# MA 374
# Financial Engineering Lab

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**Question 1:**

The price of European Call and Put Option given by BSM framework obtained after solving Black-Scholes-Merton PDE is:

$$C(x,t) = xN(d_1) - Ke^{-r(T-t)}N(d_2)$$
$$P(x,t) = Ke^{-r(T-t)}N(-d_2) - xN(-d_1)$$

Where ,

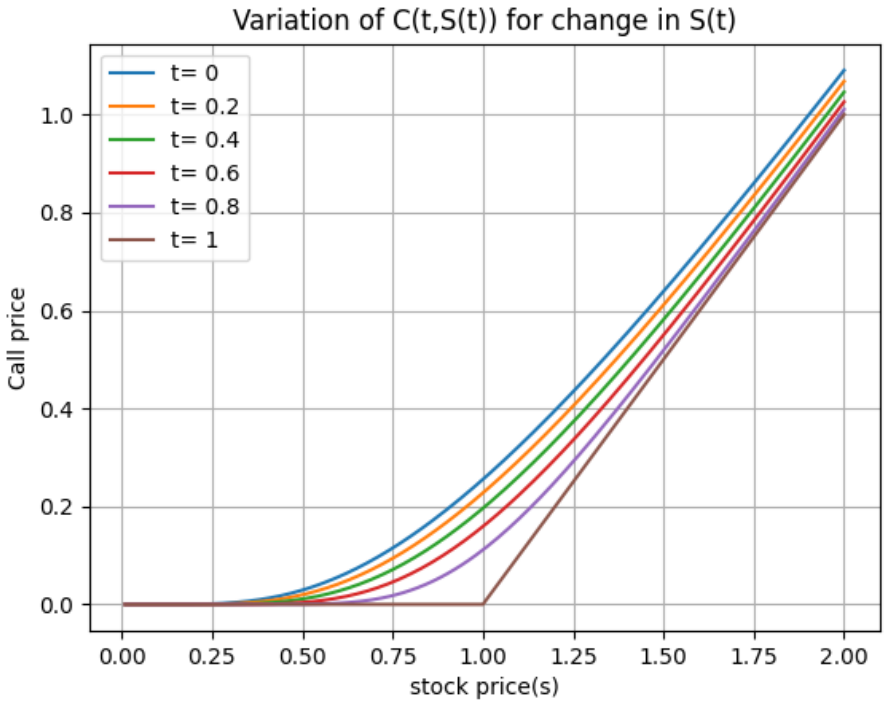
$$d_1 = \frac{\log\left(\frac{x}{K}\right) + (r + \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$
$$d_2 = \frac{\log\left(\frac{x}{K}\right) + (r - \frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$
$$N(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{x} e^{-\frac{1}{2}y^2}dy$$

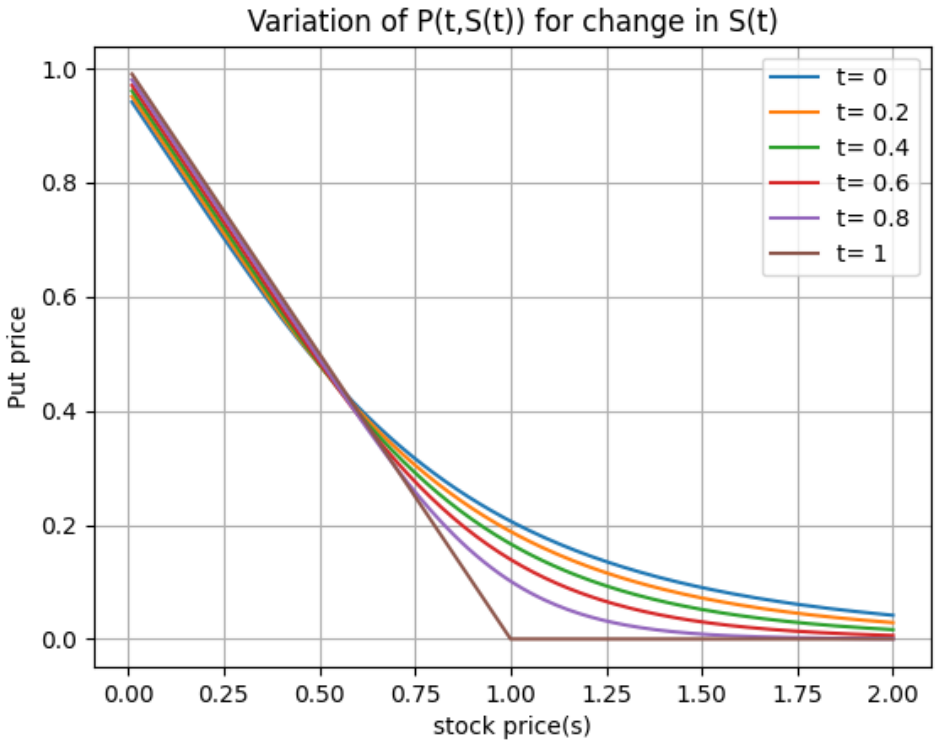
I have included an example to check the working of code:
S=1, t=0, T=1, k=1, r=5%, sigma=0.6

```
price of call option= 0.255232056656095
price of put option= 0.20646148115680896
```

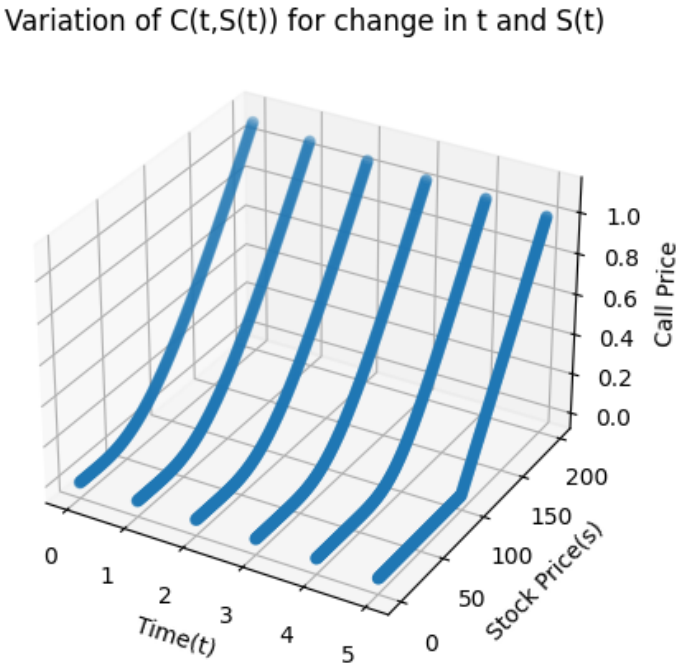
**Question 2:**

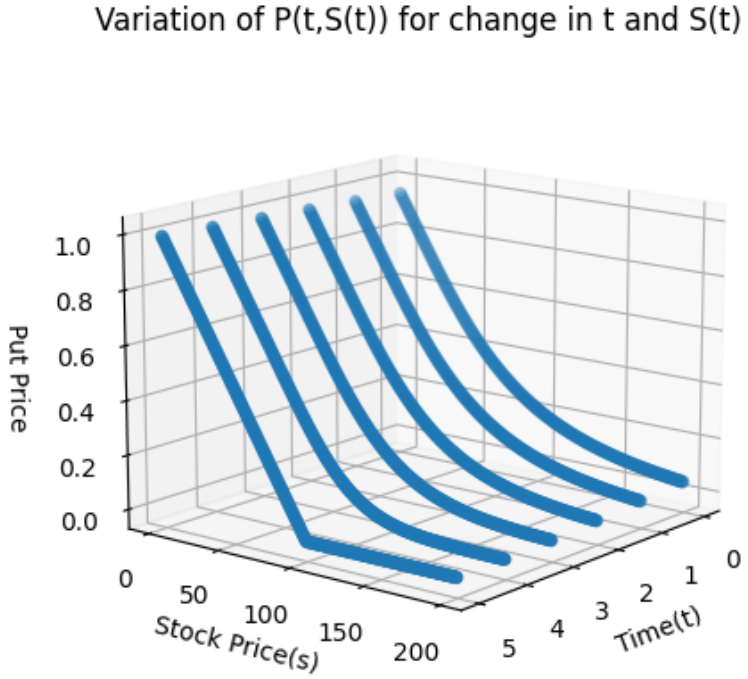
The plot of C(t, S(t)) and P(t, S(t)) as a function of S(t) is as follows:


Variation of C(t,S(t)) for change in S(t)
t= 0
t= 0.2
t= 0.4
t= 0.6
t= 0.8
t= 1
Call price
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
stock price(s)


Variation of P(t,S(t)) for change in S(t)
t= 0
t= 0.2
t= 0.4
t= 0.6
t= 0.8
t= 1
Put price
0.0
0.2
0.4
0.6
0.8
1.0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
stock price(s)

