MA-374 Lab-09

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Roll No.- 200123074

Question 1:

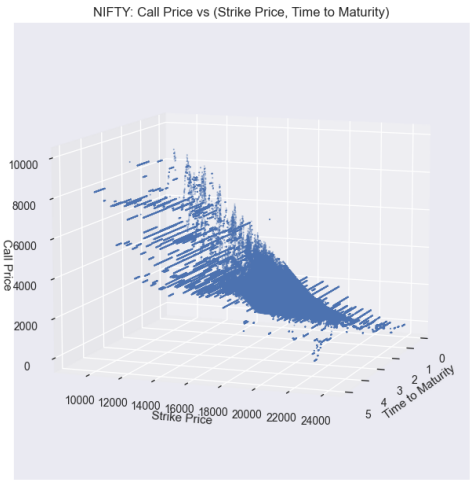
Historical data from the "nseindia" website for 5 stocks: HDFCBANK, INFOSYS, ITC, RELIANCE, and TITAN. Data contains option prices from 30/03/2021 to 28/02/2023 with various strike prices and maturity.

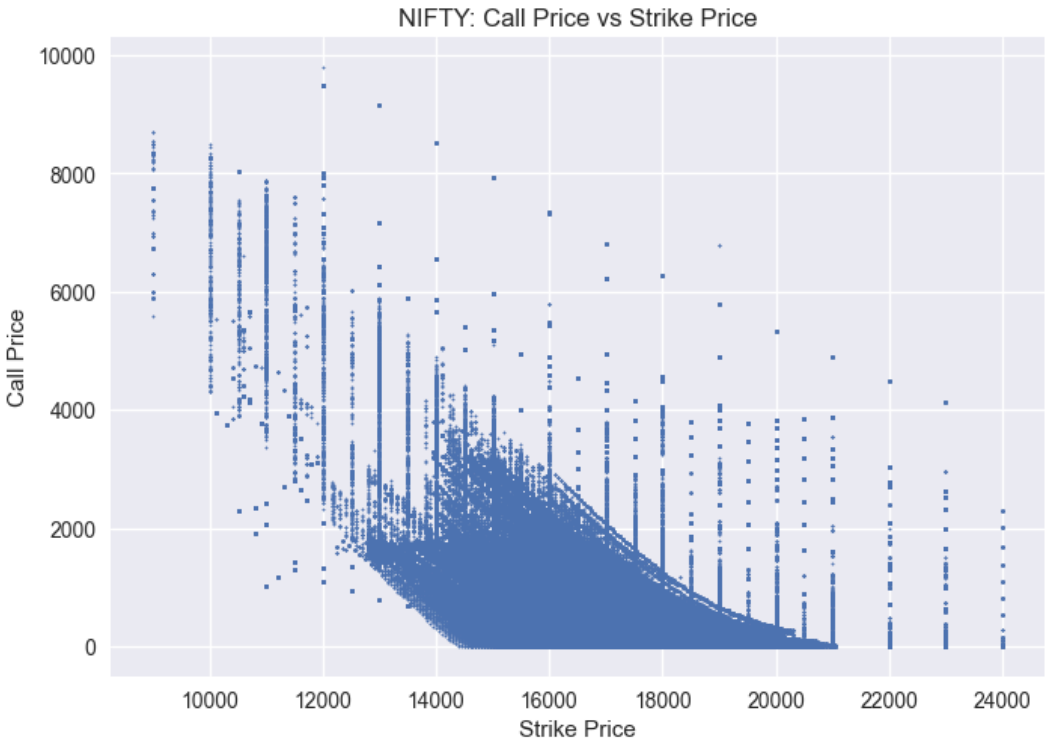
Question 2:

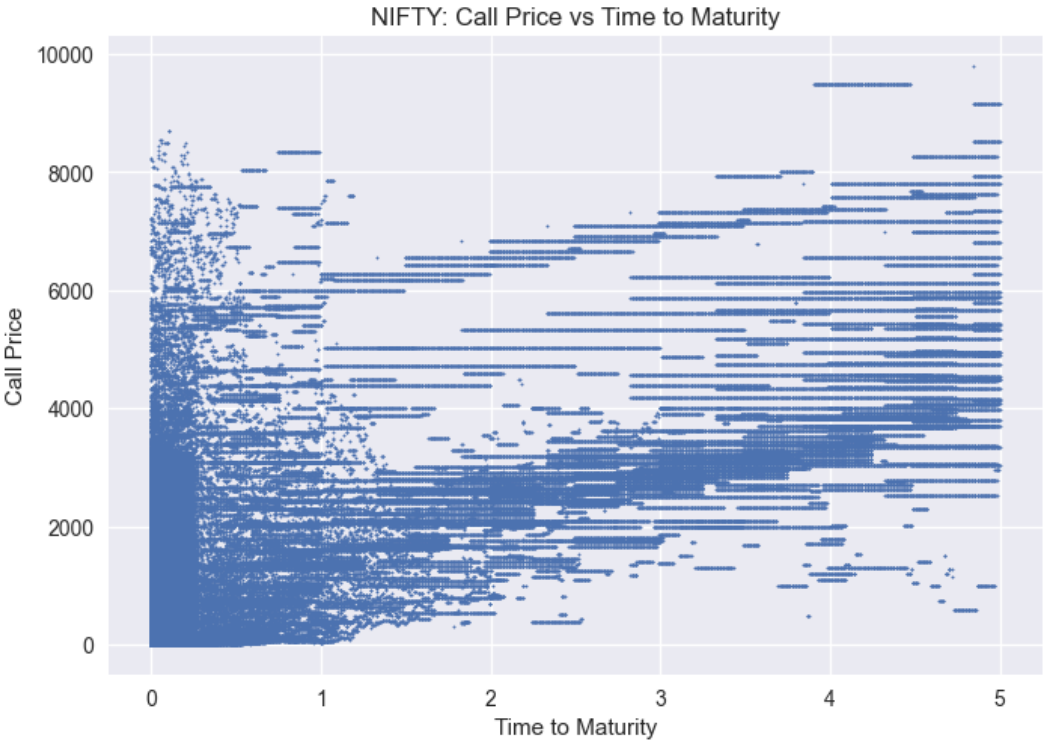
Part-A)

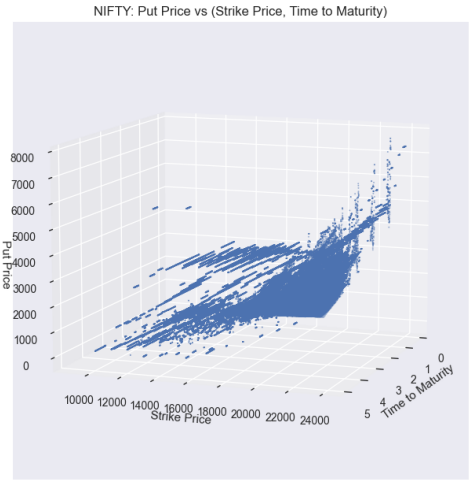
- A new column, Time to Maturity, is added by subtracting starting date of the option price from the exercising date. It is then divided by 365 to get it in years.
- Option prices were plotted against time to maturity and strike price in three dimensions and against each of these 2 parameters in two dimensions. These plots are shown below.

Output-


NIFTY: Call Price vs (Strike Price, Time to Maturity)
Call Price
10000
8000
6000
4000
2000
0
10000 12000 14000 16000 18000 20000 22000 24000
Strike Price
0 1 2 3 4 5
Time to Maturity


NIFTY: Call Price vs Strike Price
Call Price
10000
8000
6000
4000
2000
0
10000 12000 14000 16000 18000 20000 22000 24000
Strike Price


NIFTY: Call Price vs Time to Maturity
Call Price
Time to Maturity
10000
8000
6000
4000
2000
0
0
1
2
3
4
5


NIFTY: Put Price vs (Strike Price, Time to Maturity)
Put Price
Strike Price
Time to Maturity
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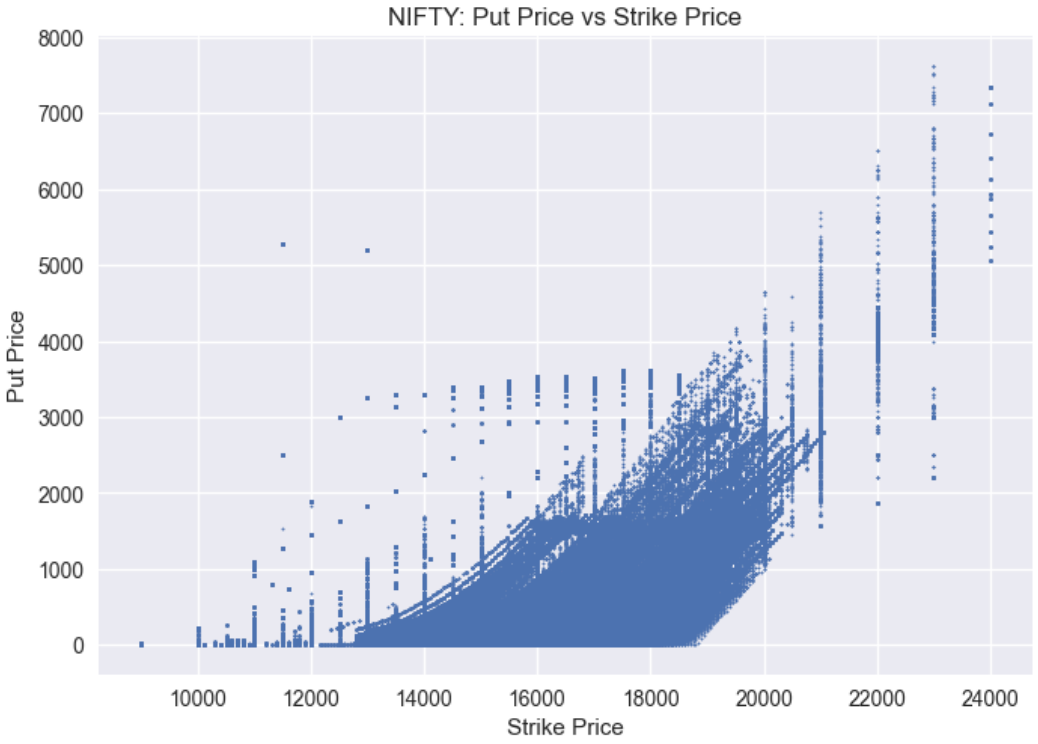
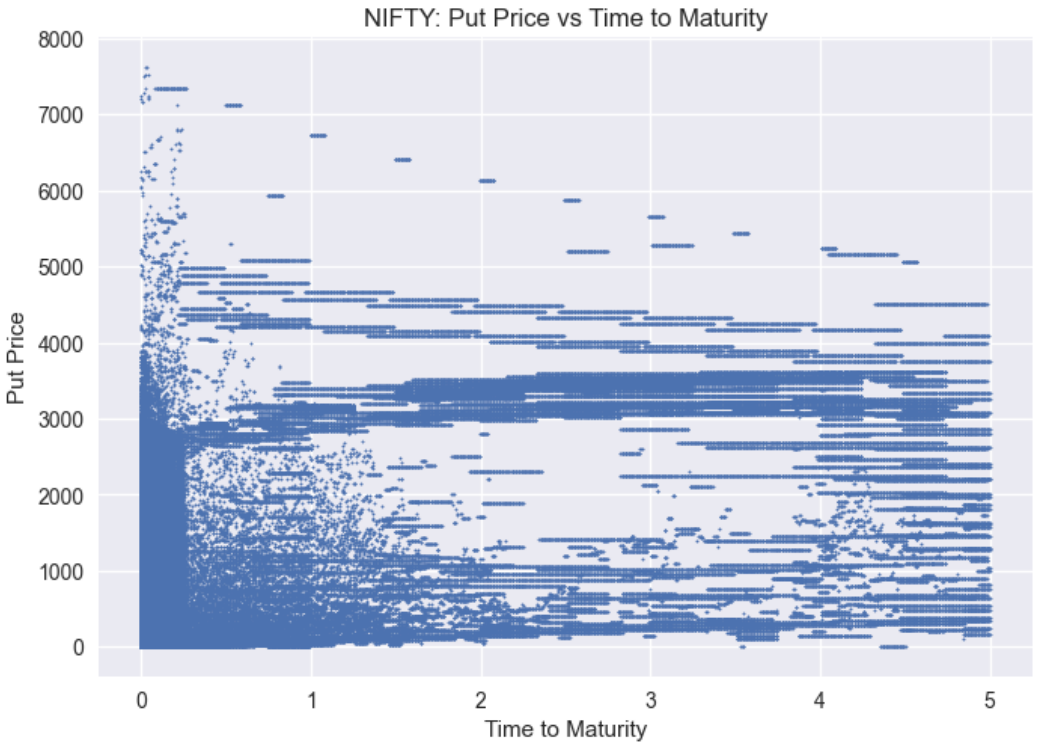
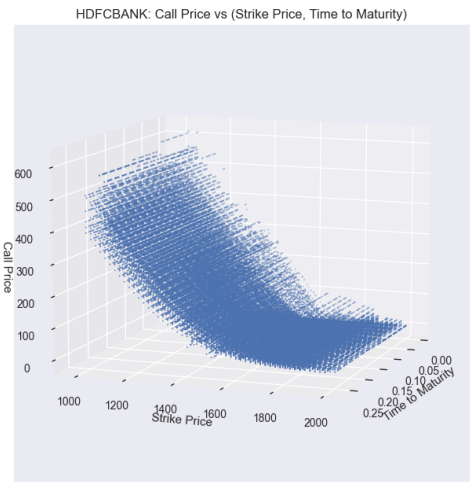
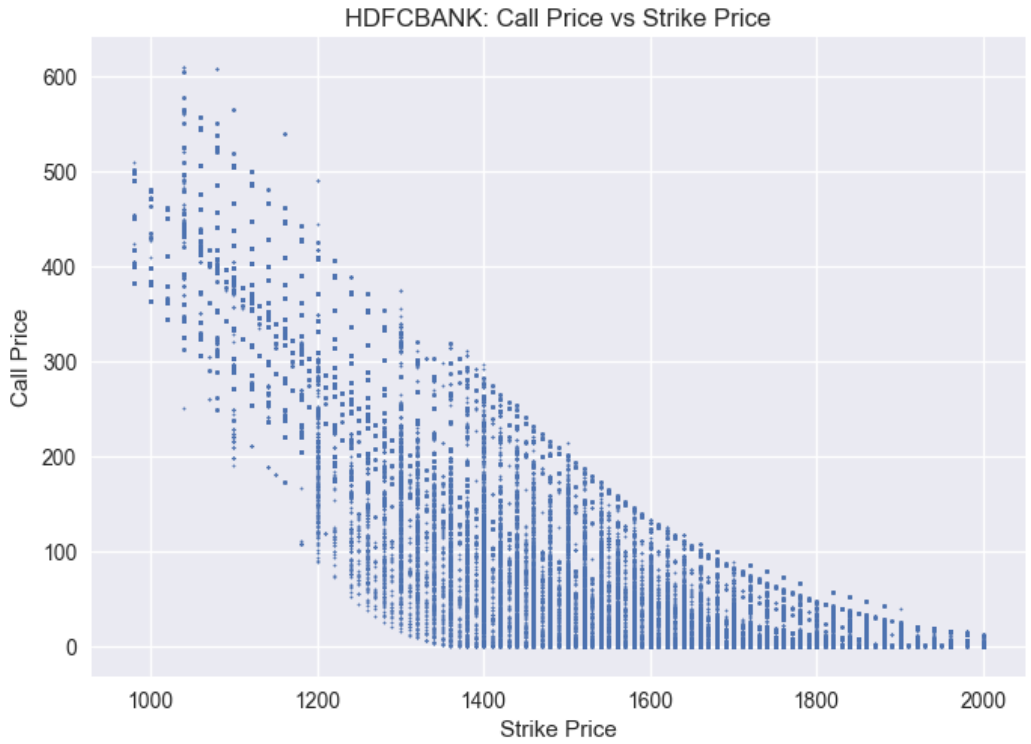
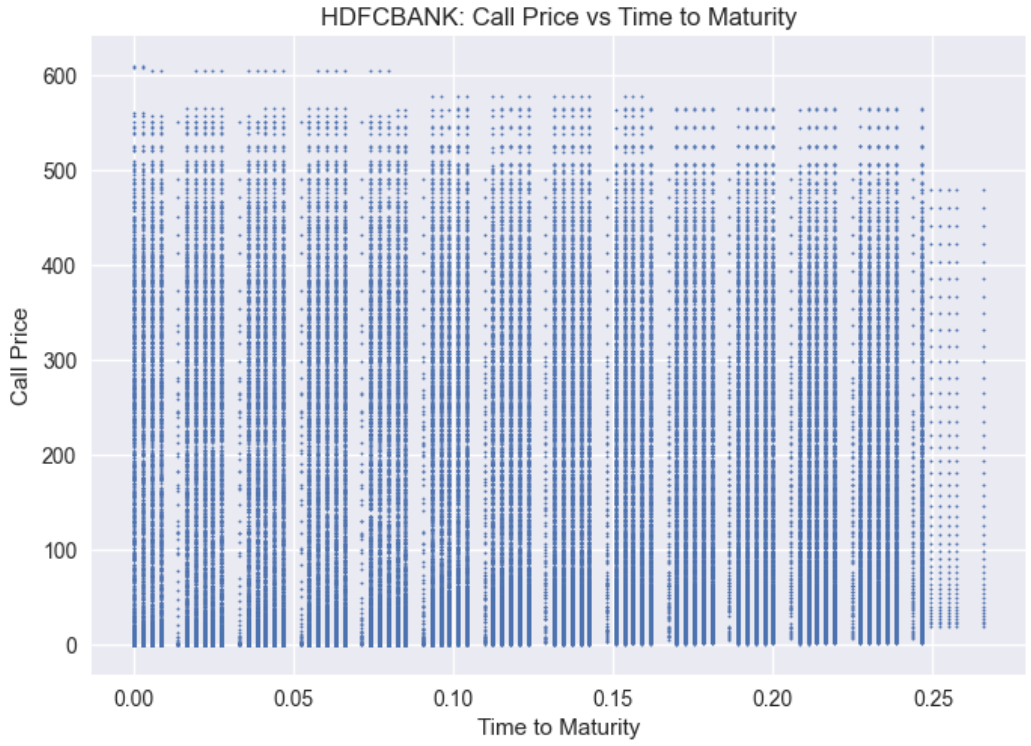
7000
6000
5000
4000
3000
2000
1000
0
10000 12000 14000 16000 18000 20000 22000 24000
0 1 2 3 4 5

