0]
```

[34]:
```
N=[10,20,30,40,50,100,150,200,250,300,350,400]

S=100
```

```
K=100

T=1
t=1
sig=0.2

r=0.0008

abs_error=[]

for i in N:

    tree=sing_AdditiveEP(S,K,T,r,sig,N=i)

    blackscholes= blackscholes_P(S,K,sig,r,t)

    abs_error.append(abs(tree-blackscholes))

#abs_error


df_error=pd.DataFrame({"N":N, "Error":abs_error})



df_error
```

[34]:

	N	Error
0	10	8.346581
1	20	8.109600
2	30	8.072393
3	40	8.054400
4	50	8.043768
5	100	8.022865
6	150	8.016002
7	200	8.012590
8	250	8.010549
9	300	8.009190
10	350	8.008222
11	400	8.007496

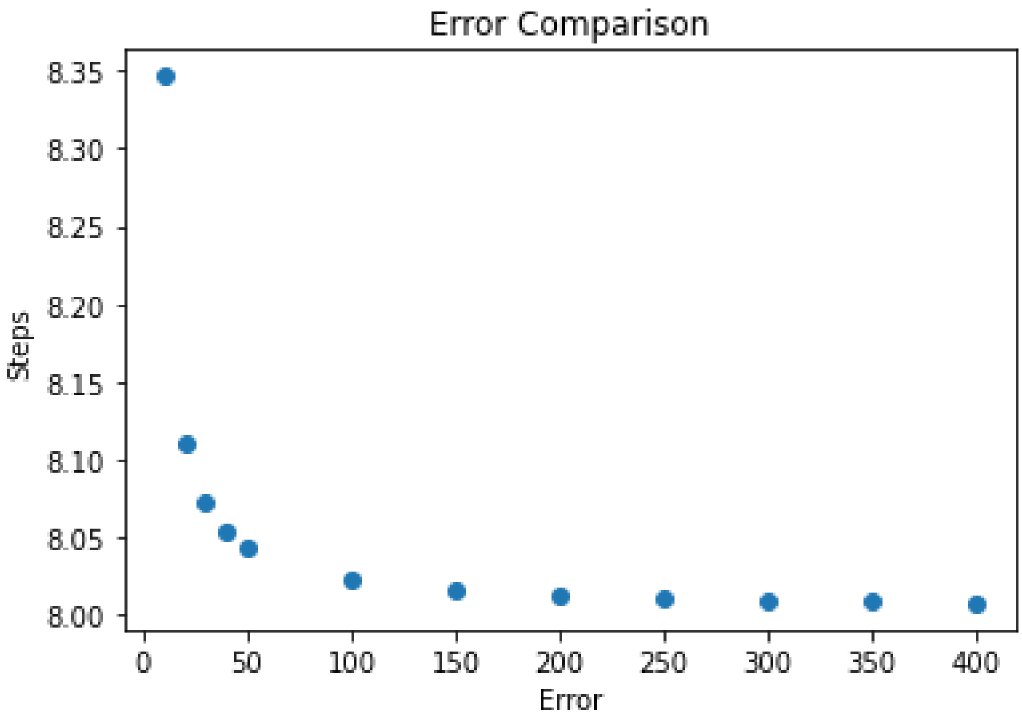
Plot of Error

[35]:
```
plt.scatter(df_error["N"],df_error["Error"] )

plt.title("Error Comparison")
```

```
plt.xlabel("Error")
plt.ylabel("Steps")
```

[35]: Text(0, 0.5, 'Steps')



- According to computation and graph it could be easily see that error value decreases dramatically as number of steps increases. After, some value, acceleration of the decrease gets small.

2 Part2

2.0.1 Standard European Call Option by Trinomial Tree

[40]:
```
def TrinomialEC(S,K,T,sig,r,div,N):


    dt= T/N

    nu= r- div - (0.5 * sig**2)

    dx= sig * np.sqrt(3*dt)

```

```
edx= np.exp(dx)

pu= 0.5*((sig**2*dt + nu**2*dt**2)/ dx**2 + nu*dt/dx)

pd= 0.5* (( sig**2*dt + nu**2*dt**2 -  nu*dt/dx ))

pm= 1- (sig**2*dt + nu**2*dt**2)/ dx**2

disc= np.exp(-r*dt)