The 3-dimensional plots for C(t, S(t)) & P(t, S(t)) are:

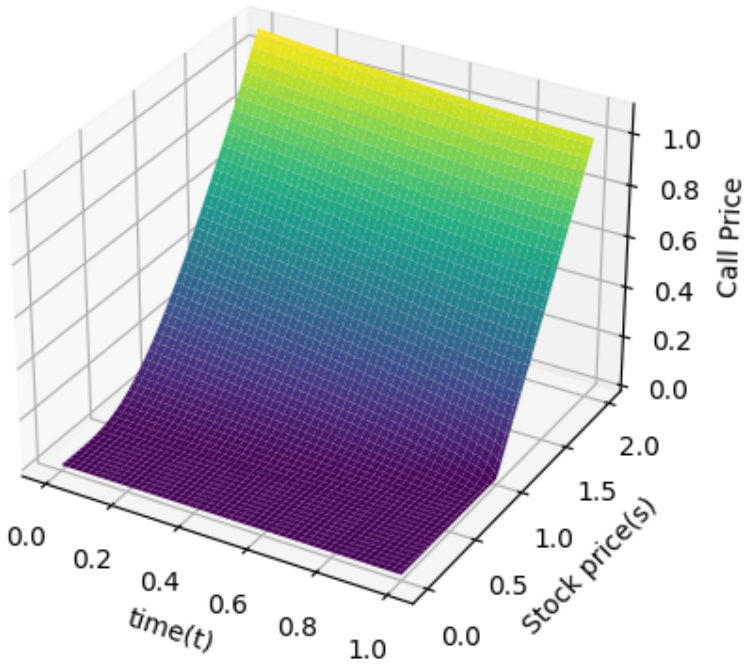


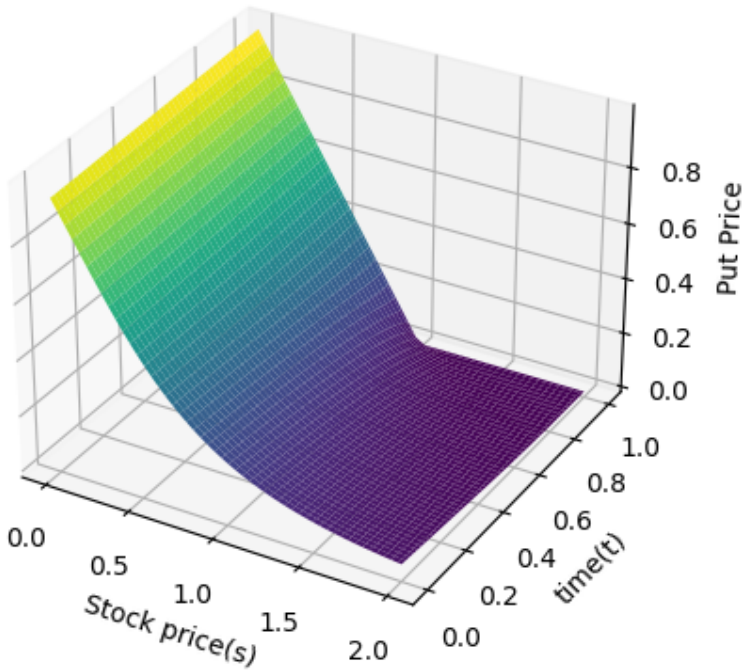

## Question 3:

The plots for C(t, S(t)) and P(t, S(t)) as smooth surfaces above the (t, S(t)) plane are:

Variation of C(t,S(t)) for change in t and S(t)




Variation of P(t,S(t)) for change in t and S(t)



## Question 4:

The parameters values are varied accordingly, and where some particular values of parameters are required, they are taken from the following:

$$s = 0.8,\ t = 0,\ T = 1,\ k = 1,\ r = 0.05,\ \sigma = 0.6$$

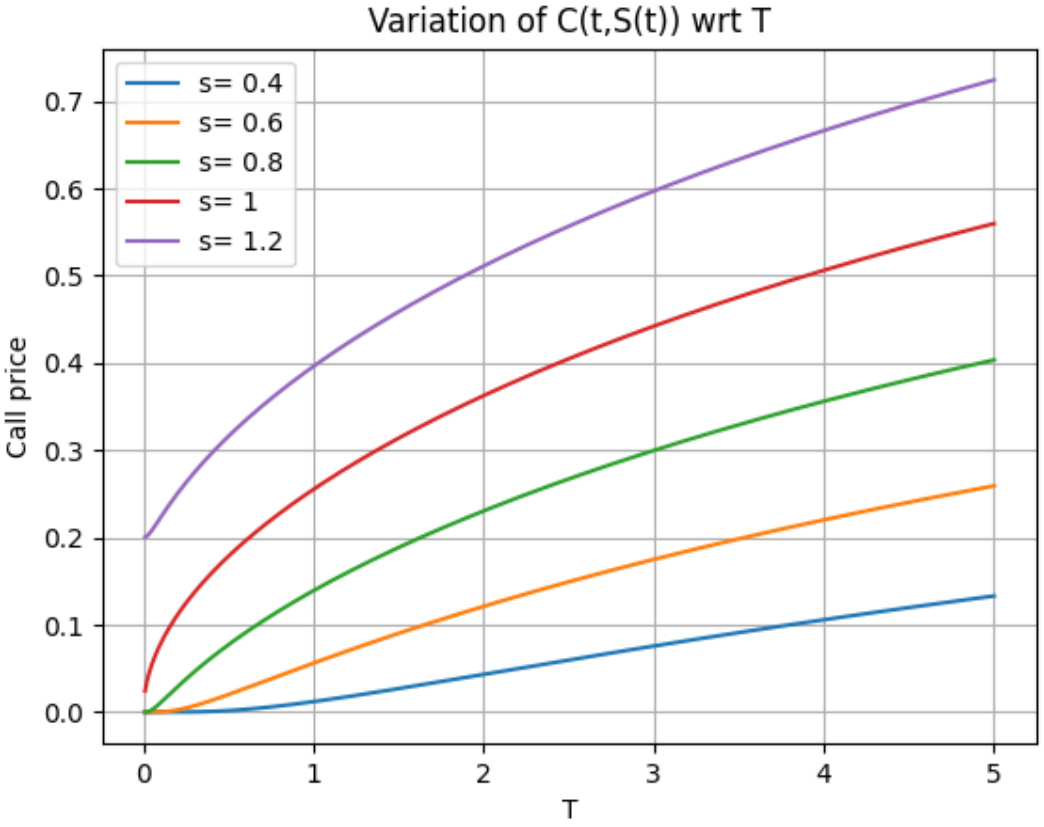
Variation of Call and Put price with stock price has been done in question 2 and 3 already. Rest of the sensitivity analysis plots are attached here:

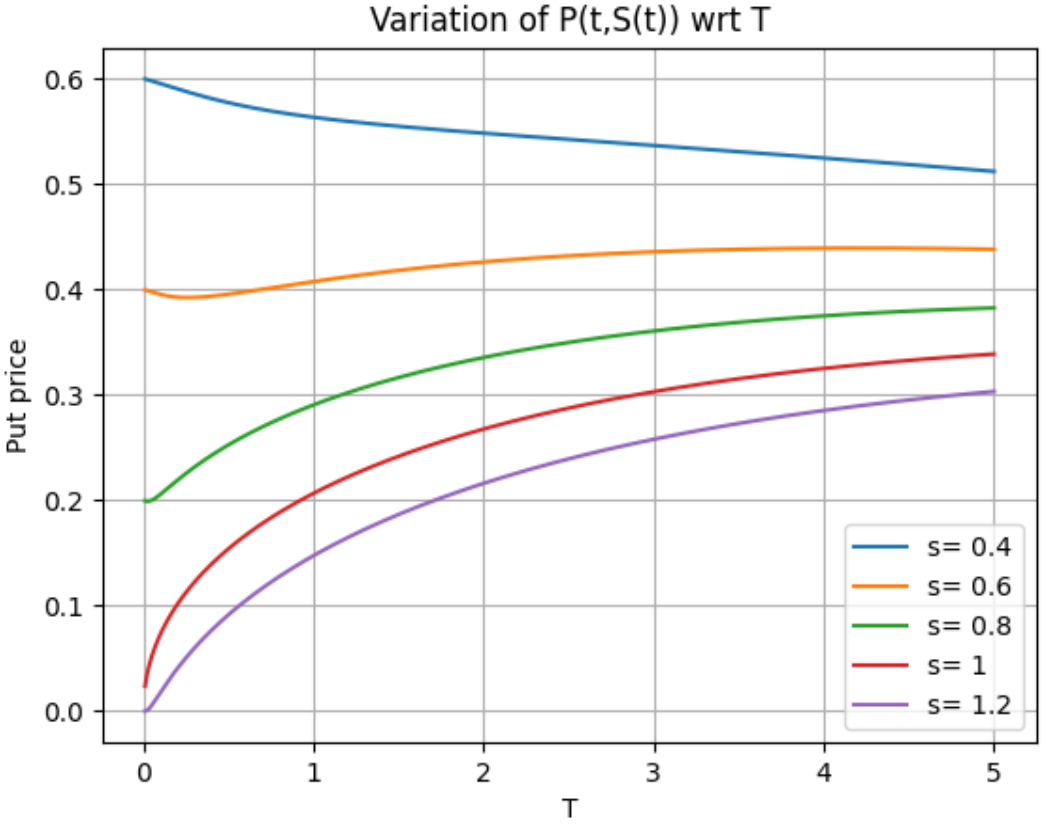
| T | C(t,S(t)) | P(t,S(t)) |
|---|---|---|
| 0.5 | 0.0771391 | 0.252449 |
| 1 | 0.139135 | 0.290364 |
| 1.5 | 0.188581 | 0.316324 |
| 2 | 0.230477 | 0.335314 |
| 2.5 | 0.267111 | 0.349608 |
| 3 | 0.299765 | 0.360473 |
| 3.5 | 0.329249 | 0.368706 |
| 4 | 0.356118 | 0.374849 |
| 4.5 | 0.380775 | 0.379291 |
| 5 | 0.403524 | 0.382325 |