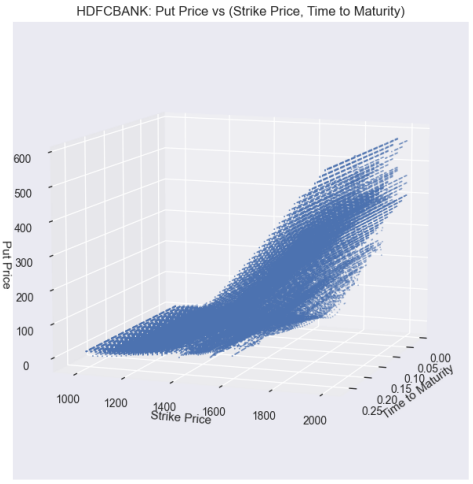

NIFTY: Put Price vs Strike Price
Put Price
Strike Price
0
1000
2000
3000
4000
5000
6000
7000
8000
10000
12000
14000
16000
18000
20000
22000
24000


NIFTY: Put Price vs Time to Maturity
Put Price
Time to Maturity
0
1000
2000
3000
4000
5000
6000
7000
8000
0
1
2
3
4
5

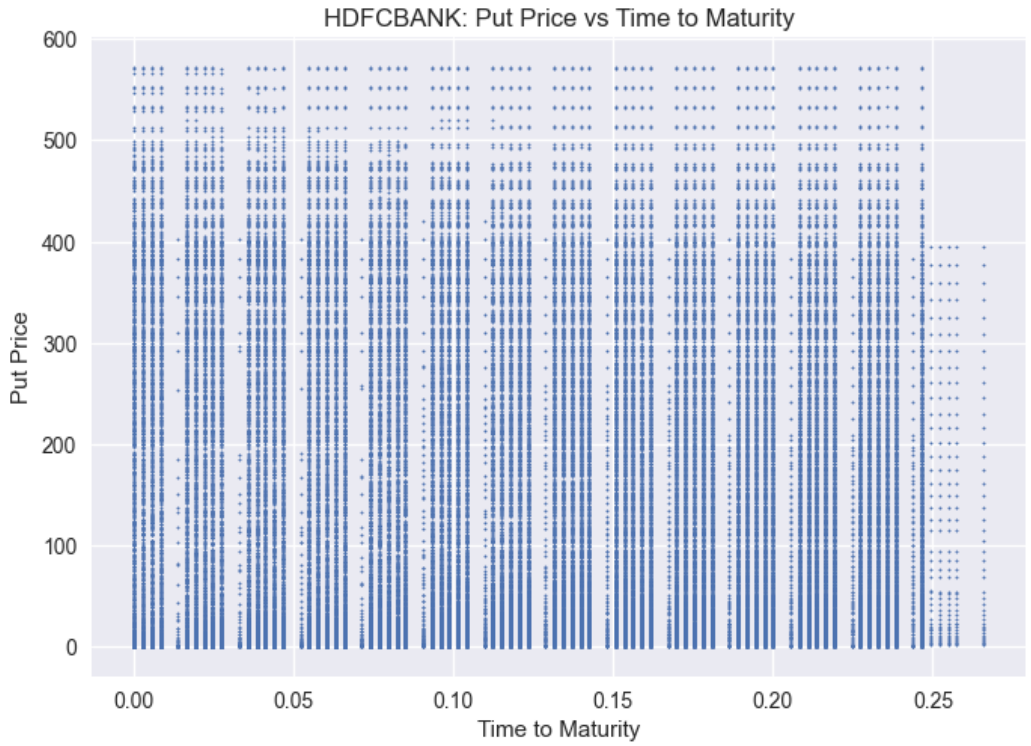

HDFCBANK: Call Price vs (Strike Price, Time to Maturity)
Call Price
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


HDFCBANK: Call Price vs Strike Price
Call Price
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
Strike Price


HDFCBANK: Call Price vs Time to Maturity
Call Price
600
500
400
300
200
100
0
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


HDFCBANK: Put Price vs (Strike Price, Time to Maturity)
Put Price
600
500
400
300
200
100
0
1000
1200
1400
1600
1800
2000
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


HDFCBANK: Put Price vs Strike Price
Put Price
Strike Price
0
100
200
300
400
500
600
1000
1200
1400
1600
1800
2000


HDFCBANK: Put Price vs Time to Maturity
Put Price
Time to Maturity
0
100
200
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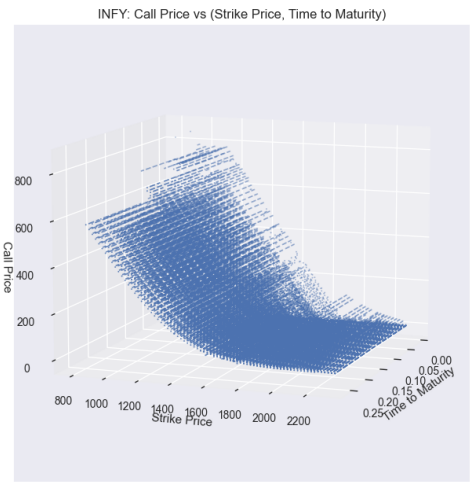
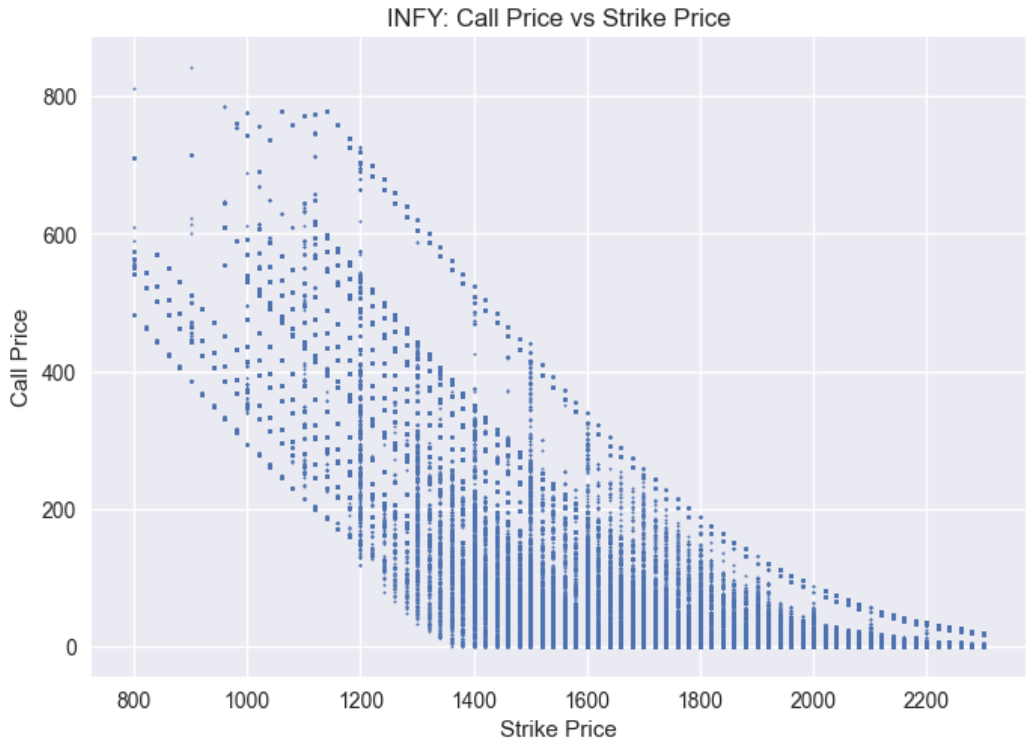
600
0.00
0.05
0.10
0.15
0.20
0.25


INFY: Call Price vs (Strike Price, Time to Maturity)
Call Price
800
600
400
200
0
800
1000
1200
1400
1600
1800
2000
2200
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


INFY: Call Price vs Strike Price
Call Price
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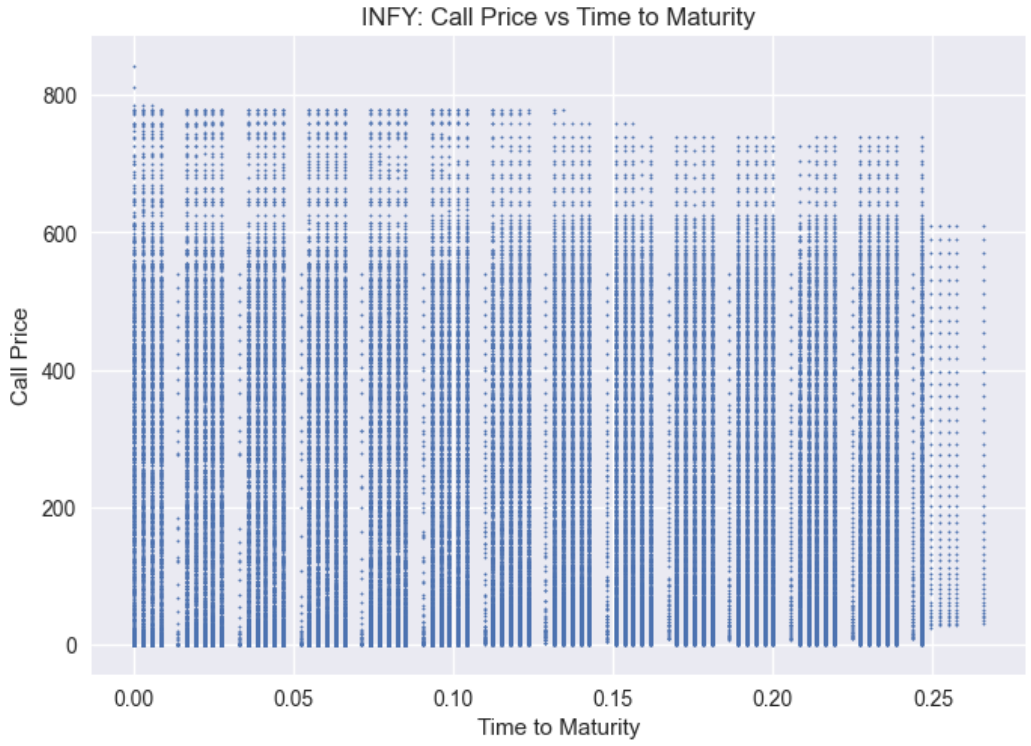
2000
2200
Strike Price