# Creating stock and call matrices to hold values
stock_prices=np.zeros((N+1,2*N+1))

call_prices=np.zeros((N+1,2*N+1))


stock_prices[0,0]=S

for j in range(1,N+1):

    M=j*2+1


    stock_prices[j,0]= S* np.exp(-j*dx)

    #return stock_prices

    for i in range(1,M):

        stock_prices[j,i]=stock_prices[j,i-1]*edx


#return stock_prices



call_prices[0,0]=0
for j in range(1,N+1):

        M=j*2+1


        call_prices[j,0]=max(0,stock_prices[j,0]-K)
```

```
        for i in range(1,M):

            call_prices[j,i]=max(0,stock_prices[j,i]-K)

    #return call_prices

    rcall_prices=np.zeros((N+1,2*N+1))

    for j in range(N,-1,-1):

        if j==N:

            for i in range(0,2*N+1):

                rcall_prices[j,i]=call_prices[j,i]

        else:

            for i in range(0,j*2+1):

                rcall_prices[j,i]=  disc* (pd*rcall_prices[j+1,i] 
↪+pm*rcall_prices[j+1,i+1] + pu*rcall_prices[j+1,i+2] )

                #print(rcall_prices[j,i])

    return rcall_prices
```

European Call Option Trinomial Tree with random parameters

[42]:
```
TrinomialEC(S=100,K=100,T=1,sig=0.2,r=0.06,div=0.03,N=3)
```

[42]:
```
array([[ 8.11808501,  0.        ,  0.        ,  0.        ,  0.        ,
         0.        ,  0.        ],
       [ 0.65249386,  6.41482125, 22.88697555,  0.        ,  0.        ,
         0.        ,  0.        ],
       [ 0.        ,  0.        ,  3.80084122, 22.90508353, 46.20300856,
         0.        ,  0.        ],
       [ 0.        ,  0.        ,  0.        ,  0.        , 22.14027582,
        49.18246976, 82.21188004]])
```

2.1 Up and Out Trinomial Tree

[44]:
```python
def TrinomialUO(S,K,T,sig,r,div,N,H):


    dt= T/N

    nu= r- div - (0.5 * sig**2)

    dx= sig * np.sqrt(3*dt)

    edx= np.exp(dx)

    pu= 0.5*((sig**2*dt + nu**2*dt**2)/ dx**2 + nu*dt/dx)

    pd= 0.5* (( sig**2*dt + nu**2*dt**2 -  nu*dt/dx ))

    pm= 1- (sig**2*dt + nu**2*dt**2)/ dx**2

    disc= np.exp(-r*dt)



    # Creating stock and call matrices to hold values
    stock_prices=np.zeros((N+1,2*N+1))

    call_prices=np.zeros((N+1,2*N+1))


    stock_prices[0,0]=S

    for j in range(1,N+1):

        M=j*2+1


        stock_prices[j,0]= S* np.exp(-j*dx)

        #return stock_prices

        for i in range(1,M):

            stock_prices[j,i]=stock_prices[j,i-1]*edx


    #return stock_prices
```

```
call_prices[0,0]=0
for j in range(1,N+1):



        M=j*2+1

        for i in range(0,M):

            if stock_prices[j,i]>H :

                call_prices[j,i]=max(0,stock_prices[j,i]-K)



            else:

                call_prices[j,i]=0

            #for i in range(1,M):


                #call_prices[j,i]=0


#return call_prices


rcall_prices=np.zeros((N+1,2*N+1))

for j in range(N,-1,-1):

    if j==N:

        for i in range(0,2*N+1):

            rcall_prices[j,i]=call_prices[j,i]

    else:
```

```
            for i in range(0,j*2+1):

                rcall_prices[j,i]=  disc* (pd*rcall_prices[j+1,i] ␣
↪+pm*rcall_prices[j+1,i+1] + pu*rcall_prices[j+1,i+2] )