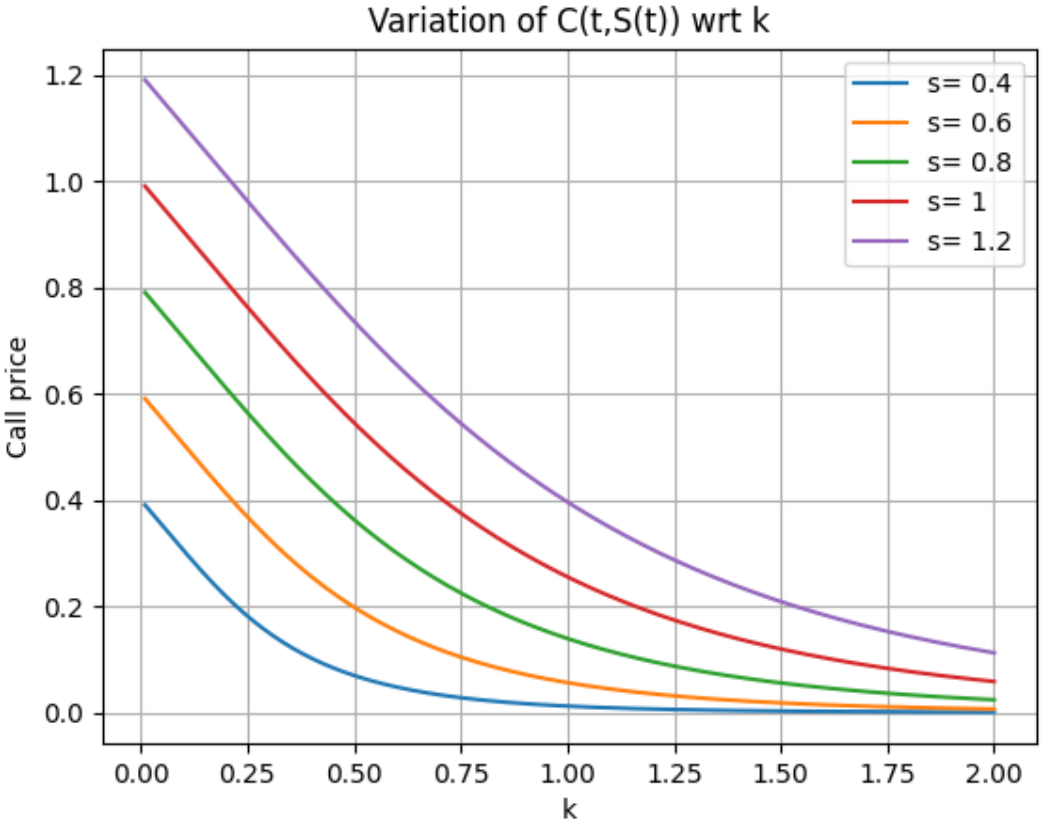
| k | C(t,S(t)) | P(t,S(t)) |
|---|---|---|
| 0.205411 | 0.605331 | 0.00072379 |
| 0.40481 | 0.432374 | 0.0174404 |
| 0.604208 | 0.297769 | 0.0725099 |
| 0.803607 | 0.202769 | 0.167184 |
| 1.00301 | 0.138342 | 0.292431 |
| 1.2024 | 0.0951514 | 0.438914 |
| 1.4018 | 0.0661524 | 0.599589 |
| 1.6012 | 0.0465331 | 0.769644 |
| 1.8006 | 0.0331217 | 0.945907 |
| 2 | 0.0238485 | 1.12631 |

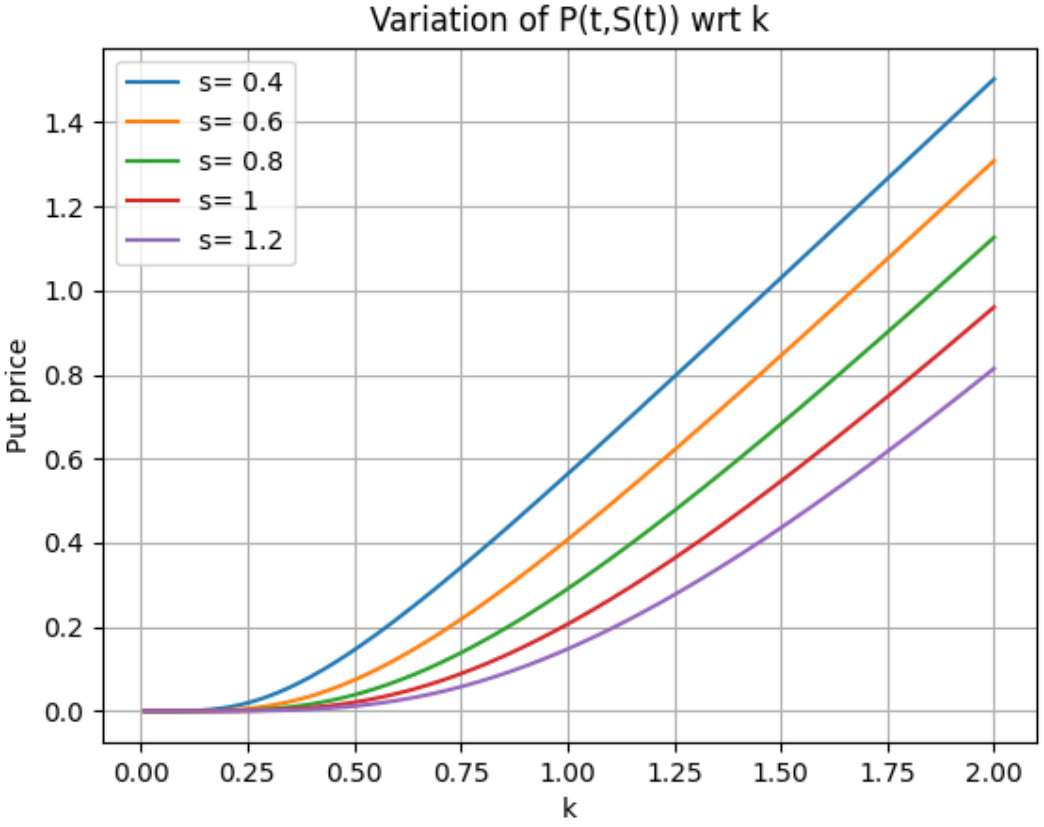
| r | C(t,S(t)) | P(t,S(t)) |
|---|---|---|
| 0.098 | 0.152134 | 0.258783 |
| 0.198 | 0.181038 | 0.201408 |
| 0.298 | 0.212075 | 0.154376 |
| 0.398 | 0.244772 | 0.116434 |
| 0.498 | 0.278598 | 0.086343 |
| 0.598 | 0.312995 | 0.062905 |
| 0.698 | 0.347413 | 0.044993 |
| 0.798 | 0.381344 | 0.0315727 |
| 0.898 | 0.414339 | 0.0217228 |
| 0.998 | 0.446029 | 0.0146454 |

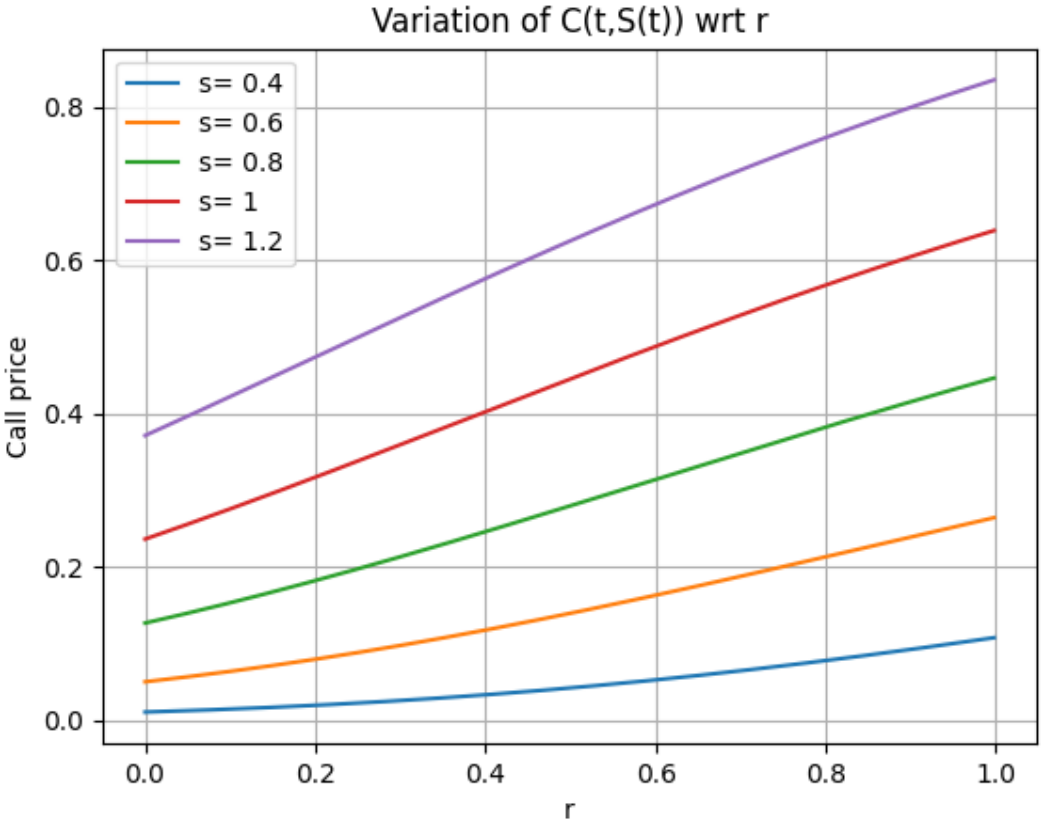
| sigma | C(t,S(t)) | P(t,S(t)) |
|---|---|---|
| 0.0990982 | 0.00140663 | 0.152636 |
| 0.199198 | 0.0184037 | 0.169633 |
| 0.299299 | 0.0453279 | 0.196557 |
| 0.399399 | 0.0755956 | 0.226825 |
| 0.499499 | 0.107102 | 0.258331 |
| 0.599599 | 0.139007 | 0.290236 |
| 0.699699 | 0.17089 | 0.322119 |
| 0.7998 | 0.202501 | 0.353731 |
| 1 | 0.264275 | 0.415504 |

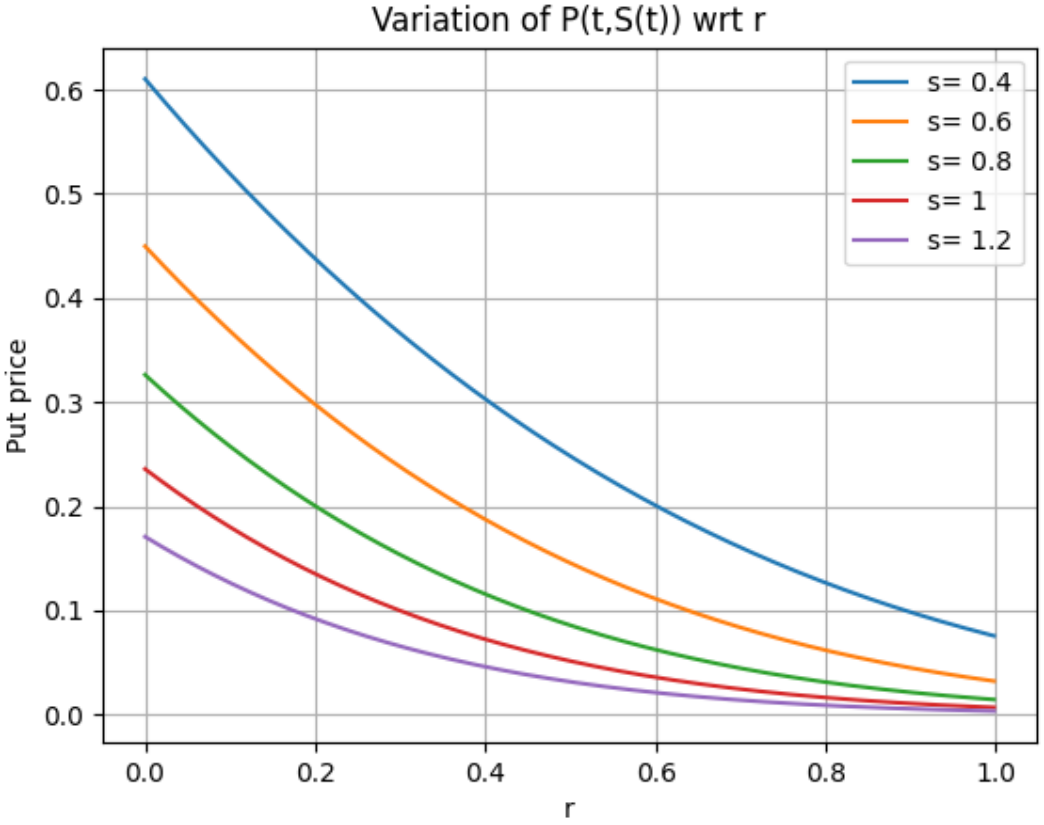

Variation of C(t,S(t)) wrt T
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
Call price
T
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
1
2
3
4
5

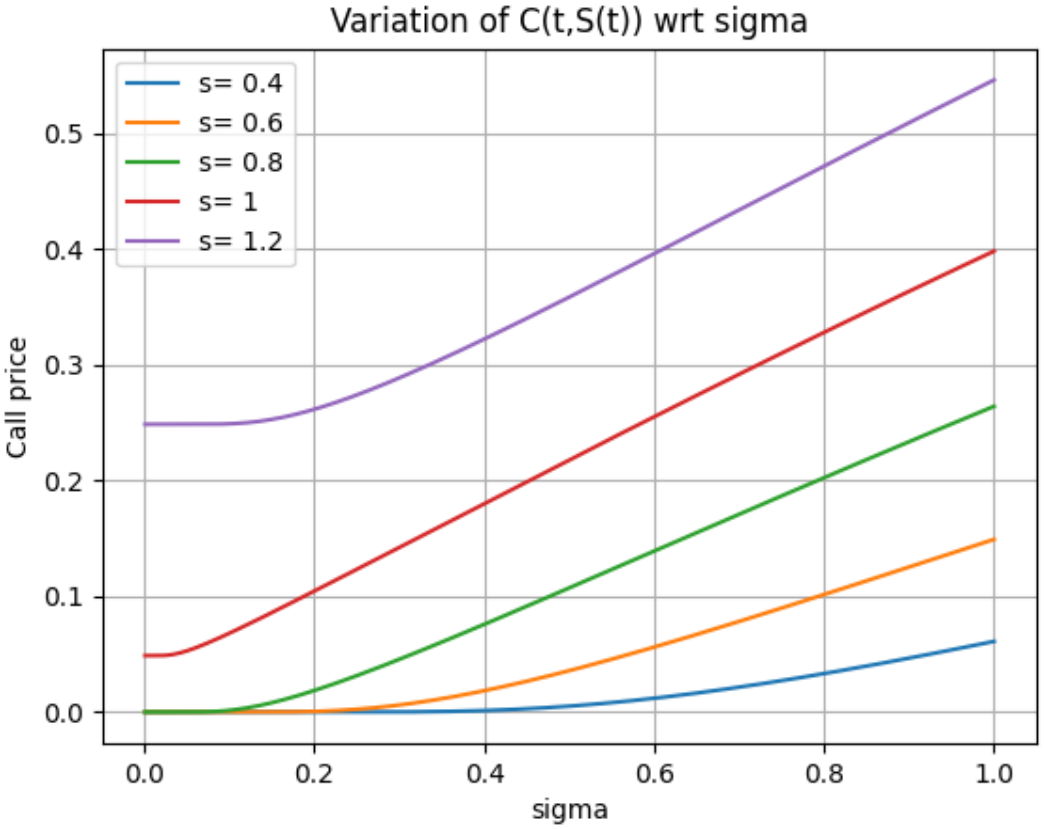

Variation of P(t,S(t)) wrt T
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
Put price
T
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
1
2
3
4
5

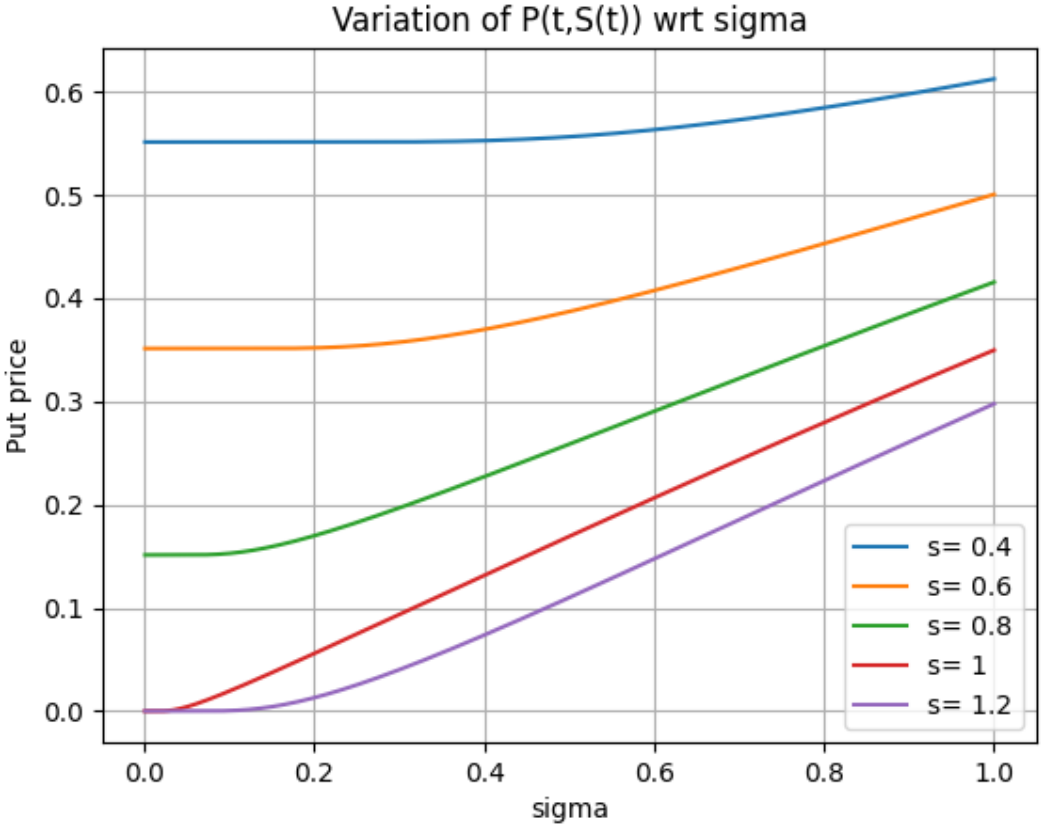

Variation of C(t,S(t)) wrt k
Call price
k
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00


Variation of P(t,S(t)) wrt k
Put price
k
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00

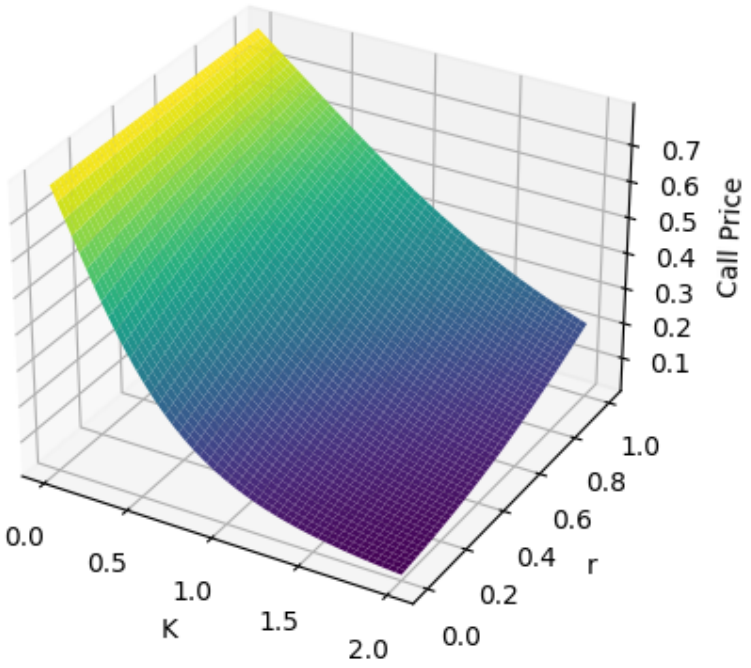

Variation of C(t,S(t)) wrt r
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
Call price
r
0.0
0.2
0.4
0.6
0.8
1.0


Variation of P(t,S(t)) wrt r
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
Put price
r
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1.0

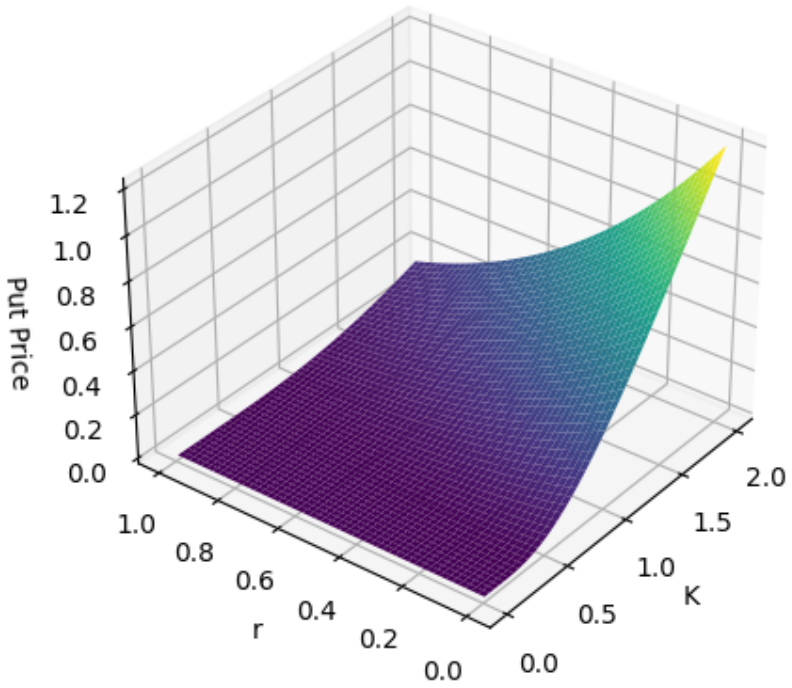

Variation of C(t,S(t)) wrt sigma
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
Call price
sigma
0.0
0.1
0.2
0.3
0.4
0.5
0.0
0.2
0.4
0.6
0.8
1.0


Variation of P(t,S(t)) wrt sigma
s= 0.4
s= 0.6
s= 0.8
s= 1
s= 1.2
Put price
sigma
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.0
0.2
0.4
0.6
0.8
1.0

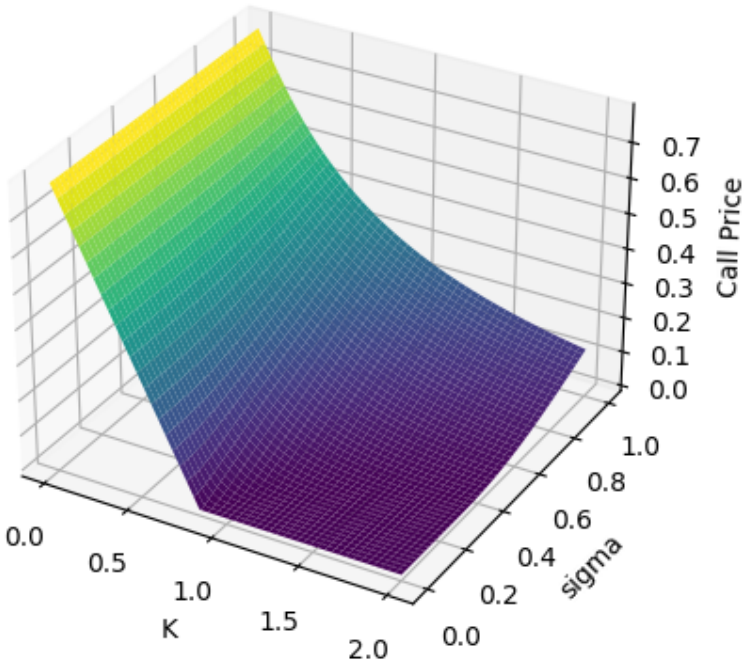
Variation of C(t,S(t)) for change in k and r



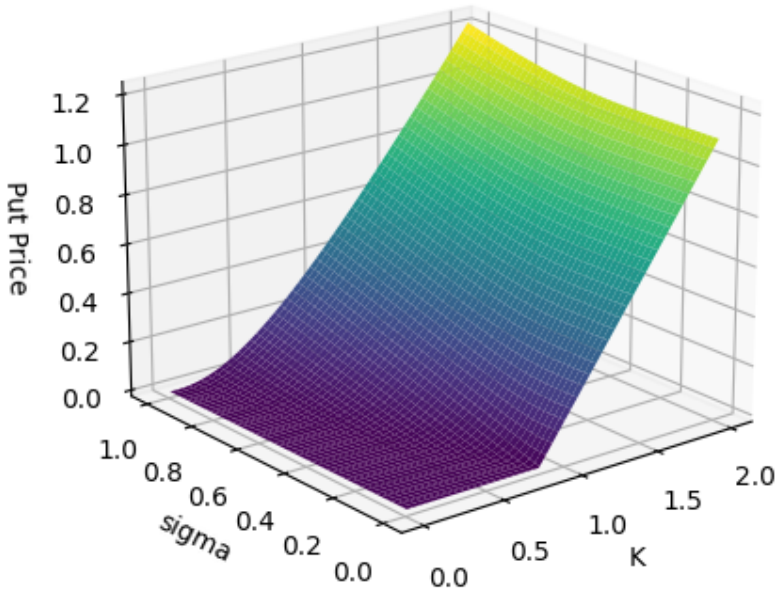

Variation of P(t,S(t)) for change in k and r



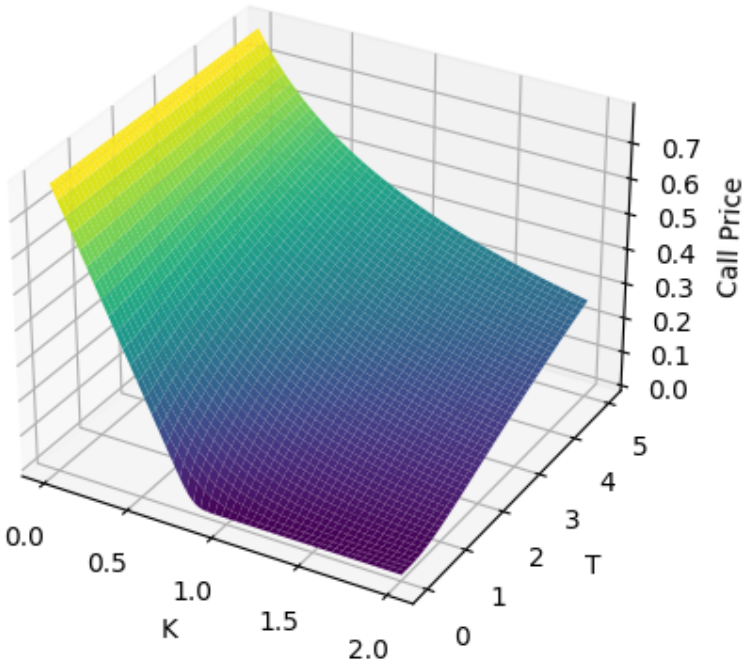
Variation of C(t,S(t)) for change in k and sigma



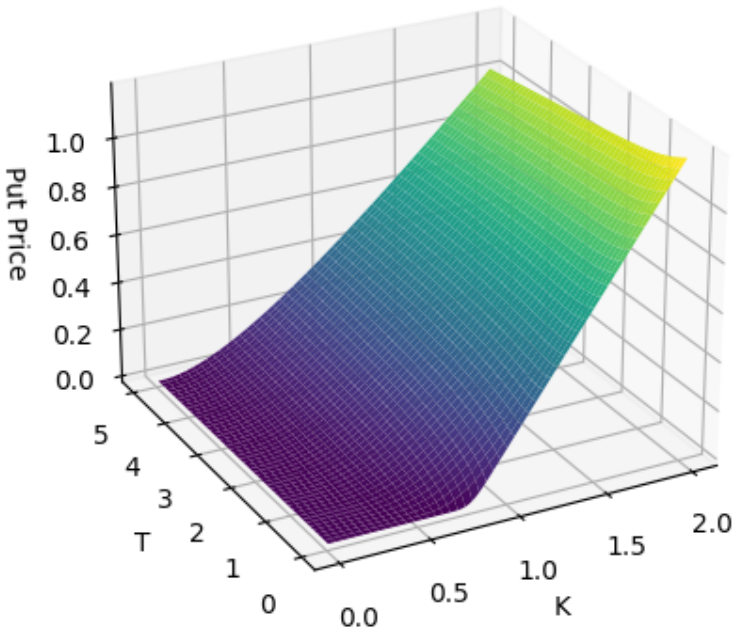

Variation of P(t,S(t)) for change in k and sigma



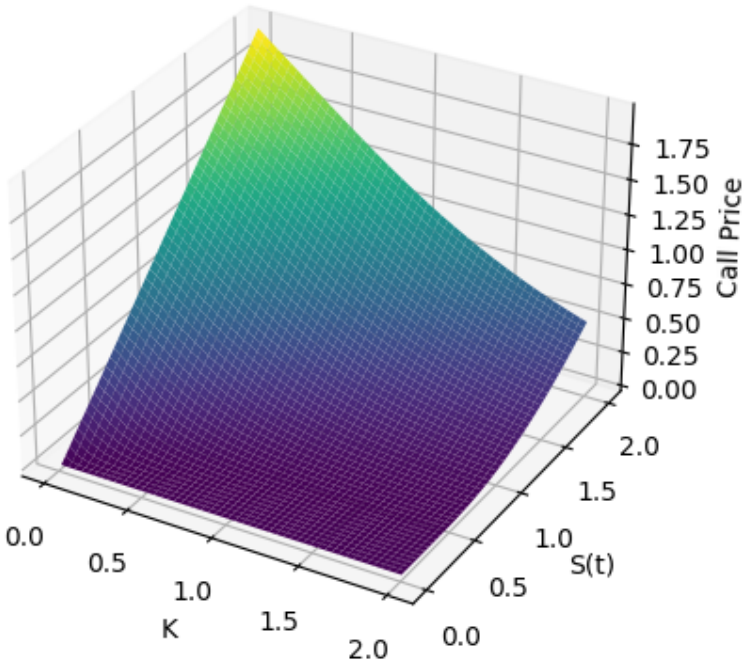
Variation of C(t,S(t)) for change in k and T



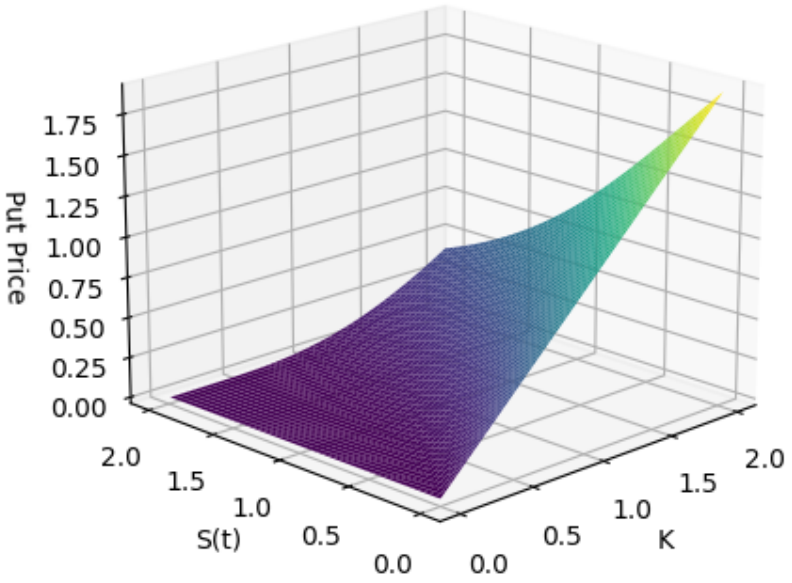

Variation of P(t,S(t)) for change in k and T



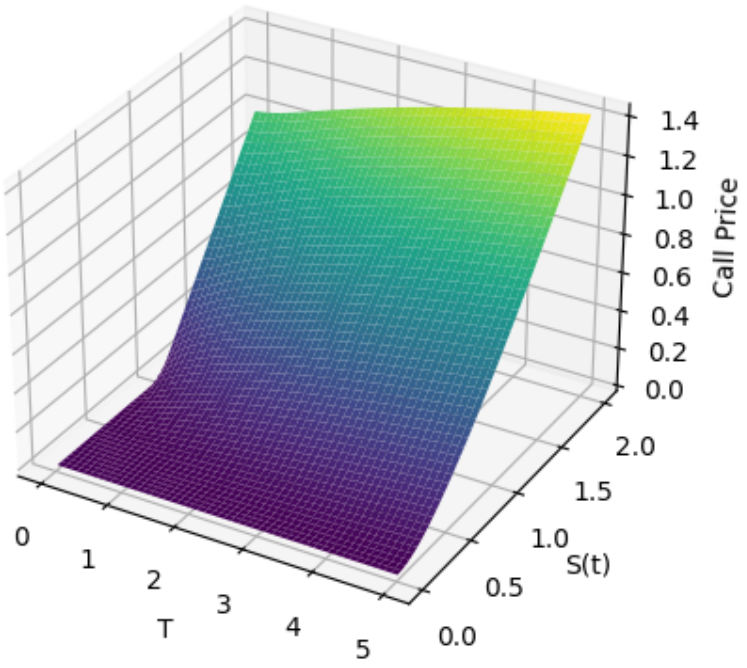
Variation of C(t,S(t)) for change in k and S(t)



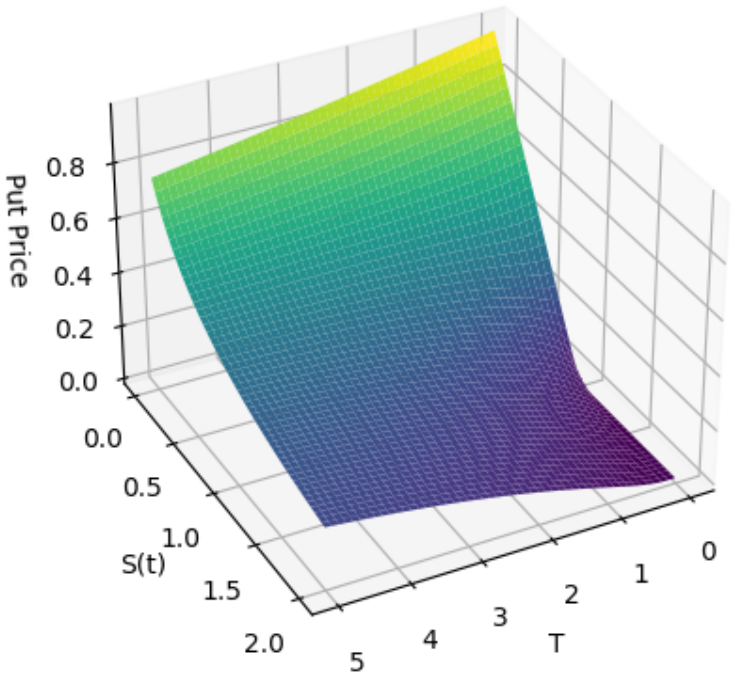

Variation of P(t,S(t)) for change in k and S(t)



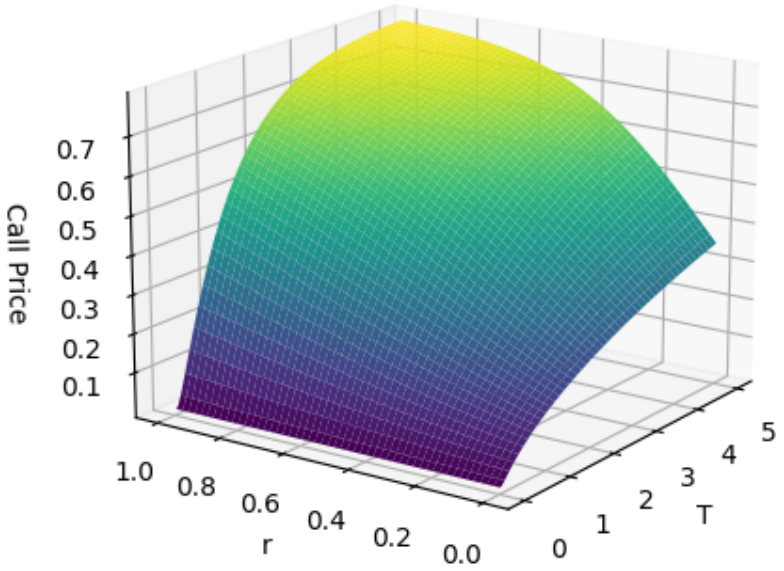
Variation of C(t,S(t)) for change in T and S(t)



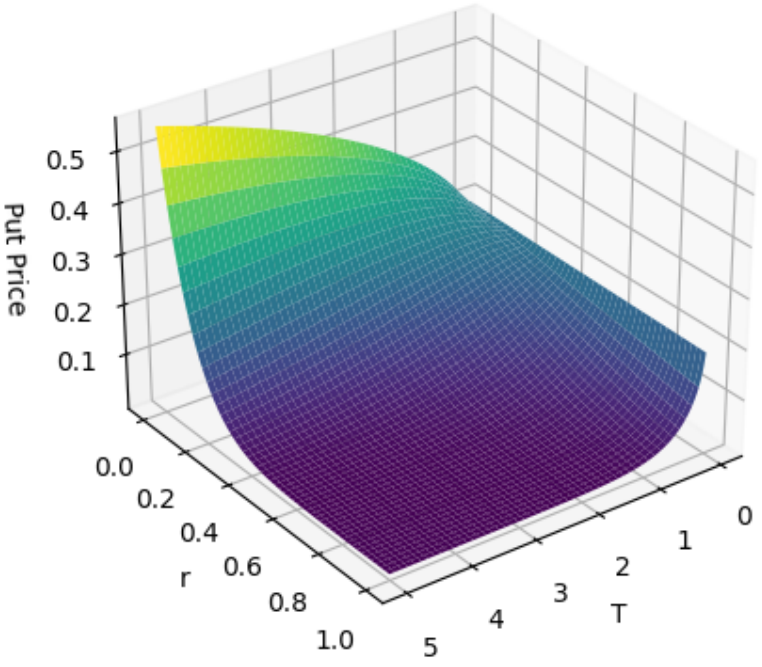

Variation of P(t,S(t)) for change in T and S(t)



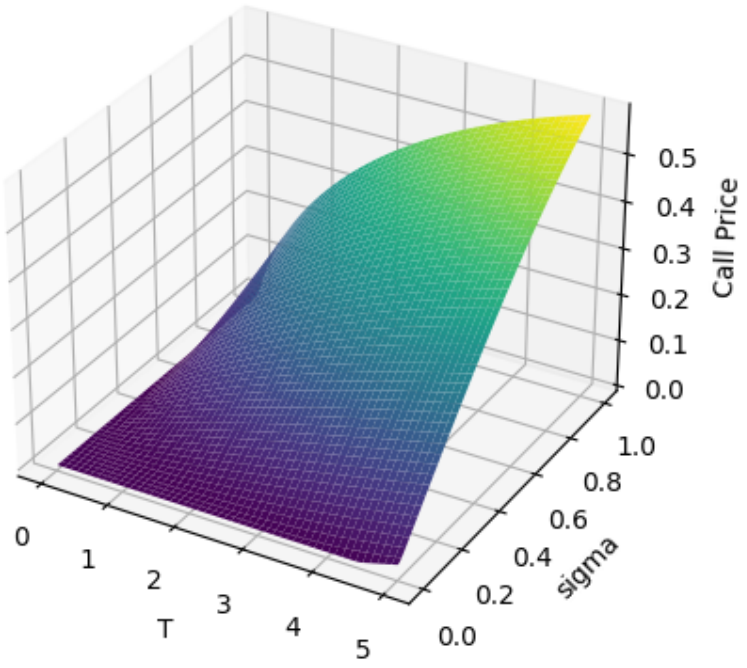
Variation of C(t,S(t)) for change in T and r



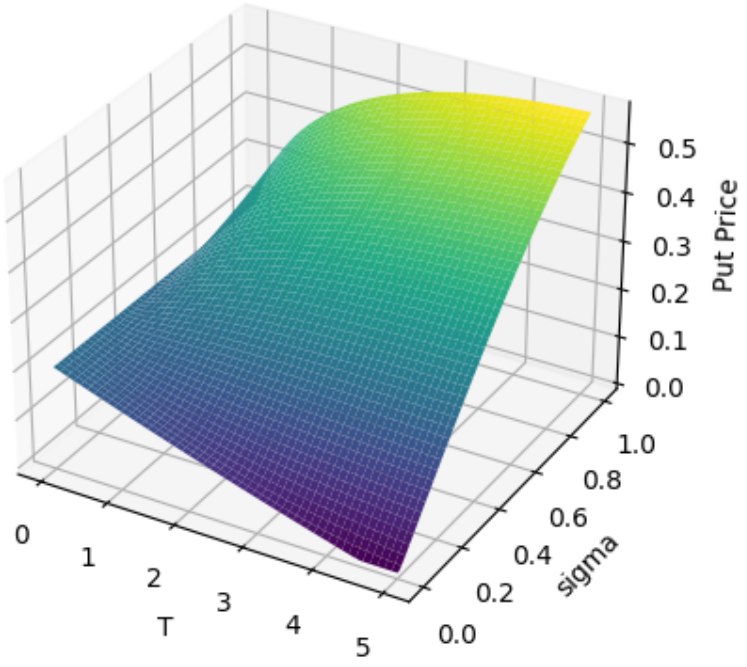

Variation of P(t,S(t)) for change in T and r



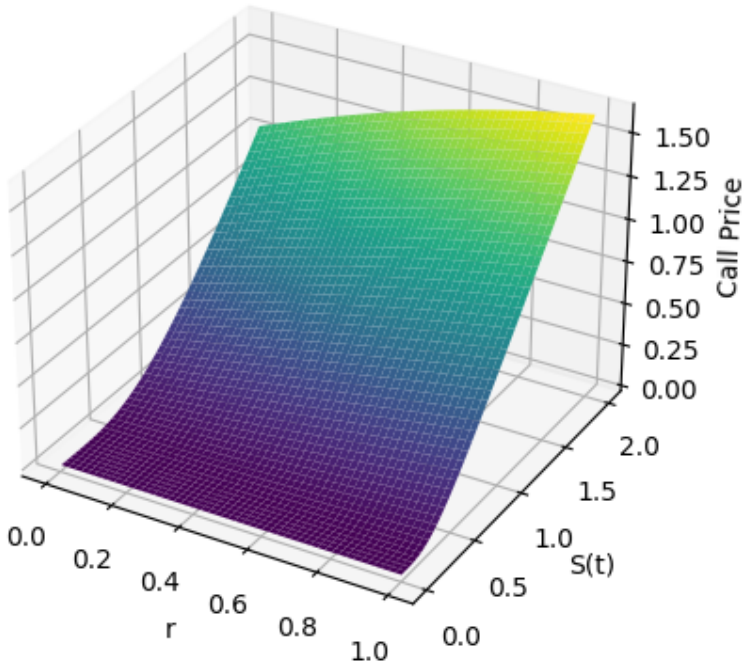
Variation of C(t,S(t)) for change in T and sigma



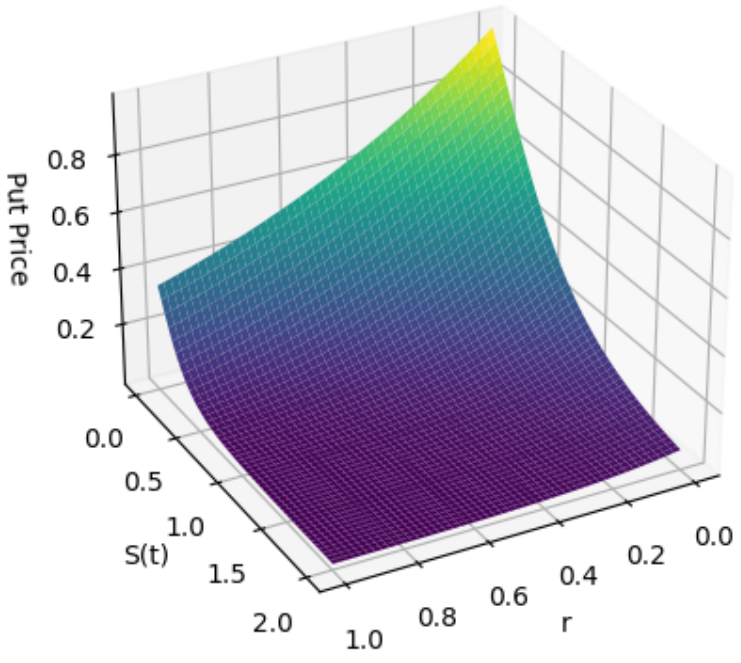

Variation of P(t,S(t)) for change in T and sigma



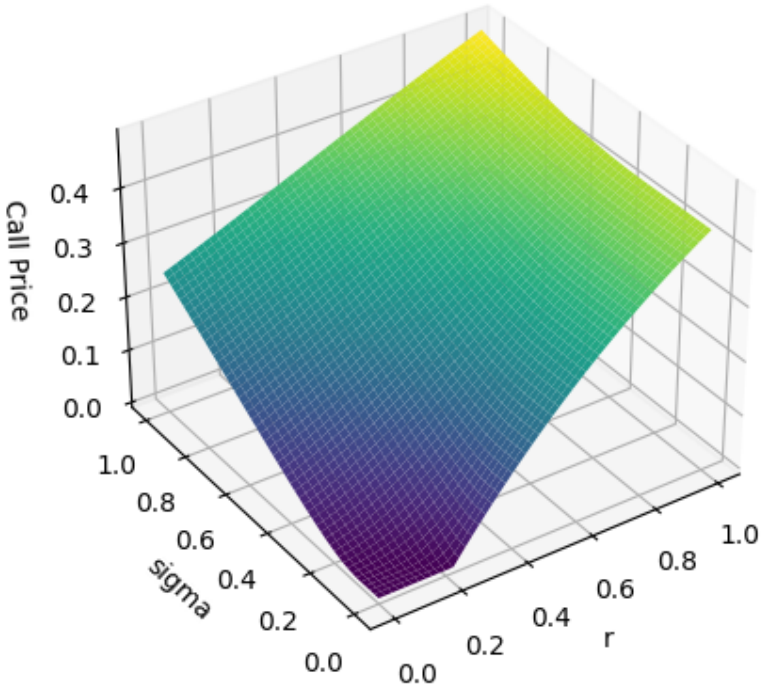
Variation of C(t,S(t)) for change in r and S(t)



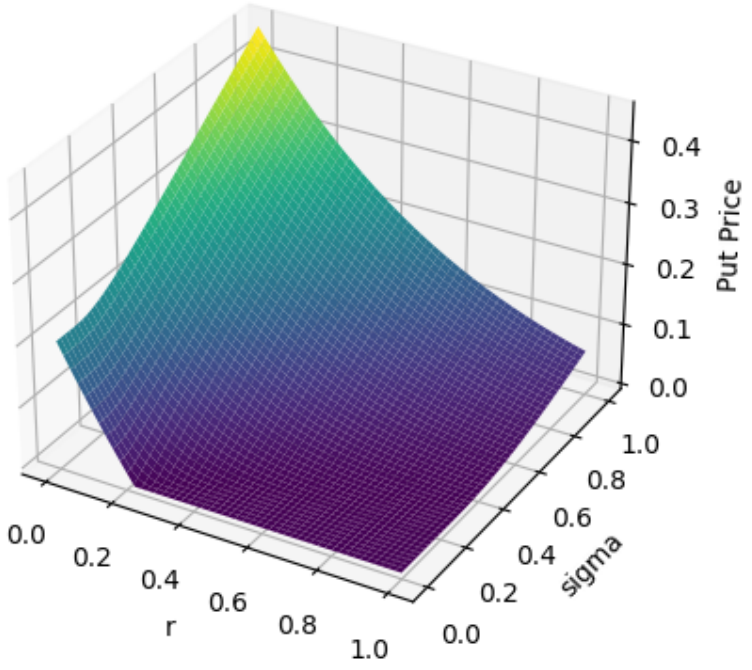

Variation of P(t,S(t)) for change in r and S(t)



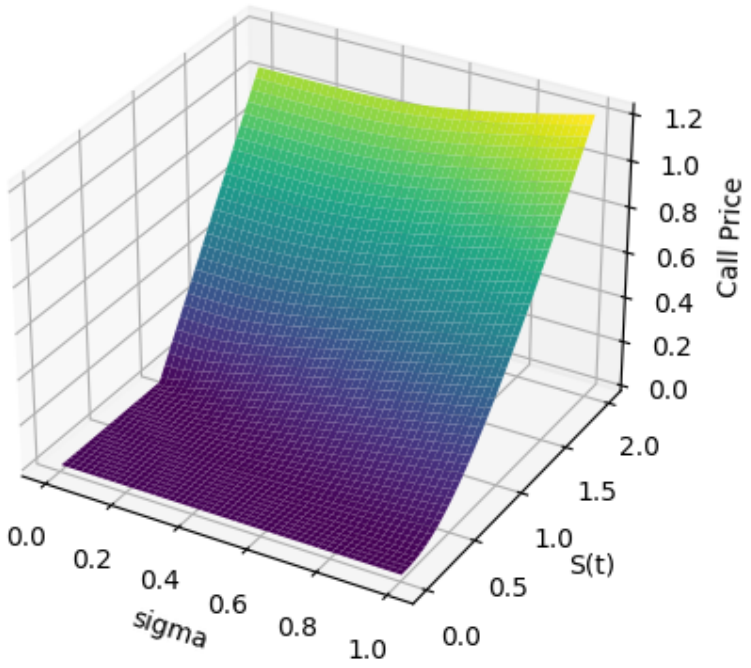
Variation of C(t,S(t)) for change in r and sigma




Variation of P(t,S(t)) for change in r and sigma



Variation of C(t,S(t)) for change in sigma and S(t)




Variation of P(t,S(t)) for change in sigma and S(t)