INFY: Call Price vs Time to Maturity
Call Price
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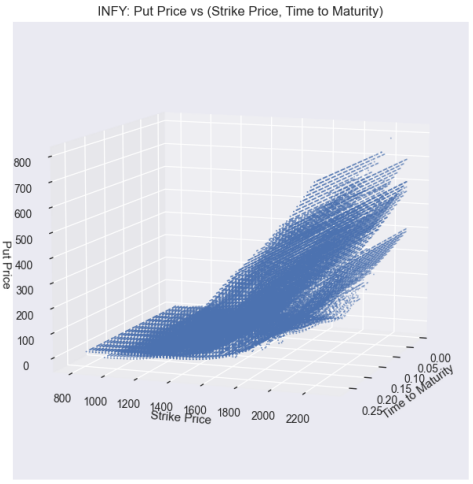
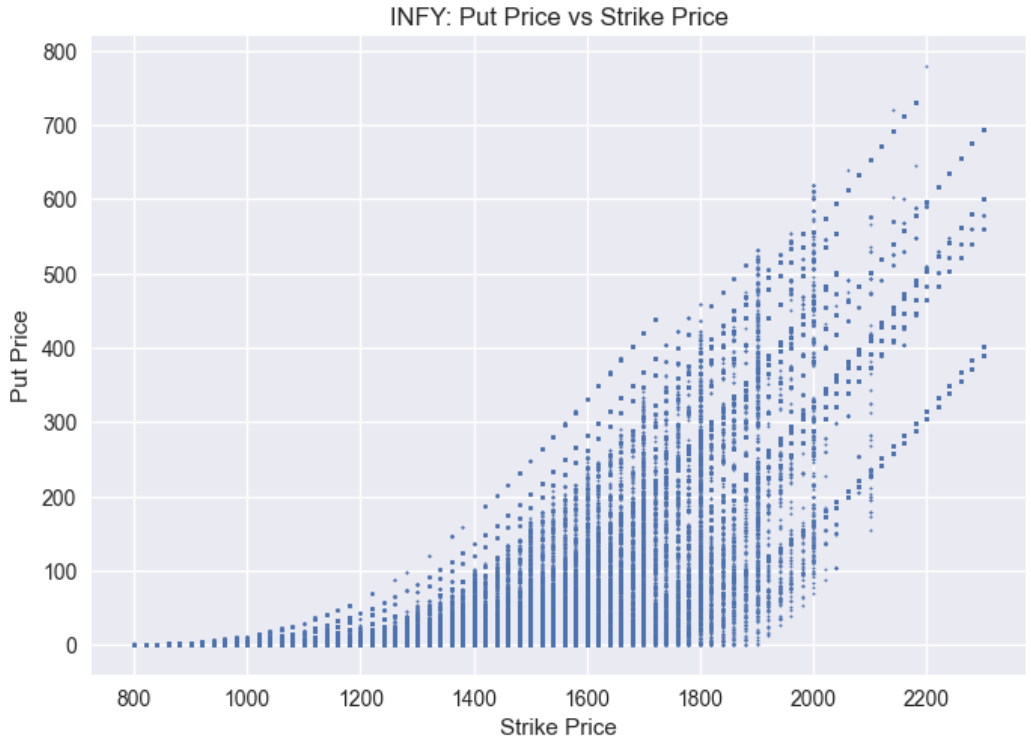
0.15
0.20
0.25
Time to Maturity


INFY: Put Price vs (Strike Price, Time to Maturity)
Put Price
800
700
600
500
400
300
200
100
0
800
1000
1200
1400
1600
1800
2000
2200
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


INFY: Put Price vs Strike Price
Put Price
Strike Price
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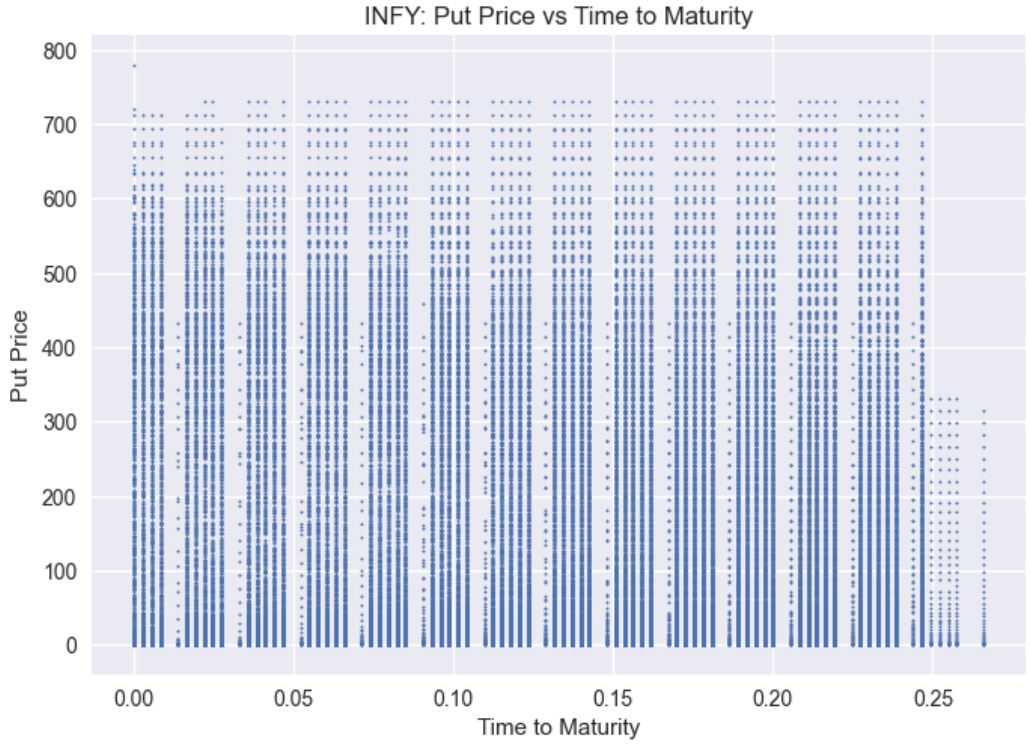
700
800
800
1000
1200
1400
1600
1800
2000
2200


INFY: Put Price vs Time to Maturity
Put Price
Time to Maturity
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200
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600
700
800
0.00
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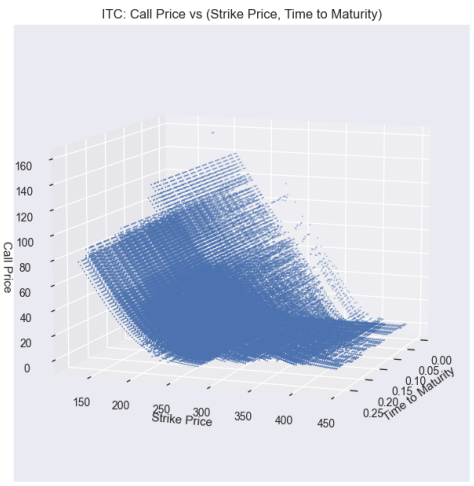
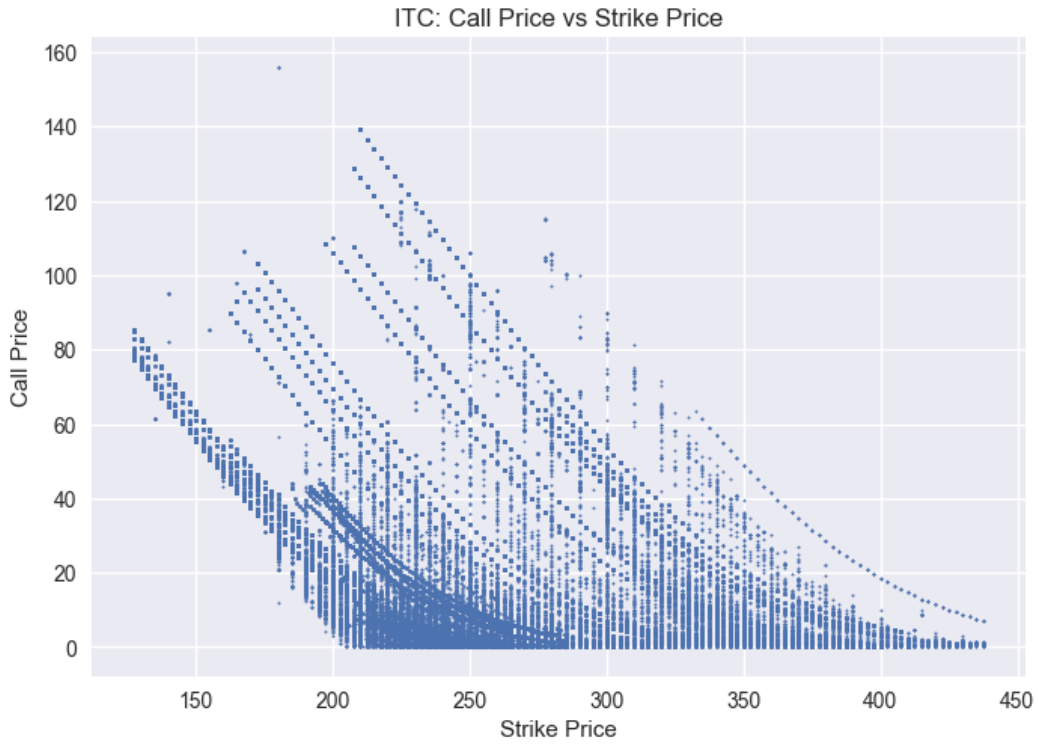
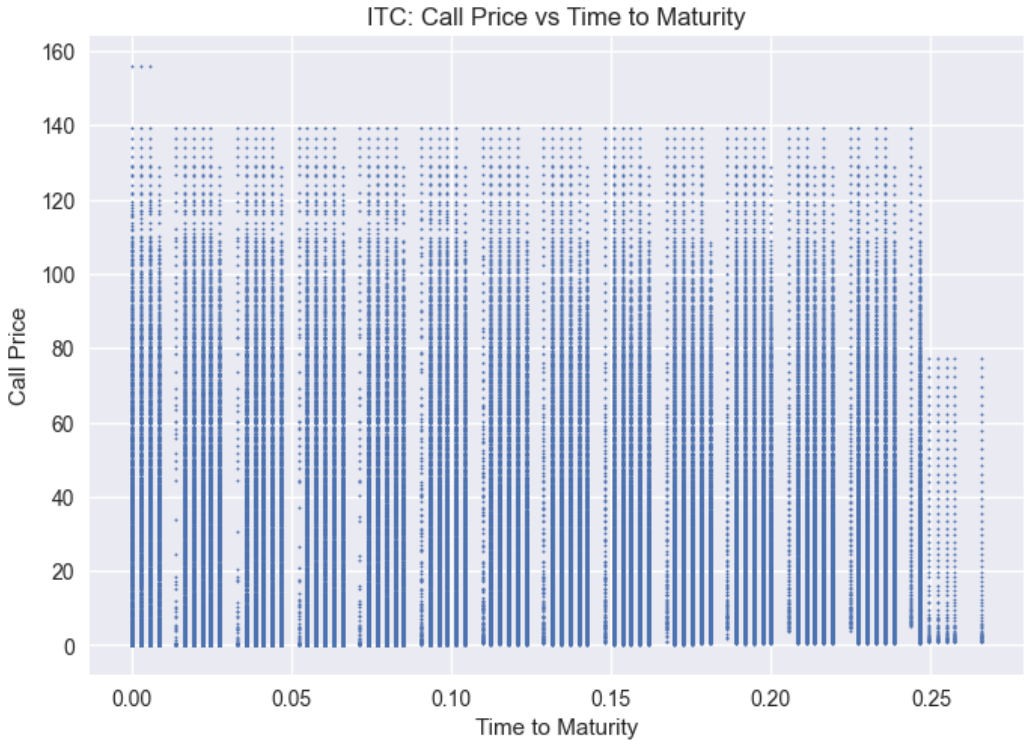
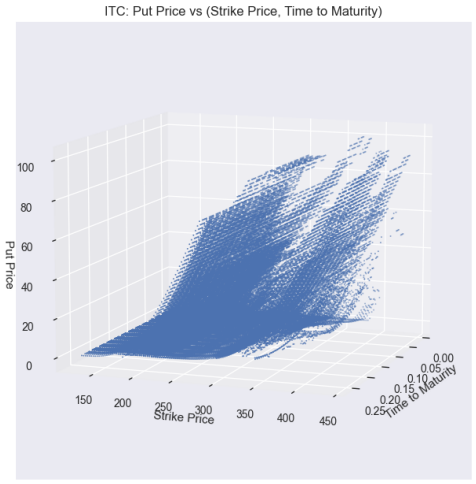
0.10
0.15
0.20
0.25

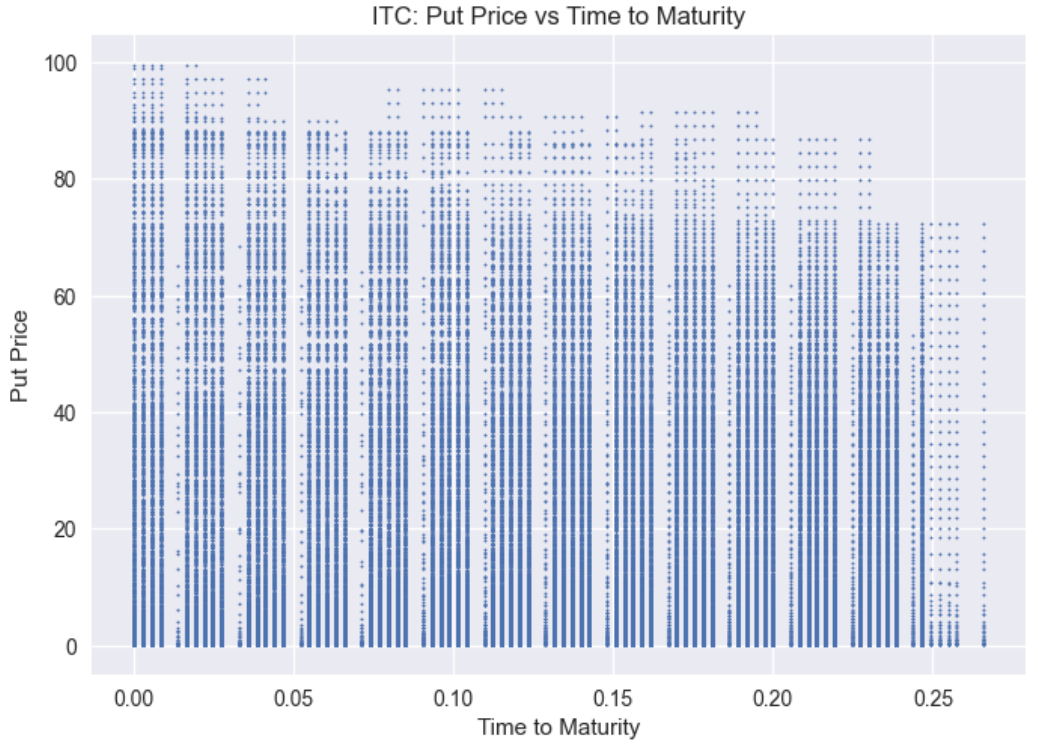

ITC: Call Price vs (Strike Price, Time to Maturity)
Call Price
160
140
120
100
80
60
40
20
0
150
200
250
300
350
400
450
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