                #print(rcall_prices[j,i])


    return rcall_prices
```

Applying the Treenomial Up and Out, and we got 0.39499821 for option price

[45]:
```
TrinomialUO(S=10,K=10,T=0.3,sig=0.2,r=0.01,div=0,N=3,H=11)
```

[45]:
```
array([[0.39499821, 0.        , 0.        , 0.        , 0.        ,
         0.        , 0.        ],
        [0.03037583, 0.31402183, 1.14634091, 0.        , 0.        ,
         0.        , 0.        ],
        [0.        , 0.        , 0.18752603, 1.16769235, 2.26892477,
         0.        , 0.        ],
        [0.        , 0.        , 0.        , 0.        , 1.15769734,
         2.449421  , 3.89068717]])
```

2.2 Up-and-Out Call option explicit

2.2.1 Blackscholes for Call Option

[46]:
```
## Blackscholes function to calulate call option price

# S= Stock Price

# K= Strike Price

# t= Expiration Date

# sig= Volatility

# optype= Type

# r= risk free interest rate



def blackscholes_C(S,K,t,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)

    return call_price
```

2.2.2 Blackscholes for Put Option

[47]:
```
## Blackscholes function to calulate Put option price

# S= Stock Price

# K= Strike Price

# t= Expiration Date

# sig= Volatility

# optype= Type

# r= risk free interest rate



def blackscholes_P(S,K,t,sig,r=0.0008):

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

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

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

    return put_price
```

2.3 Up-and-Out Call option explicit

[48]:
```
# Parameters used in Formula: S,K,T,sig,H,r,
# We also use standard normal cumulative distribution function in the formula




def UOexplicit(S,K,t,sig,r,div,H):

```

```
    BS_k=blackscholes_C(S,K,t,sig)
    BS_h=blackscholes_C(S,H,t,sig)

    BS_K= blackscholes_C((H**2/S),K,t,sig)

    BS_H= blackscholes_C((H**2/S),H,t,sig)


    v= r-div- (sig**2)/2
    dbs= (np.log(S/H) + v*t)/ (sig*np.sqrt(t))

    dbs_rev= (np.log(H/S) + v*t)/ (sig*np.sqrt(t))



    UObs= (BS_k-BS_h-(H-K)*np.exp(-r*t)*norm.cdf(dbs,0,1) -(H/S)**(2*v/
 ↪sig**2))* ( BS_K - BS_H - (H-K)*np.exp(-r*t)*norm.cdf(dbs_rev,0,1))



    return UObs
```

[49]:
```
UOexplicit(S=10,K=10,t=0.3,sig=0.2,r=0.0008,div=0,H=11)
```

[49]: -0.0722527723829439

- The result of call option using explicit formula with parameters S=10,K=10,t=0.3,sig=0.2,r=0.0008,div=0,H=11 is -0.0722527723829439
- The result of call option using Trinomial Tree with parameters S=10,K=10,t=0.3,sig=0.2,r=0.0008,div=0,H=11 is 0.39499821
- We can say that result are very close to each other

2.4 European Up-and-In call option explicit

[50]:
```
def UIexplicit(S,K,t,sig,r,div,H):


    BS_K= blackscholes_P((H**2/S),K,t,sig)

    BS_H= blackscholes_P((H**2/S),H,t,sig)

    BS_h=blackscholes_C(S,H,t,sig)


    v= r-div- (sig**2)/2
    dbs= (np.log(S/H) + v*t)/ (sig*np.sqrt(t))
```

```
    dbs_rev= - (np.log(H/S) + v*t)/ (sig*np.sqrt(t))


    BS_h_C=blackscholes_C(S,H,t,sig)







    UIbs=(H/S)**(2*v/sig**2)* ( BS_K -  BS_H + (H-K)*np.exp(-r*t) *norm.
↪cdf(dbs_rev)) + BS_h_C + (H-K)*np.exp(-r*t)*norm.cdf(dbs,0,1)


    return UIbs
```

[51]:
```
UIexplicit(S=10,K=10,t=0.3,sig=0.2,r=0.0008,div=0,H=11)
```

[51]: 0.3853601597487307

3 Part3

[52]:
```
# Binomial General Additive American Put

def AdditiveAP(S,K,r,sig,T,N):



    dt=T/(N-1)                                         # Dividing time into N␣
↪periods

    nu=r- 0.5*(sig**2)                                 # risk neutral drift

    dxu=np.sqrt((sig**2)*dt + (nu*dt)**2)          # Small increment in x

    dxd= -dxu

    pu= 0.5+ 0.5*((nu*dt)/dxu)                         # Prob up

    pd=1-pu                                           # Prob down

    disc=np.exp(-r*dt)                                # continuous discount
```

```python
#St=S* np.exp(N*dxd)