ITC: Call Price vs Strike Price
Call Price
160
140
120
100
80
60
40
20
0
150
200
250
300
350
400
450
Strike Price


ITC: Call Price vs Time to Maturity
Call Price
Time to Maturity
0
20
40
60
80
100
120
140
160
0.00
0.05
0.10
0.15
0.20
0.25


ITC: Put Price vs (Strike Price, Time to Maturity)
Put Price
Strike Price
Time to Maturity
0
20
40
60
80
100
150
200
250
300
350
400
450
0.00
0.05
0.10
0.15
0.20
0.25


ITC: Put Price vs Strike Price
Put Price
Strike Price
0
20
40
60
80
100
150
200
250
300
350
400
450


ITC: Put Price vs Time to Maturity
Put Price
Time to Maturity
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20
40
60
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0.00
0.05
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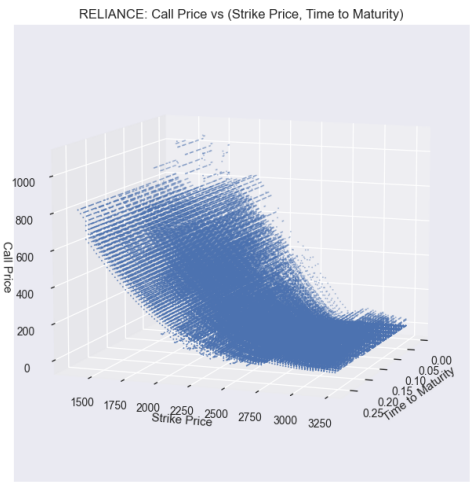
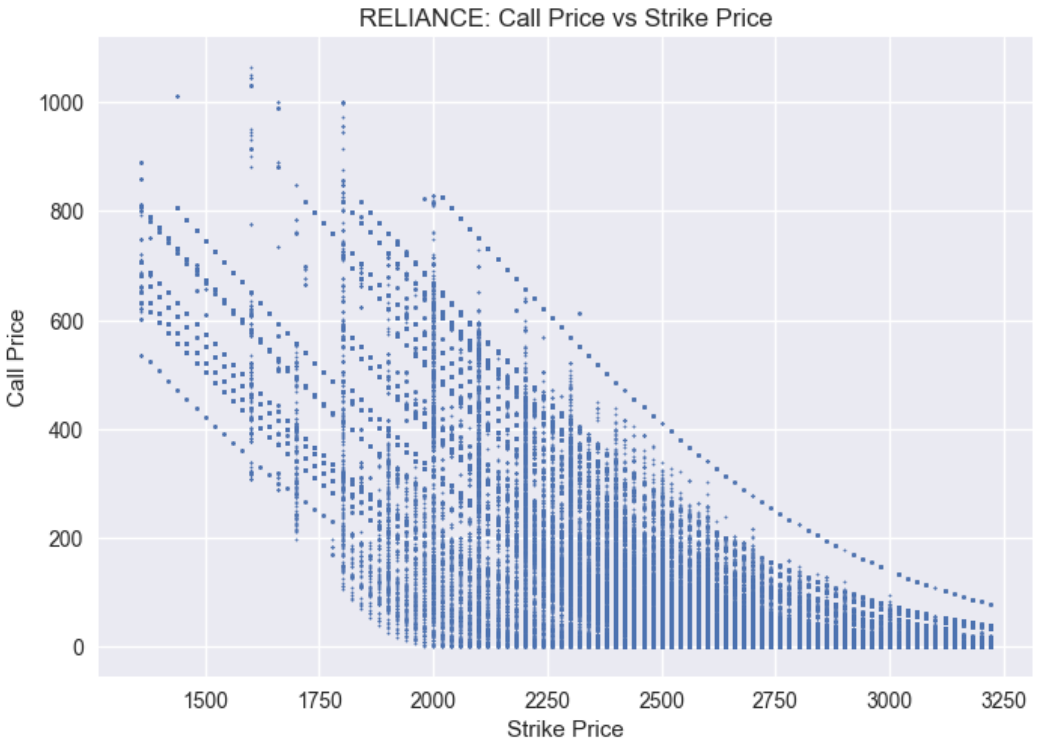
0.15
0.20
0.25


RELIANCE: Call Price vs (Strike Price, Time to Maturity)
Call Price
1000
800
600
400
200
0
1500
1750
2000
2250
2500
2750
3000
3250
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


RELIANCE: Call Price vs Strike Price
Call Price
1000
800
600
400
200
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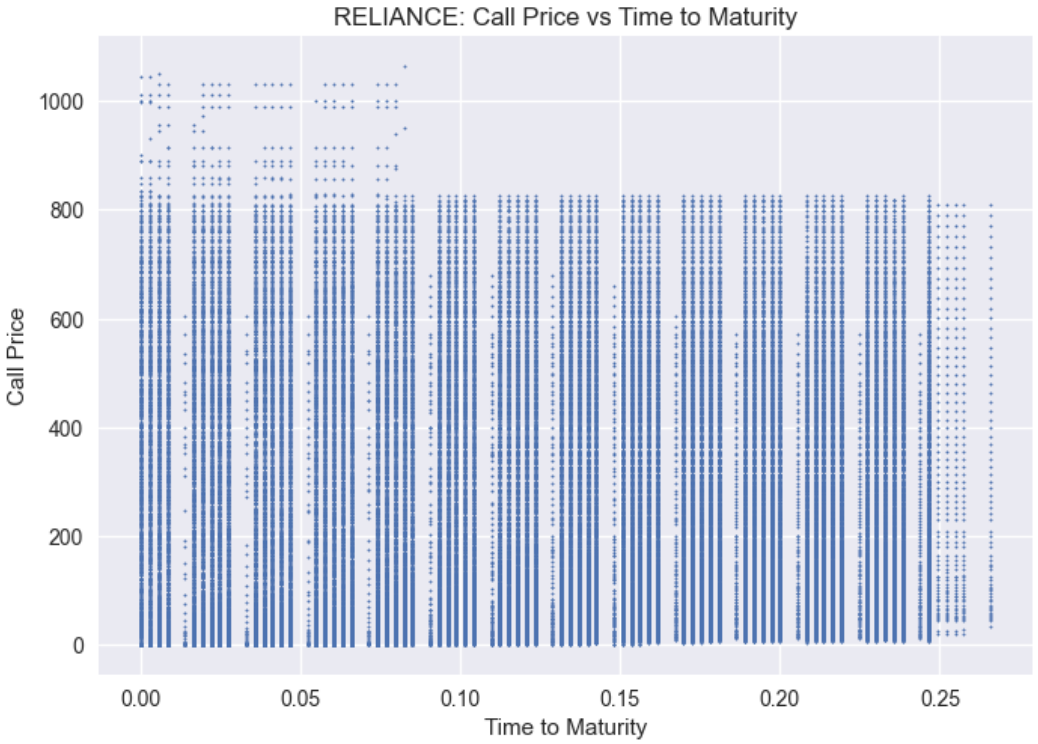
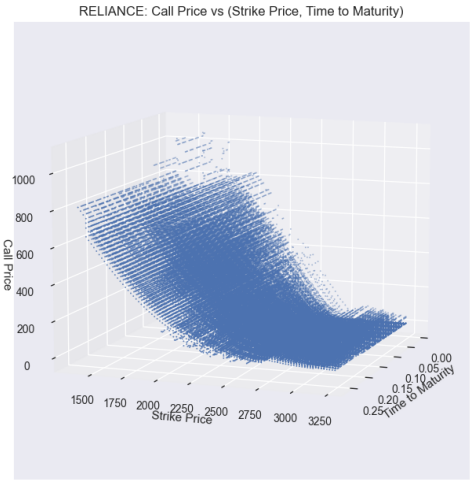
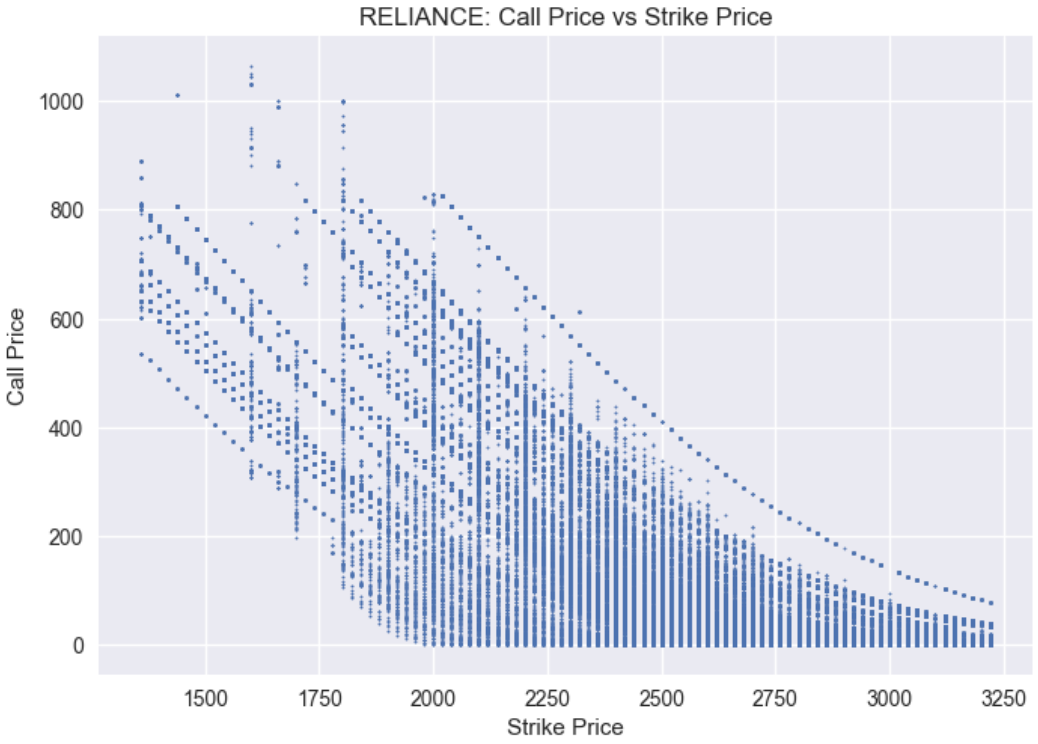
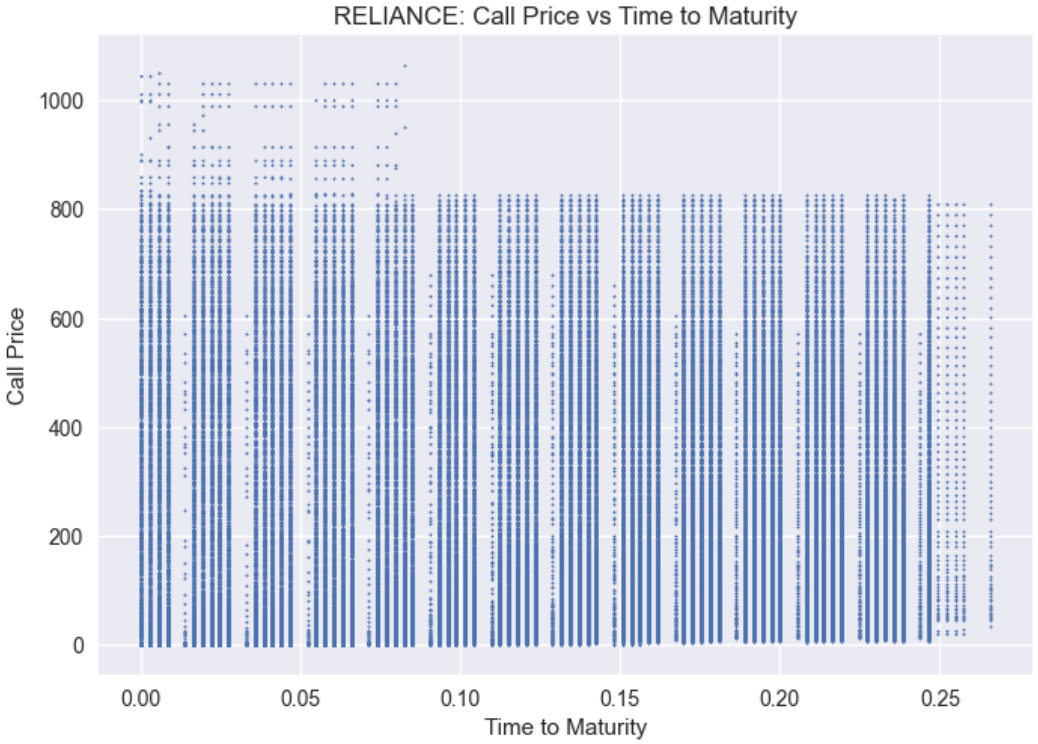
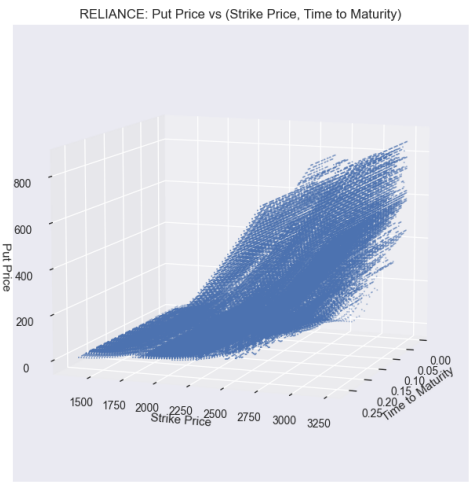
1500
1750
2000
2250
2500
2750
3000
3250
Strike Price


RELIANCE: Call Price vs Time to Maturity
Call Price
Time to Maturity
0
200
400
600
800
1000
0.00
0.05
0.10
0.15
0.20
0.25

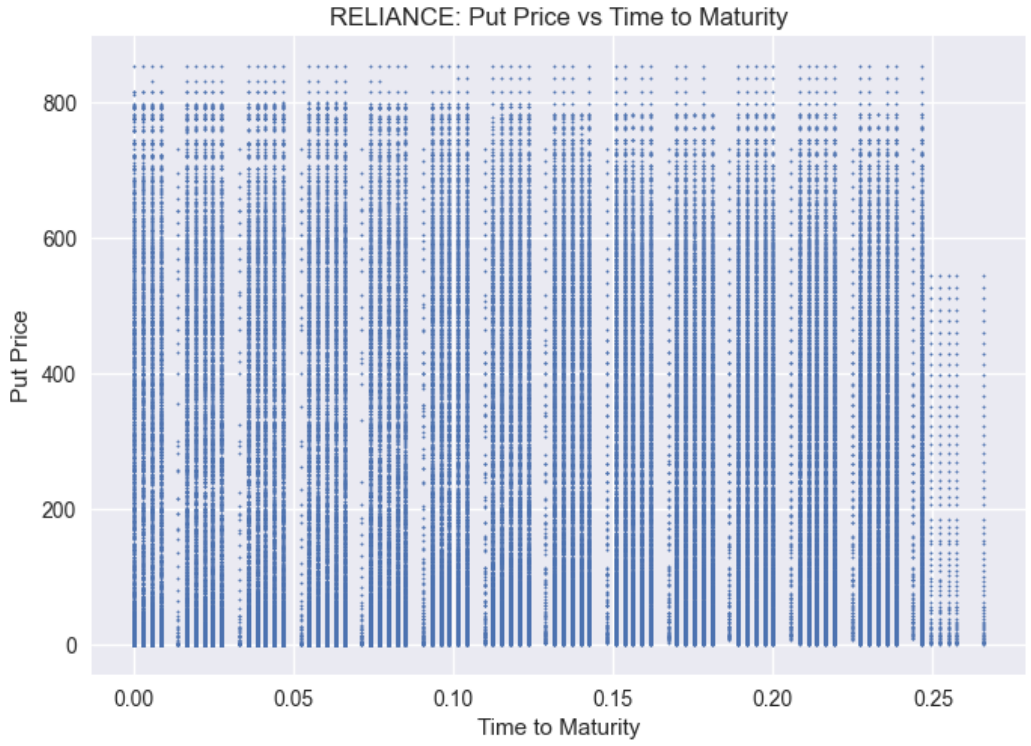

RELIANCE: Call Price vs (Strike Price, Time to Maturity)
Call Price
Strike Price
Time to Maturity


RELIANCE: Call Price vs Strike Price
Call Price
Strike Price
0
200
400
600
800
1000
1500
1750
2000
2250
2500
2750
3000
3250

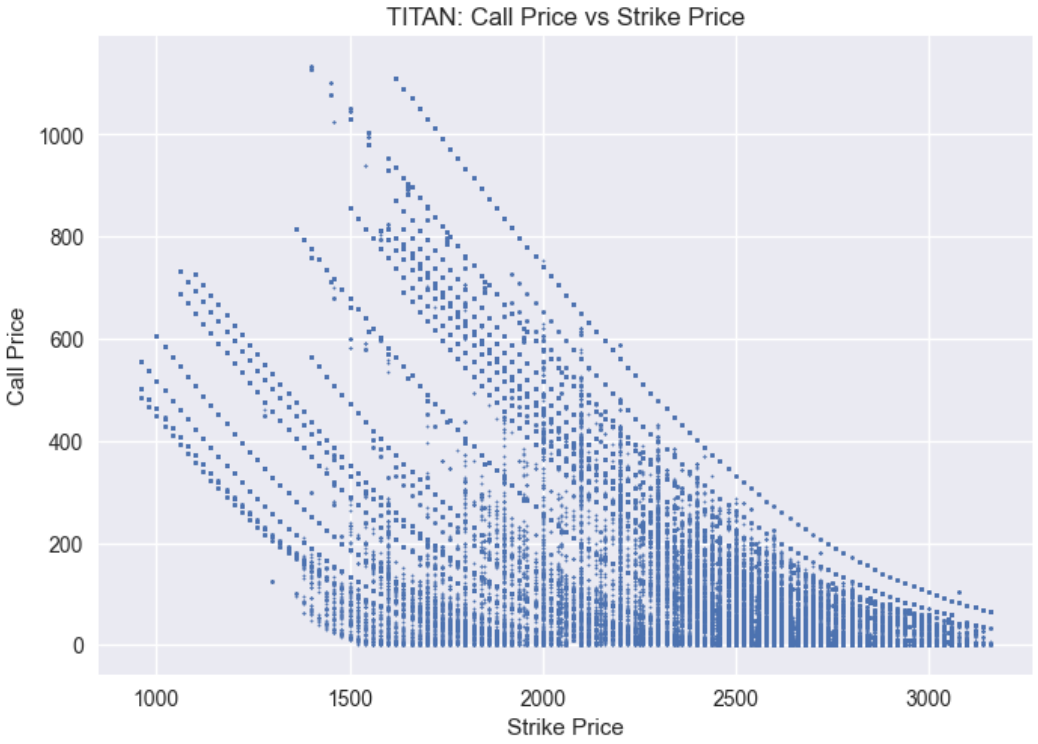

RELIANCE: Call Price vs Time to Maturity
Call Price
Time to Maturity
0
200
400
600
800
1000
0.00
0.05
0.10
0.15
0.20
0.25

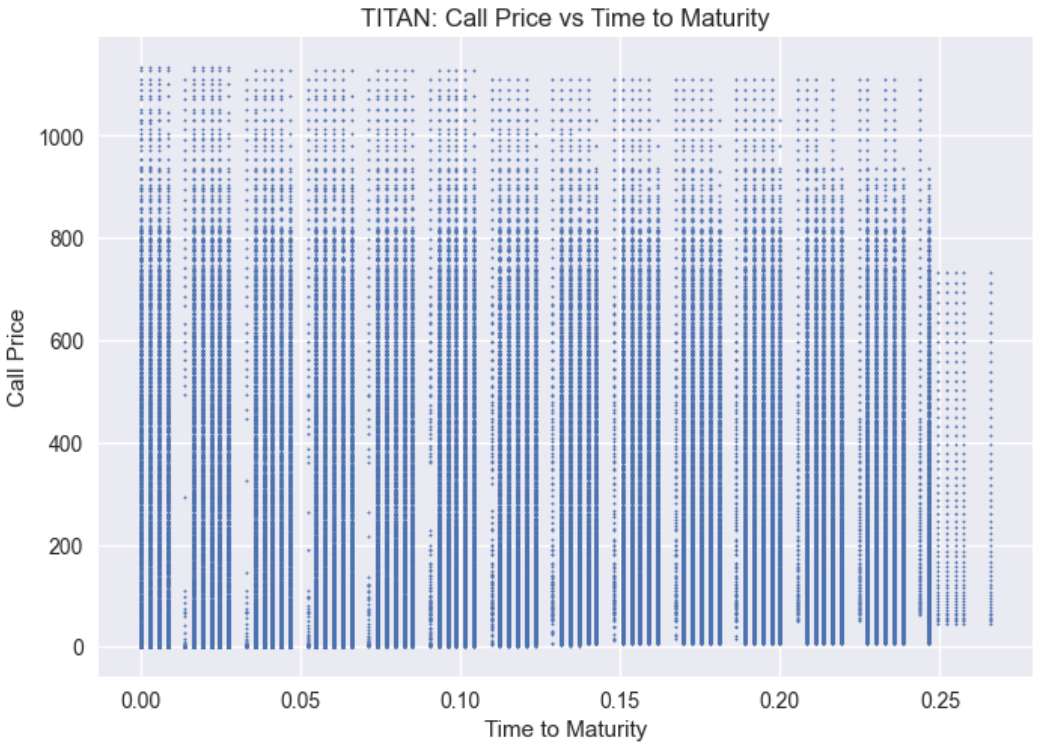

RELIANCE: Put Price vs (Strike Price, Time to Maturity)
Put Price
800
600
400
200
0
1500
1750
2000
2250
2500
2750
3000
3250
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity

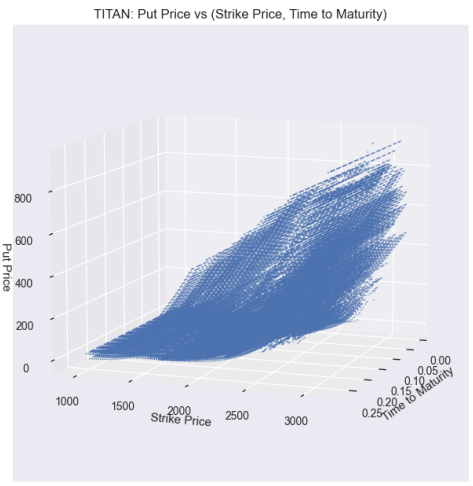

RELIANCE: Put Price vs Strike Price
Put Price
800
600
400
200
0
1500
1750
2000
2250
2500
2750
3000
3250
Strike Price

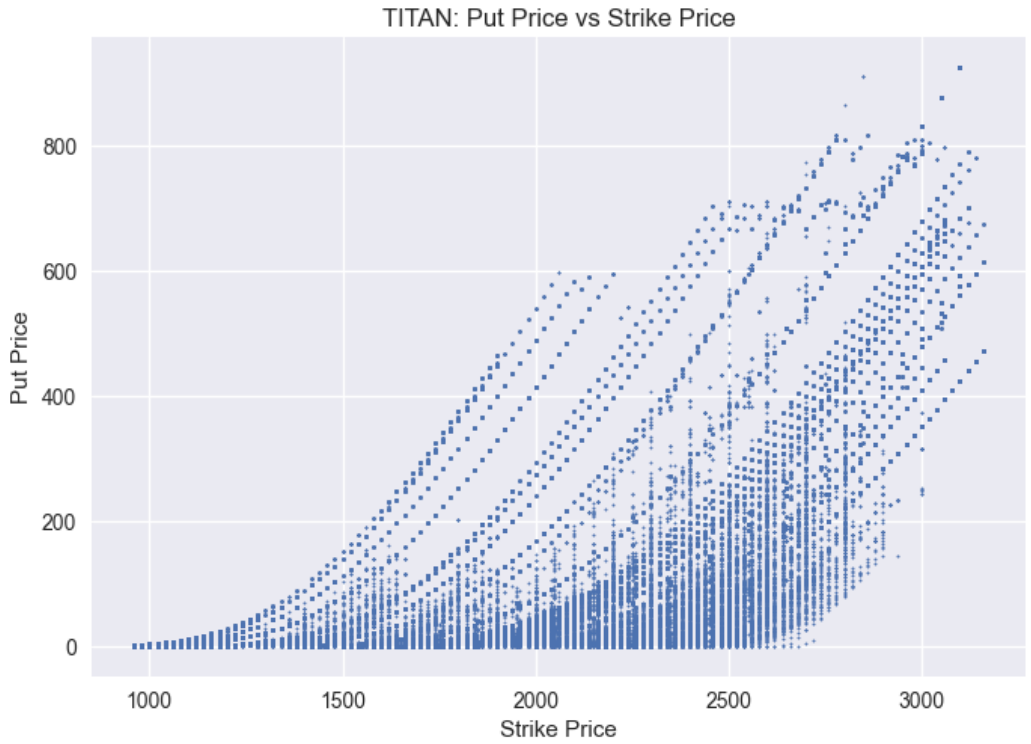

RELIANCE: Put Price vs Time to Maturity
Put Price
800
600
400
200
0
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity

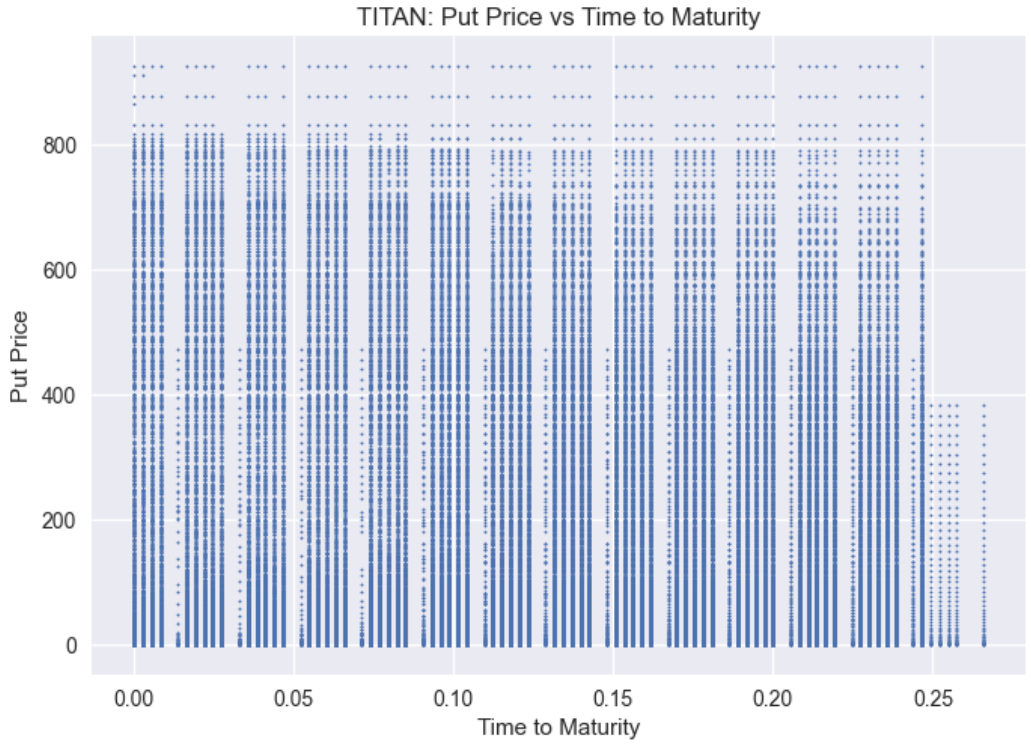

TITAN: Call Price vs (Strike Price, Time to Maturity)
Call Price
1000
800
600
400
200
0
1000
1500
2000
2500
3000
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


TITAN: Call Price vs Strike Price
Call Price
0
200
400
600
800
1000
1000
1500
2000
2500
3000
Strike Price


TITAN: Call Price vs Time to Maturity
Call Price
0
200
400
600
800
1000
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


TITAN: Put Price vs (Strike Price, Time to Maturity)
Put Price
800
600
400
200
0
1000
1500
2000
2500
3000
Strike Price
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity


TITAN: Put Price vs Strike Price
Put Price
800
600
400
200
0
1000
1500
2000
2500
3000
Strike Price



Observations-

- The call options prices decrease with the strike price and put option prices increase with the strike price, which is the expected behavior.
- Options prices are evenly distributed in two dimensions when plotted against time to maturity.

Part-B)

- Implied volatility is calculated by finding the roots of the following equation-

$$f(\sigma) = C(\sigma) - C_m$$

where,

$C(\sigma)$ = BSM price for given S0, K, r, T which would be a function of implied volatility.

C_m = Market price of the Call option.

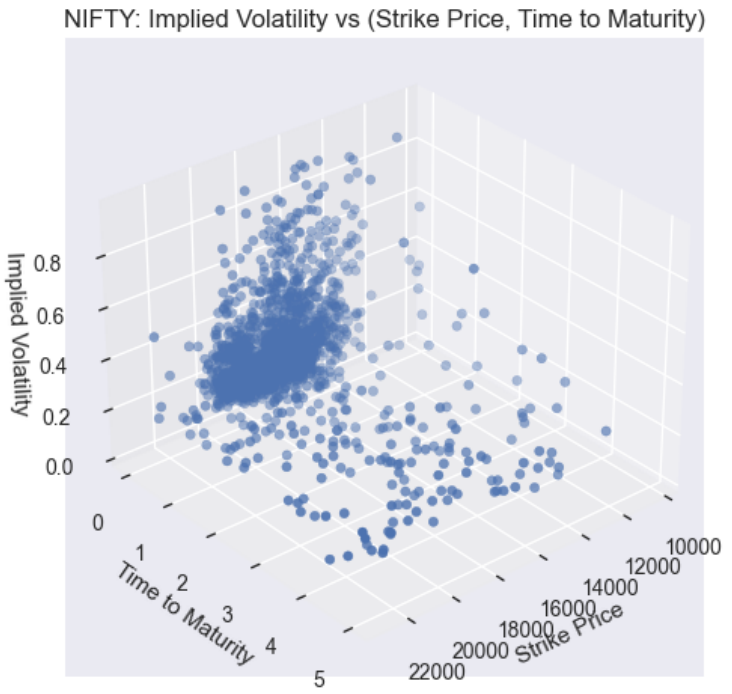
- Root is founded by newton raphson method using the following iteration:

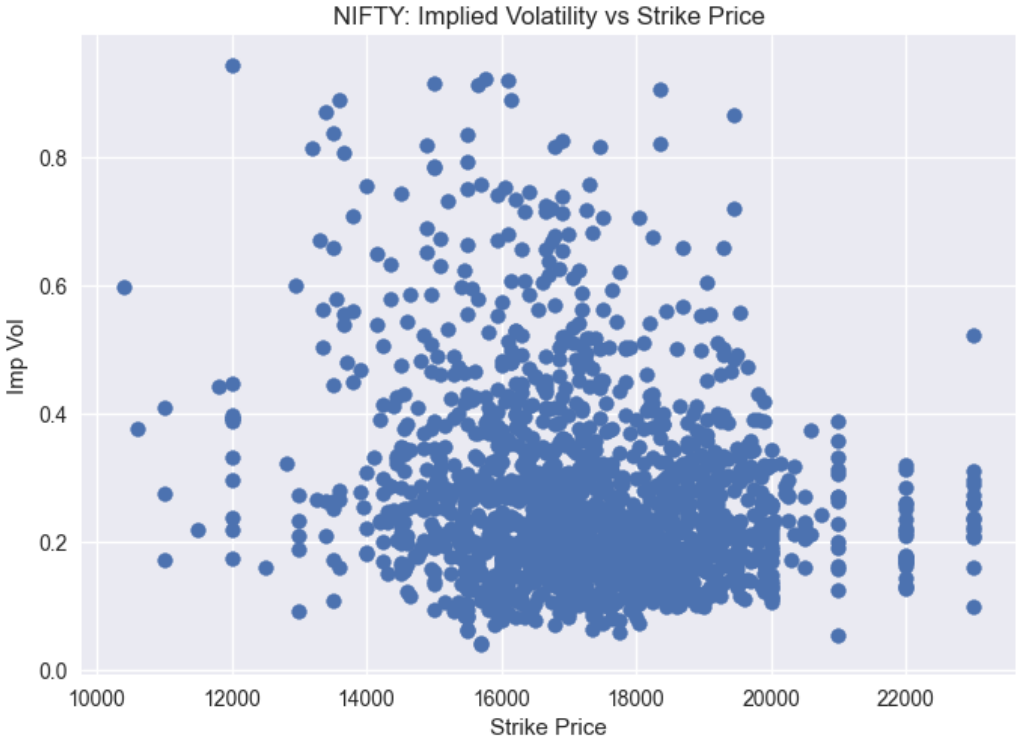
$$\sigma_{n+1} = \sigma_n - f(\sigma_n)/f'(\sigma_n)$$

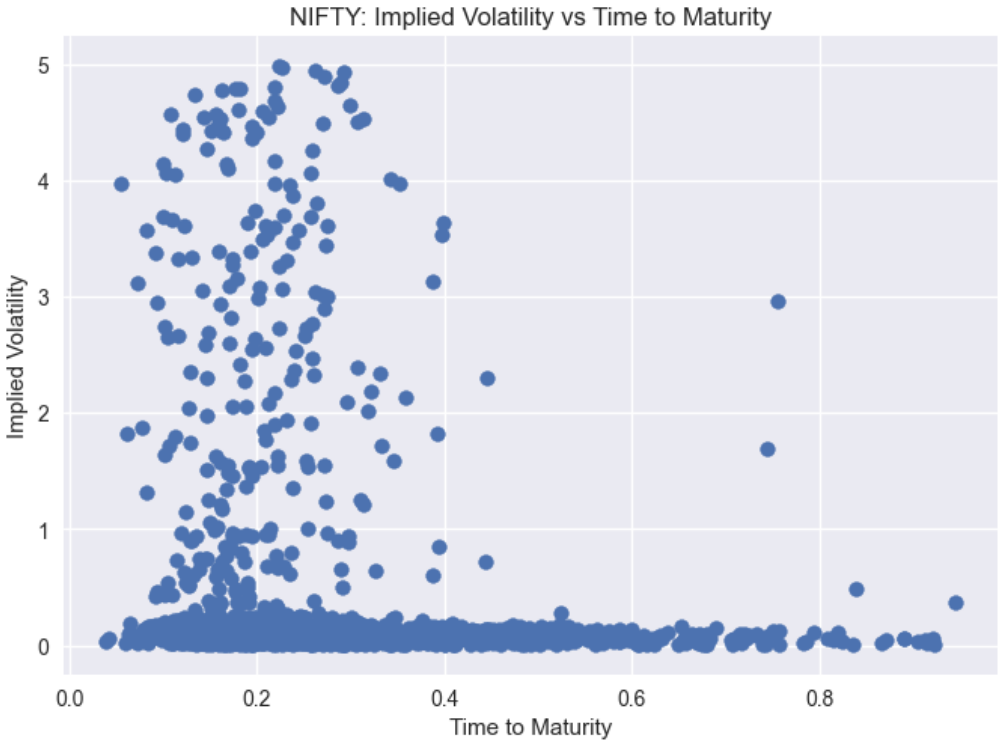
$$\text{where } f'(\sigma_n) = \text{Vega}(\sigma_n) = \sqrt{T}.S0.\frac{1}{\sqrt{2\pi}}e^{-\frac{d_1{}^2}{2}}$$

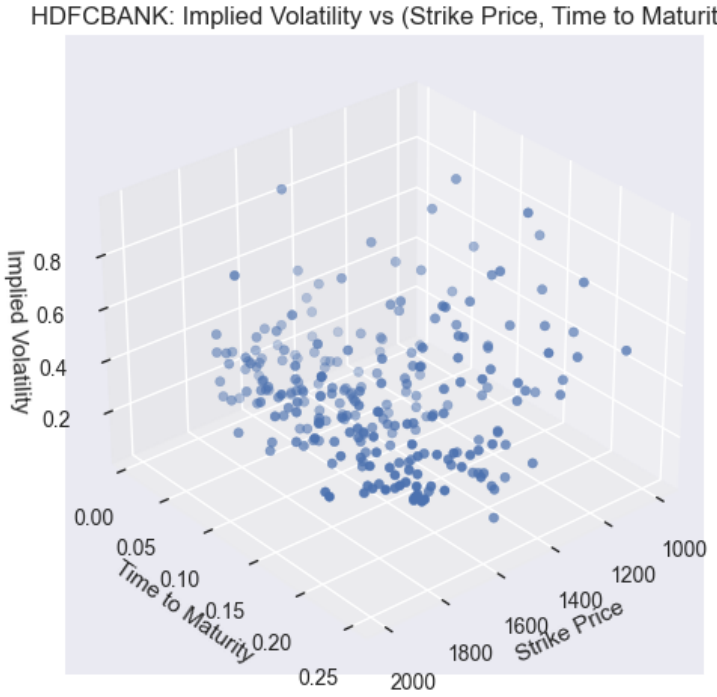
$$d_1 = \frac{1}{\sigma\sqrt{T}}\left[log(S0/K) + \left(r + \frac{\sigma^2}{2}\right)T\right]$$

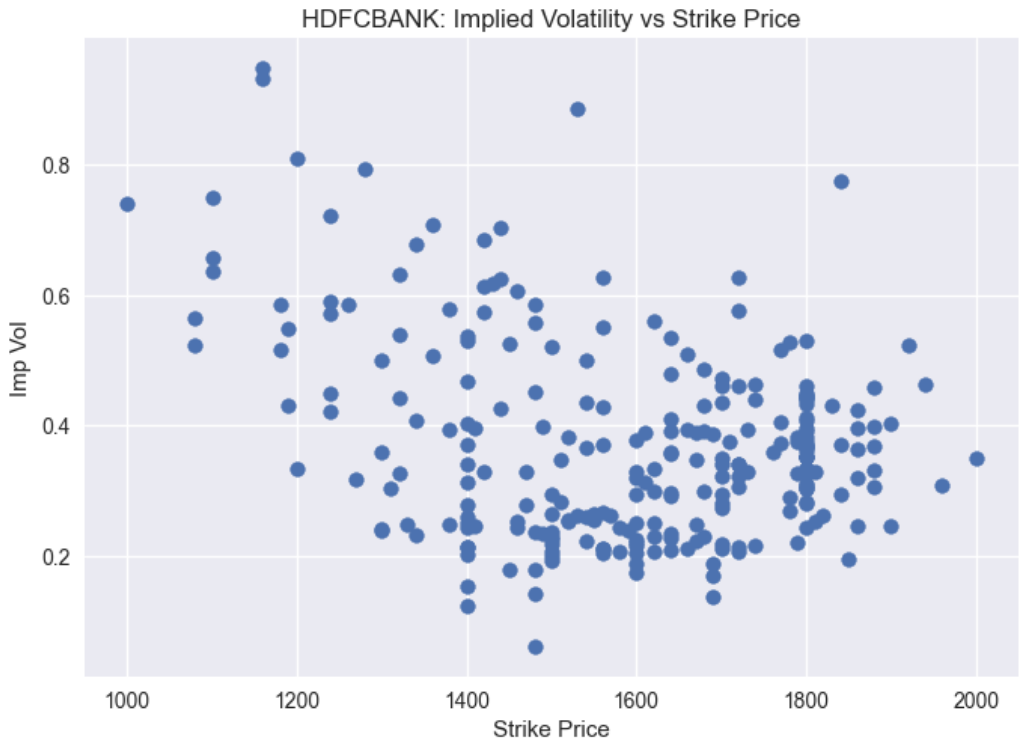
Output (next page)-

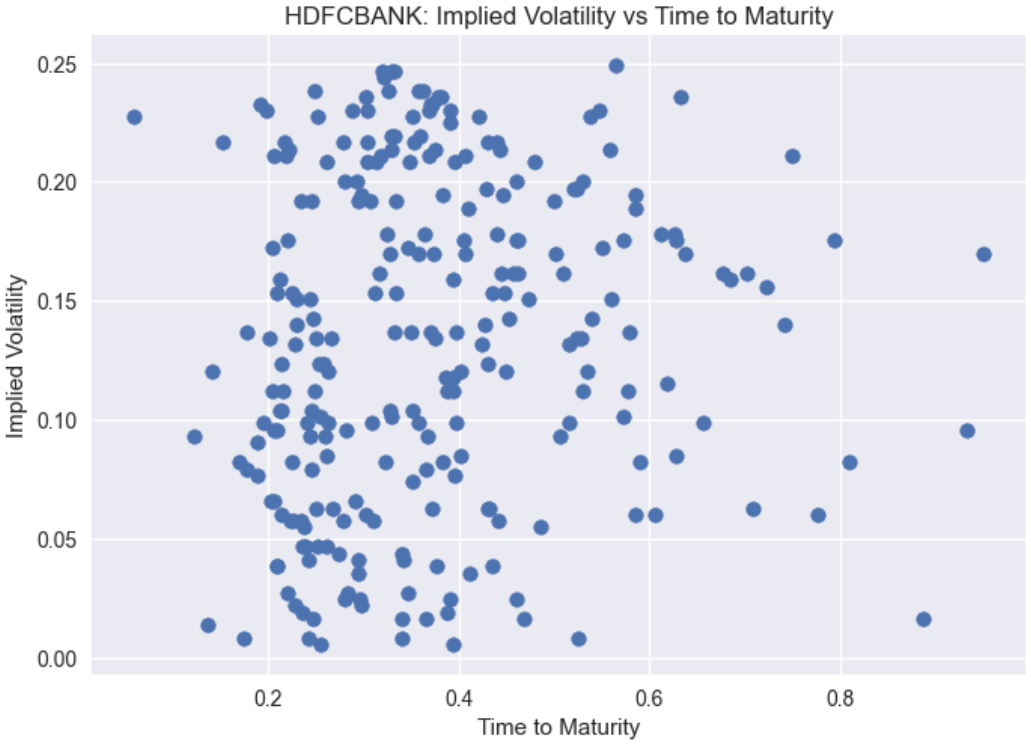

NIFTY: Implied Volatility vs (Strike Price, Time to Maturity)
Implied Volatility
0.0
0.2
0.4
0.6
0.8
Time to Maturity
0
1
2
3
4
5
Strike Price
10000
12000
14000
16000
18000
20000
22000

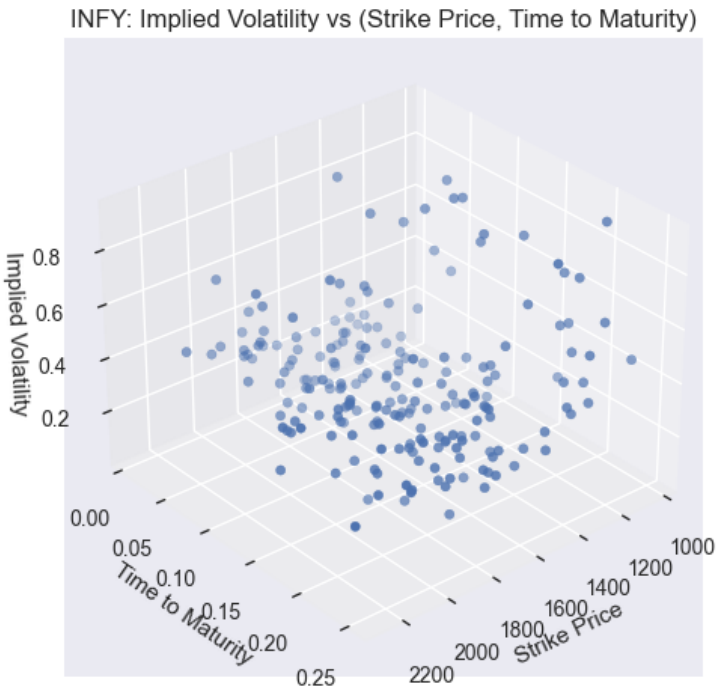

NIFTY: Implied Volatility vs Strike Price
Imp Vol
0.0
0.2
0.4
0.6
0.8
10000
12000
14000
16000
18000
20000
22000
Strike Price

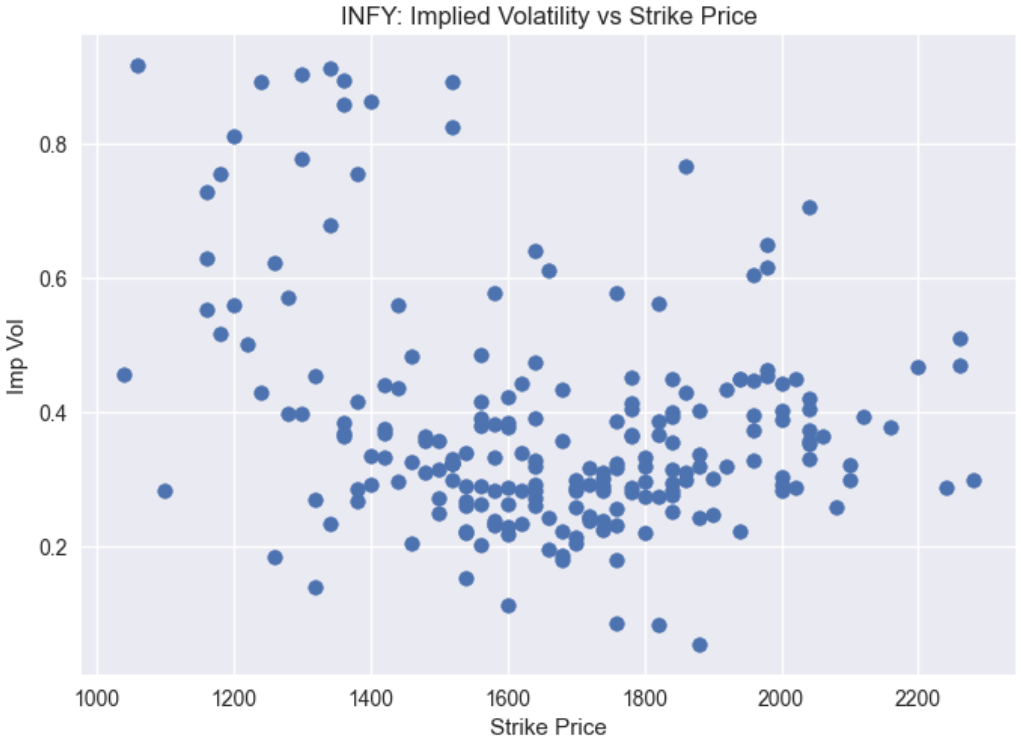

NIFTY: Implied Volatility vs Time to Maturity
Implied Volatility
Time to Maturity
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8

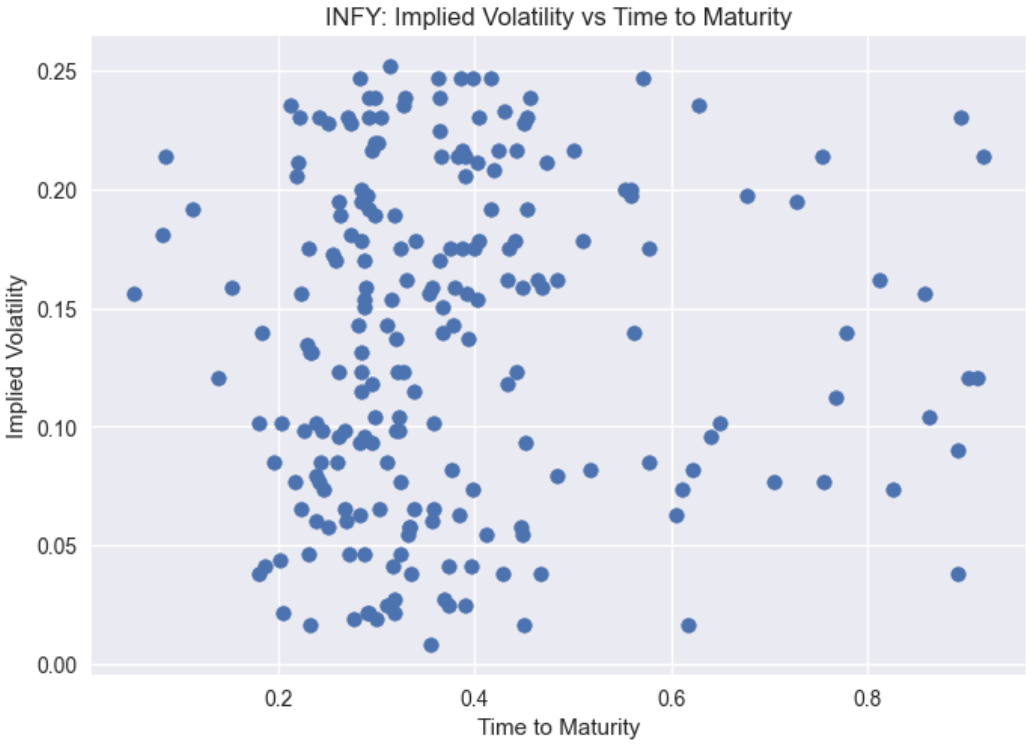

HDFCBANK: Implied Volatility vs (Strike Price, Time to Maturity)
Implied Volatility
0.2
0.4
0.6
0.8
Time to Maturity
0.00
0.05
0.10
0.15
0.20
0.25
Strike Price
1000
1200
1400
1600
1800
2000

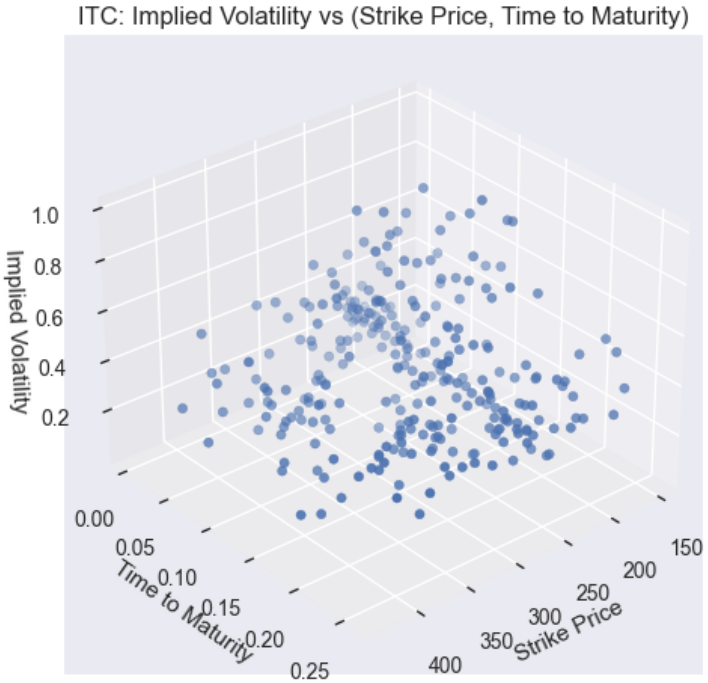

HDFCBANK: Implied Volatility vs Strike Price
Imp Vol
0.8
0.6
0.4
0.2
1000
1200
1400
1600
1800
2000
Strike Price

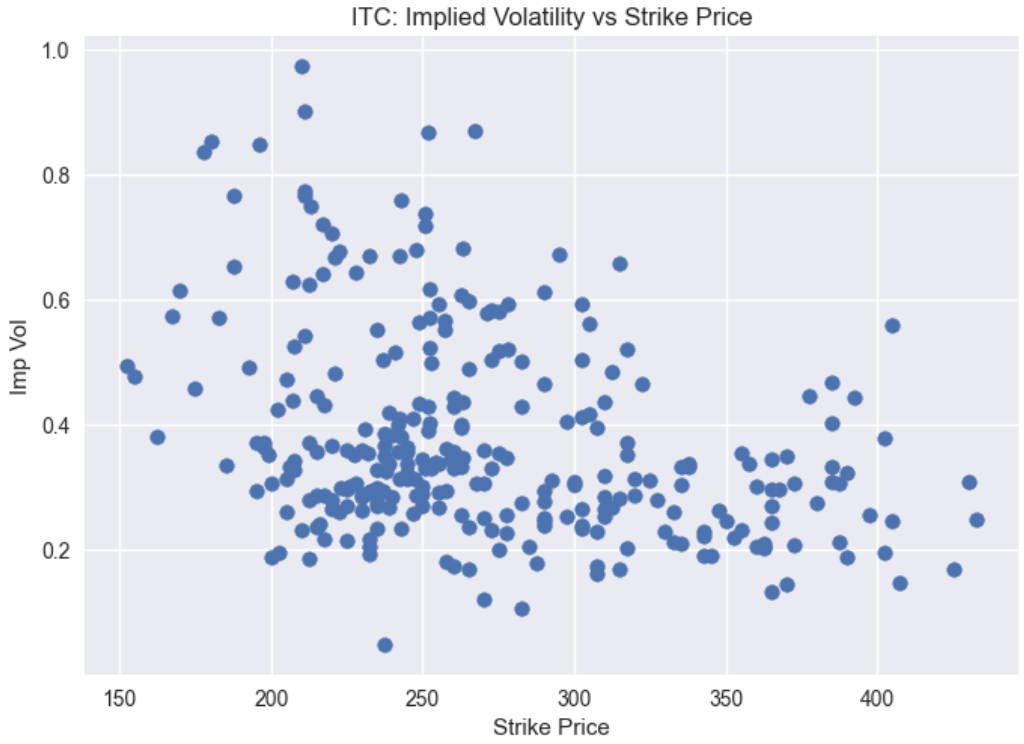

HDFCBANK: Implied Volatility vs Time to Maturity
Implied Volatility
0.25
0.20
0.15
0.10
0.05
0.00
0.2
0.4
0.6
0.8
Time to Maturity

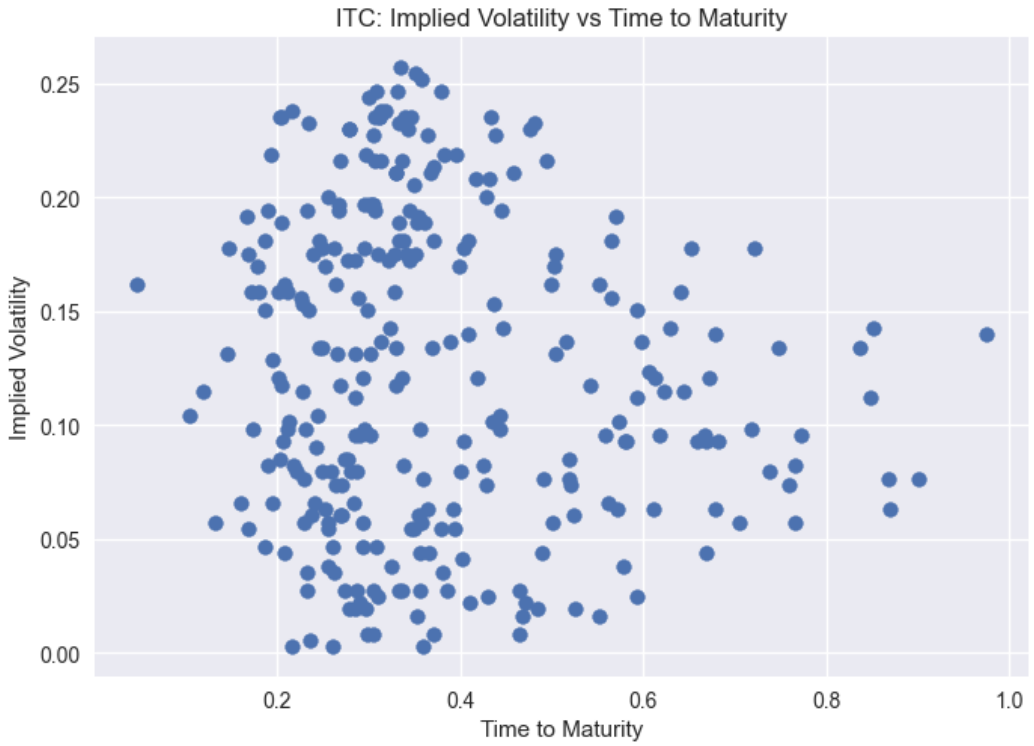

INFY: Implied Volatility vs (Strike Price, Time to Maturity)
Implied Volatility
0.8
0.6
0.4
0.2
0.00
0.05
0.10
0.15
0.20
0.25
Time to Maturity
1000
1200
1400
1600
1800
2000
2200
Strike Price

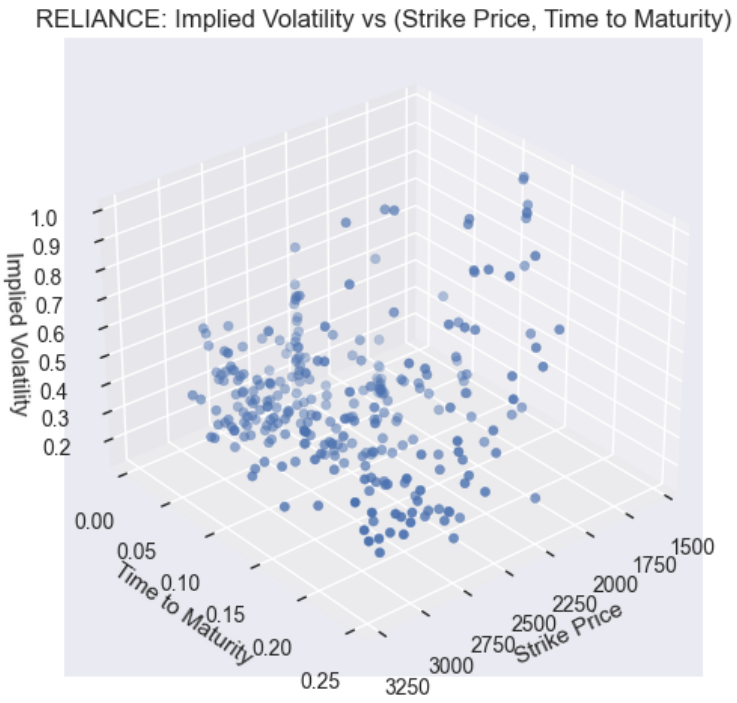

INFY: Implied Volatility vs Strike Price
Imp Vol
0.8
0.6
0.4
0.2
1000
1200
1400
1600
1800
2000
2200
Strike Price

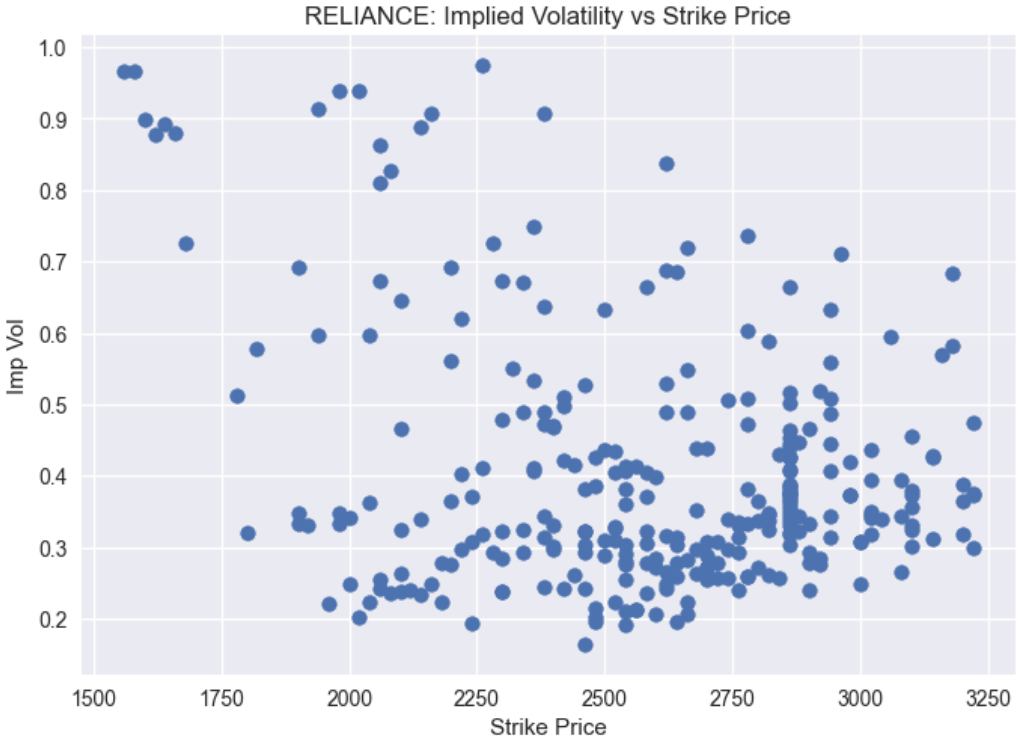

INFY: Implied Volatility vs Time to Maturity
Implied Volatility
Time to Maturity
0.25
0.20
0.15
0.10
0.05
0.00
0.2
0.4
0.6
0.8

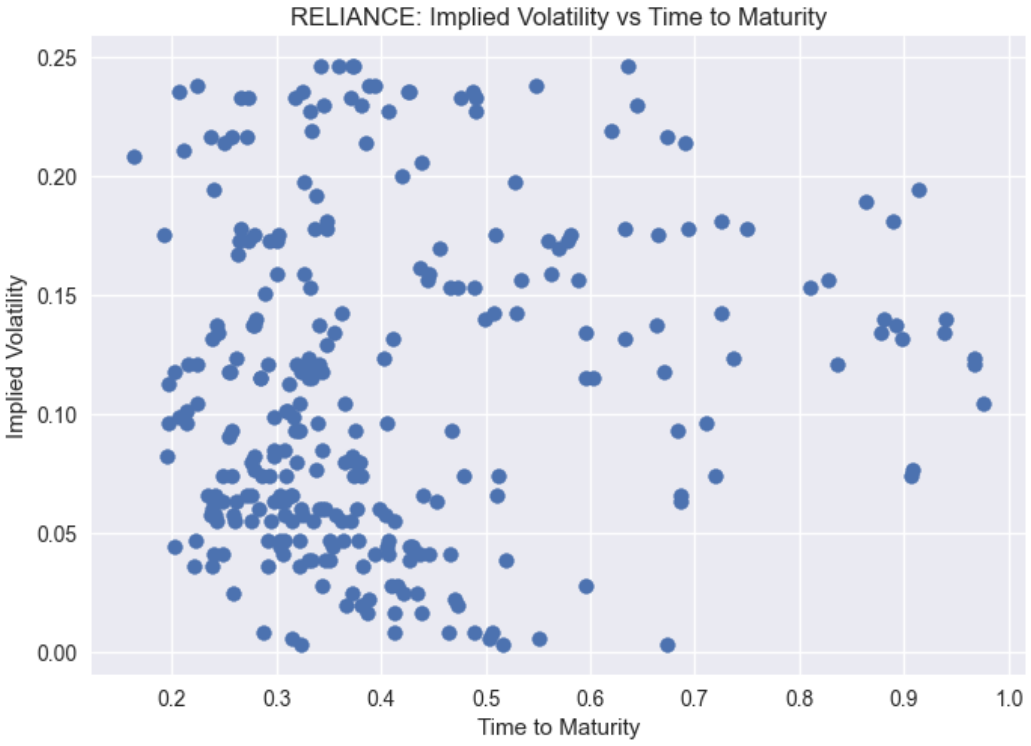

ITC: Implied Volatility vs (Strike Price, Time to Maturity)
Implied Volatility
Time to Maturity
Strike Price
1.0
0.8
0.6
0.4
0.2
0.00
0.05
0.10
0.15
0.20
0.25
150
200
250
300
350
400

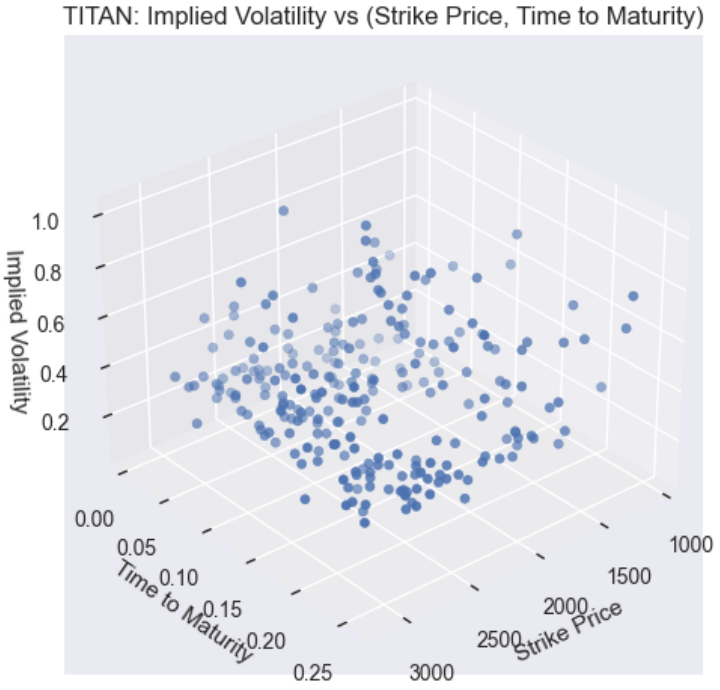

ITC: Implied Volatility vs Strike Price
Imp Vol
1.0
0.8
0.6
0.4
0.2
150
200
250
300
350
400
Strike Price

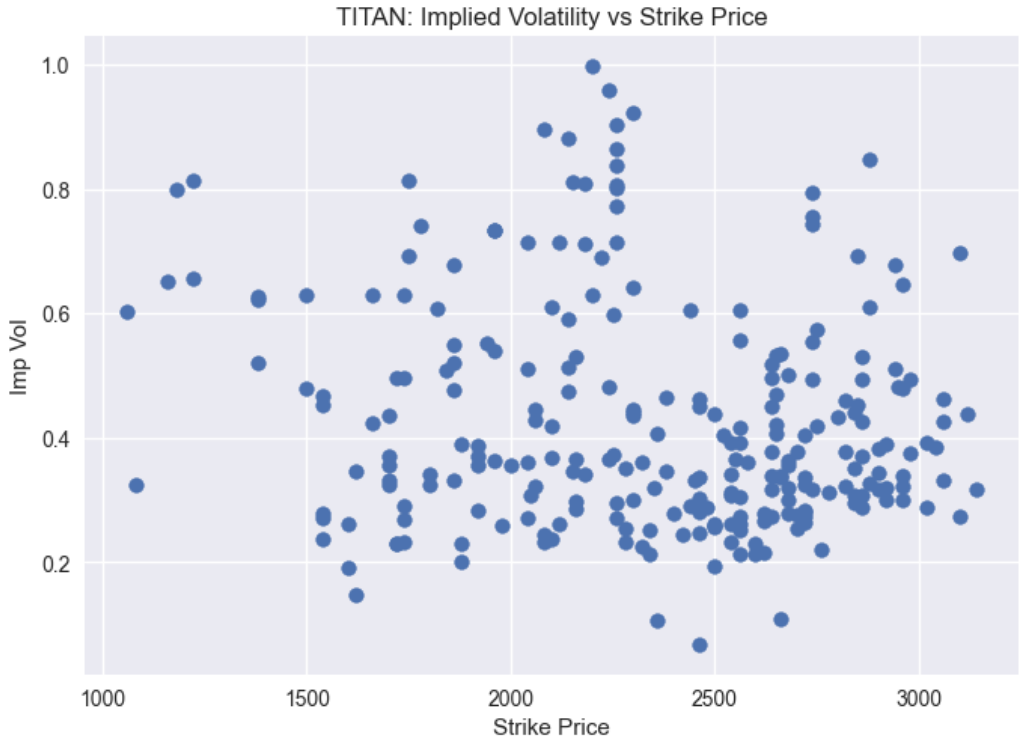

ITC: Implied Volatility vs Time to Maturity
Implied Volatility
0.25
0.20
0.15
0.10
0.05
0.00
0.2
0.4
0.6
0.8
1.0
Time to Maturity

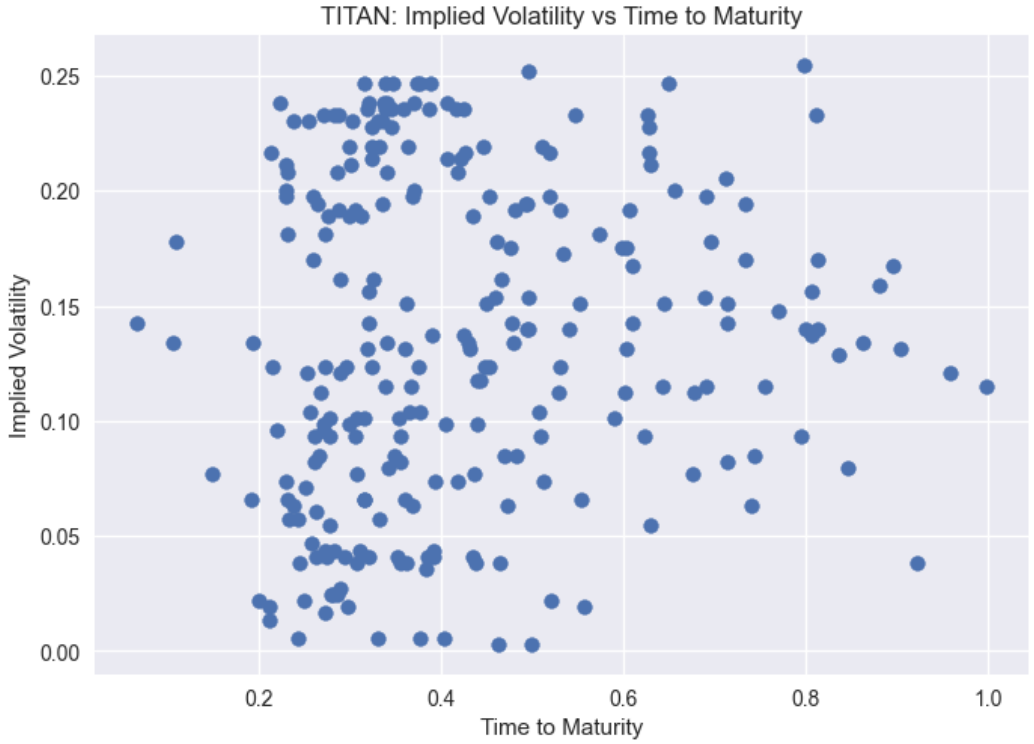

RELIANCE: Implied Volatility vs (Strike Price, Time to Maturity)
Implied Volatility
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Time to Maturity
0.00
0.05
0.10
0.15
0.20
0.25
Strike Price
1500
1750
2000
2250
2500
2750
3000
3250


RELIANCE: Implied Volatility vs Strike Price
Imp Vol
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1500
1750
2000
2250
2500
2750
3000
3250
Strike Price


RELIANCE: Implied Volatility vs Time to Maturity
Implied Volatility
Time to Maturity
0.25
0.20
0.15
0.10
0.05
0.00
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


TITAN: Implied Volatility vs (Strike Price, Time to Maturity)
Implied Volatility
Time to Maturity
Strike Price
1.0
0.8
0.6
0.4
0.2
0.00
0.05
0.10
0.15
0.20
0.25
1000
1500
2000
2500
3000


TITAN: Implied Volatility vs Strike Price
Imp Vol
1.0
0.8
0.6
0.4
0.2
1000
1500
2000
2500
3000
Strike Price


TITAN: Implied Volatility vs Time to Maturity
Implied Volatility
0.25
0.20
0.15
0.10
0.05
0.00
0.2
0.4
0.6
0.8
1.0
Time to Maturity

Observation-

-In the 3D plots for any given time to maturity, a convex curve can be observed for implied volatility and strike price. This is often referred to as a "Volatility Smile".

-In the 2D plot of implied volatility vs Strike price, many smiles (of different times to maturity) can overlap.

Part-C)

Historical data on underlying asset prices are collected from 30/03/2021 to 28/02/2023. It is the same period for which data on option prices is collected. This data is stored in a folder named "Underlying Data".

Historical Volatility is calculated using the following methodology:

- ➢ Returns were calculated using the following formula:

$$Returns(i) = \frac{S(i+1)-S(i)}{S(i)}$$

where S(i) denote the stock price at time point i.

- ➢ Annual Volatility is calculated using the following formula:

$$Volatility = Standard\_Deviation(Returns) * \sqrt{252}$$

Mean implied volatility is computed by taking the mean of the implied volatilities obtained in question Part-B.

Output-

```
PS C:\Users\Dev Sandip Shah\IITG\Sem6\FE Lab\Lab-9> python q2_c.py
  Underlying Asset  Implied Volatility  Historical Volatility
0            NIFTY            0.271461               0.164838
1         HDFCBANK            0.400848               0.232305
2            INFY             0.417651               0.242222
3             ITC             0.410609               0.226615
4         RELIANCE            0.464637               0.249717
5            TITAN            0.483704               0.280264
```