# Creating stock and call matrices to hold values
stock_prices=np.zeros((N,N))

put_prices=np.zeros((N,N))



#stock_prices[0,0]=S

for j in range(0,N):

    M=j+1


    stock_prices[j,0]= S* np.exp(j*dxd)

    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)

    for i in range(1,M):

        stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)





put_prices[0,0]=0


for j in range(1,N):

    M=j+1


    put_prices[j,0]=max(0,K-stock_prices[j,0])


    for i in range(1,M):
```

```
            put_prices[j,i]=max(0,K-stock_prices[j,i])



    #return call_prices


    #return dxd
    #return stock_prices

    #return call_prices


    C_stock_prices=np.zeros((N,N))
    rput_prices=np.zeros((N,N))





    for j in range(N-1,-1,-1):

        if j==N-1:

            for i in range(0,N):

                rput_prices[j,i]=put_prices[j,i]

        else:



            for i in range(0,j+1):

                rput_prices[j,i]=  disc* (pd*rput_prices[j+1,i]  + ␣
↪pu*rput_prices[j+1,i+1])

                C_stock_prices[j,i]=stock_prices[j,i]/ (np.exp(dxd))


                rput_prices[j,i]= max(rput_prices[j,i], K- C_stock_prices[j,i])

                #print(rcall_prices[j,i])
```

```
    #return rput_prices

    #return stock_prices

    return rput_prices

    #return dxd

    #return dt
```

[54]:
```
AdditiveAP(S=100,K=100,r=0.06,sig=0.2,T=1,N=4)
```

[54]:
```
array([[ 5.79043758,  0.        ,  0.        ,  0.        ],
       [10.74452934,  2.06581214,  0.        ,  0.        ],
       [18.76869087,  4.76124036,  0.        ,  0.        ],
       [29.44036276, 10.9736066 ,  0.        ,  0.        ]])
```

3.1 The Binomial Model for Assets Paying A Continuous Dividend Yield

[55]:
```
def Condiv_AP(S,K,r,sig,T,div,N):



    dt=T/(N-1)                                        # Dividing time into N␣
 ↪periods

    nu=r- div- 0.5*(sig**2)                               # risk neutral drift

    dxu=1.2         # Small increment in x

    dxd=0.9

    edxd= dxu/dxd

    pu= 0.5+ 0.5*((nu*dt)/dxu)                      # Prob up

    pd=1-pu                                        # Prob down

    disc=np.exp(-r*dt)                             # continuous discount



    #St=S* np.exp(N*dxd)


```

```
# Creating stock and call matrices to hold values
stock_prices=np.zeros((N,N))

put_prices=np.zeros((N,N))



#stock_prices[0,0]=S

for j in range(0,N):

    M=j+1


    stock_prices[j,0]= S*(dxd)**j

    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
    #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)

    for i in range(1,M):

        stock_prices[j,i]=stock_prices[j,i-1]*edxd





put_prices[0,0]=0


for j in range(1,N):

    M=j+1


    put_prices[j,0]=max(0,K-stock_prices[j,0])


    for i in range(1,M):


        put_prices[j,i]=max(0,K-stock_prices[j,i])
```

```
    #return call_prices


    #return dxd
    #return stock_prices

    #return call_prices


    C_stock_prices=np.zeros((N,N))
    rput_prices=np.zeros((N,N))



    for j in range(N-1,-1,-1):

        if j==N-1:

            for i in range(0,N):

                rput_prices[j,i]=put_prices[j,i]

        else:



            for i in range(0,j+1):

                rput_prices[j,i]=  disc* (pd*rput_prices[j+1,i]  + 
 ↪pu*rput_prices[j+1,i+1])

                C_stock_prices[j,i]=stock_prices[j,i]/ (np.exp(-r*T))


                rput_prices[j,i]= max(rput_prices[j,i], K- C_stock_prices[j,i])

                #print(rcall_prices[j,i])


    #return rput_prices

    #return stock_prices

    return rput_prices[0,0]

    #return dxd
```

```
    #return dt
```

Applying the function with random Strike Price value

[56]:
```
Condiv_AP(S=40,K=40,r=0.04,sig=0.1,T=0.5,div=0.02,N=3)
```

[56]:
```
1.850755807317387
```

Applying the function on various strike prices

[57]:
```
result=[]

for i in range(0,100):

    value=Condiv_AP(S=40,K=i,r=0.04,sig=0.1,T=0.5,div=0.02,N=3)


    result.append(value)

result

df=pd.DataFrame(result,columns=["Option Price"])

df
```

[57]:
```
    Option Price
0       0.000000
1       0.000000
2       0.000000
3       0.000000
4       0.000000
..           …
95     54.191946
96     55.191946
97     56.191946
98     57.191946
99     58.191946

[100 rows x 1 columns]
```

3.2 The Binomial Model With A Known Discrete Proportional Dividend

[58]:
```
def Condivdis_AP(S,K,r,sig,T,tau,div,N):
```

```
    dt=T/(N-1)                                          # Dividing time into N␣
↪periods

    nu=r- div- 0.5*(sig**2)                                 # risk neutral drift

    dxu=np.sqrt((sig**2)*dt + (nu*dt)**2)         # Small increment in x

    dxd= -dxu


    pu= 0.5+ 0.5*((nu*dt)/dxu)                          # Prob up

    pd=1-pu                                            # Prob down

    disc=np.exp(-r*dt)                                 # continuous discount


    #St=S* np.exp(N*dxd)



    # Creating stock and call matrices to hold values
    stock_prices=np.zeros((N,N))

    put_prices=np.zeros((N,N))


    tauh=T/N-1


    #stock_prices[0,0]=S

    for j in range(0,N):

        M=j+1

        tauh*(2**(j-1))


        if tauh<tau:
```

```
        stock_prices[j,0]= S* np.exp(j*dxd)

        #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(j*dxd)
        #stock_prices[j,0]= stock_prices[j-1,0]* np.exp(dxu-dxd)

        for i in range(1,M):

            stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)



    else:



        stock_prices[j,0]= S*(dxd)**j*(1-div)


        for i in range(1,M):

            stock_prices[j,i]=stock_prices[j,i-1]*np.exp(dxu-dxd)*(1-div)








put_prices[0,0]=0


for j in range(1,N):

    M=j+1


    put_prices[j,0]=max(0,K-stock_prices[j,0])


    for i in range(1,M):


        put_prices[j,i]=max(0,K-stock_prices[j,i])
```

```
    #return call_prices


    #return dxd
    #return stock_prices

    #return call_prices


    C_stock_prices=np.zeros((N,N))
    rput_prices=np.zeros((N,N))



    for j in range(N-1,-1,-1):

        if j==N-1:

            for i in range(0,N):

                rput_prices[j,i]=put_prices[j,i]

        else:



            for i in range(0,j+1):

                rput_prices[j,i]=  disc* (pd*rput_prices[j+1,i]  + ␣
↪pu*rput_prices[j+1,i+1])

                C_stock_prices[j,i]=stock_prices[j,i]/ (np.exp(-r*T))


                rput_prices[j,i]= max(rput_prices[j,i], K- C_stock_prices[j,i])

                #print(rcall_prices[j,i])


    return rput_prices[0,0]
```

[59]:
```
Condivdis_AP(S=100,K=100,r=0.06,sig=0.2,div=0.03,T=1,tau=0.6667,N=4)
```

[59]: 6.896410143010434

Applying the function on various strike prices

[61]:
```
result=[]

for i in range(0,100):

    value=Condivdis_AP(S=40,K=i,r=0.04,sig=0.1,T=1,tau=0.333,div=0.03,N=4)


    result.append(value)

df1=pd.DataFrame(result,columns=["Option Price"])

df1
```

[61]:
```
    Option Price
0       0.000000
1       0.000000
2       0.000000
3       0.000000
4       0.000000
..           …
95     53.367569
96     54.367569
97     55.367569
98     56.367569
99     57.367569

[100 rows x 1 columns]
```

[ ]: