

# 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:

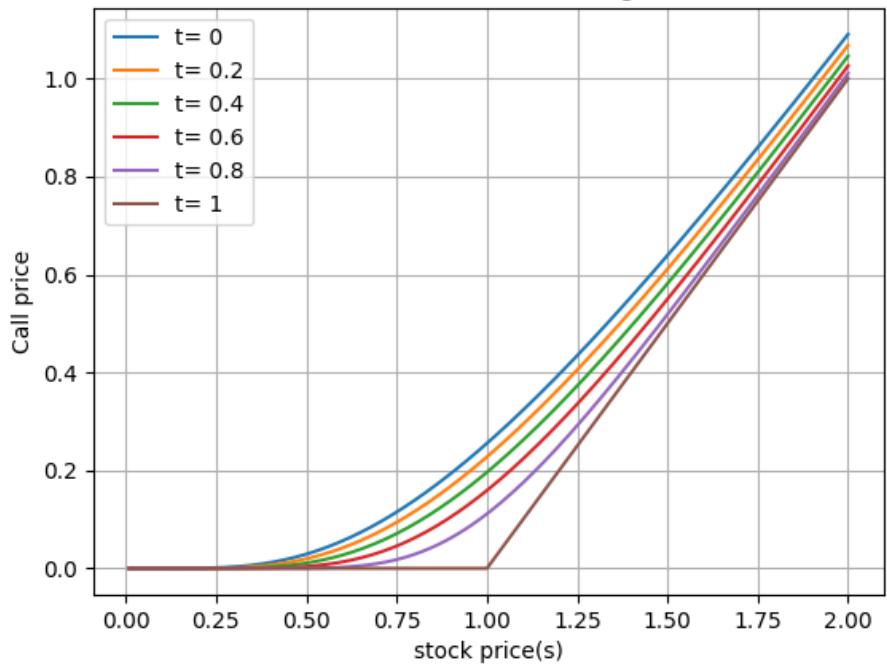
S=1, t=0, T=1, k=1, r=5%, sigma=0.6

```
PS C:\Users\amanb\Desktop\sem 6\fe lab\lab 7> python q1.py
price of call option= 0.255232056656095
price of put option= 0.20646148115680896
```

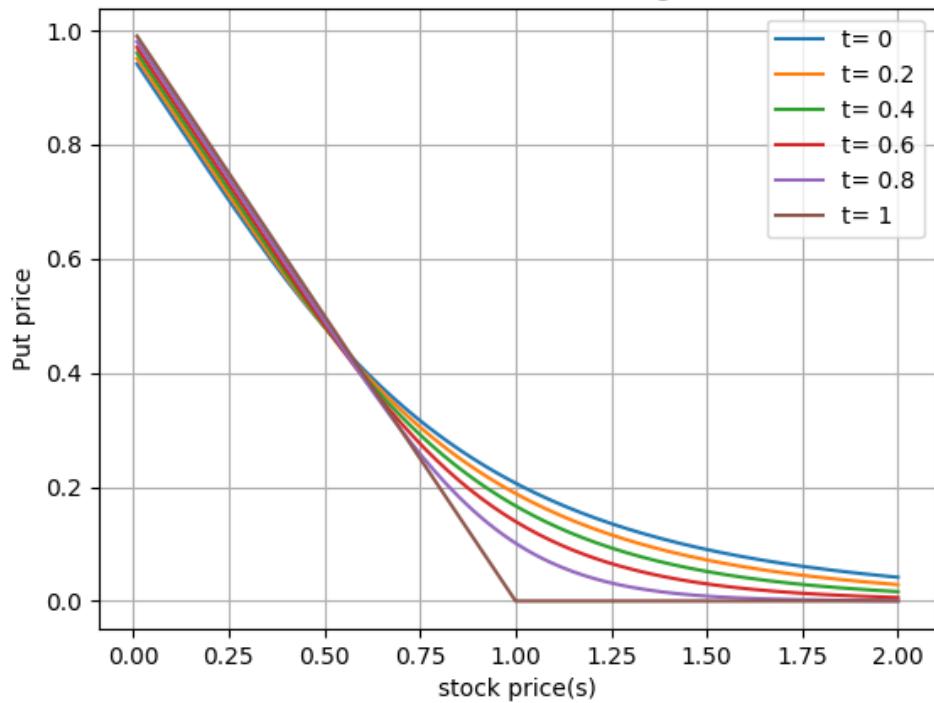
### Question 2:

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  $S(t)$

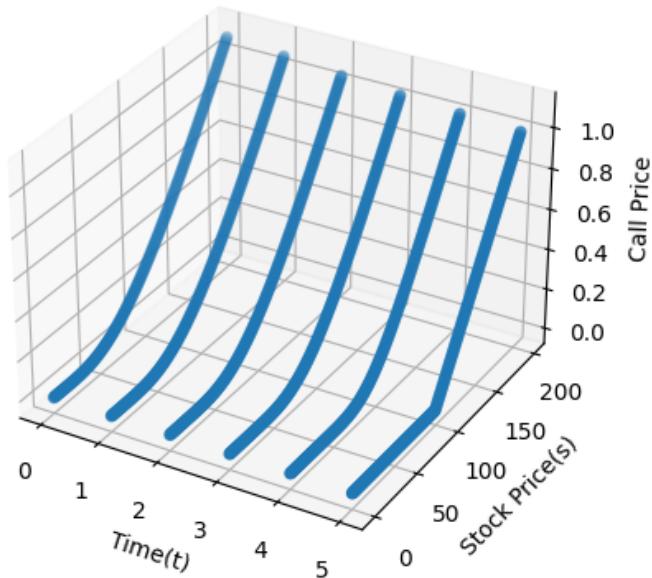


Variation of  $P(t, S(t))$  for change in  $S(t)$

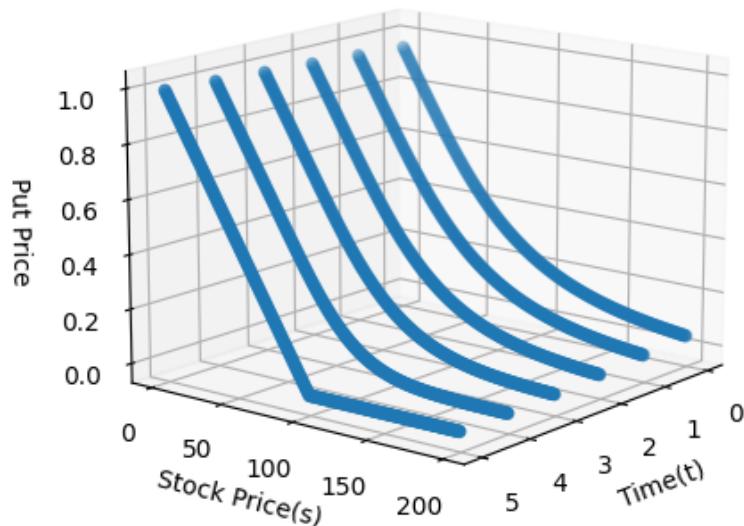


The 3-dimensional plots for  $C(t, S(t))$  &  $P(t, S(t))$  are:

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



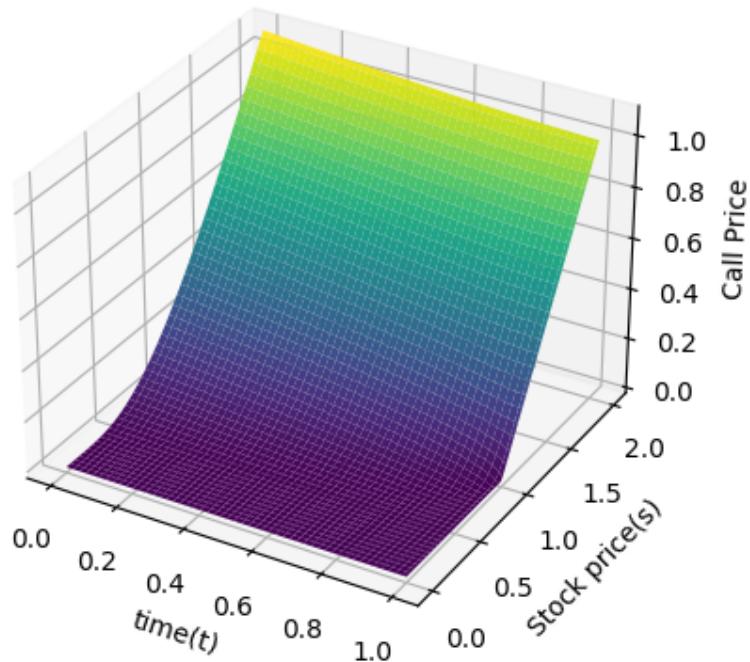
Variation of  $P(t, S(t))$  for change in  $t$  and  $S(t)$



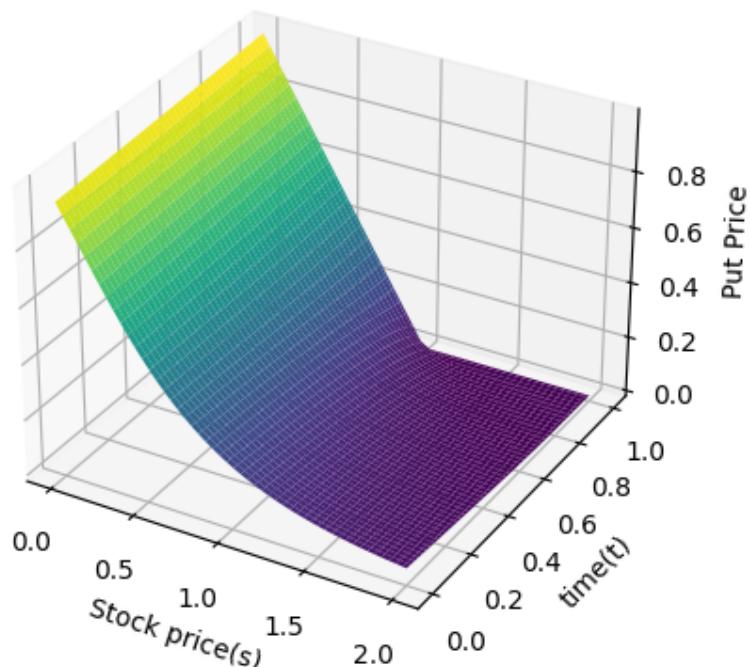
### Question 3:

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:

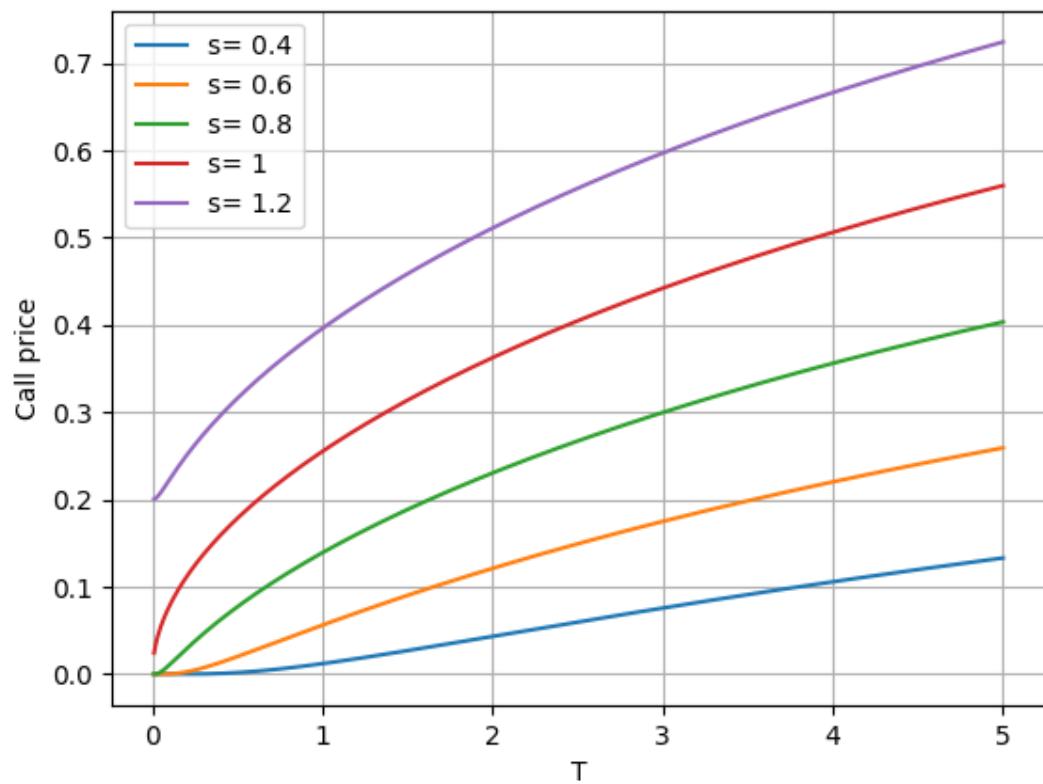
T	C(t,S(t))	P(t,S(t))
0.5	0.0771391	0.252449
1	0.139135	0.290364
1.5	0.188581	0.316324
2	0.230477	0.335314
2.5	0.267111	0.349608
3	0.299765	0.360473
3.5	0.329249	0.368706
4	0.356118	0.374849
4.5	0.380775	0.379291
5	0.403524	0.382325

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

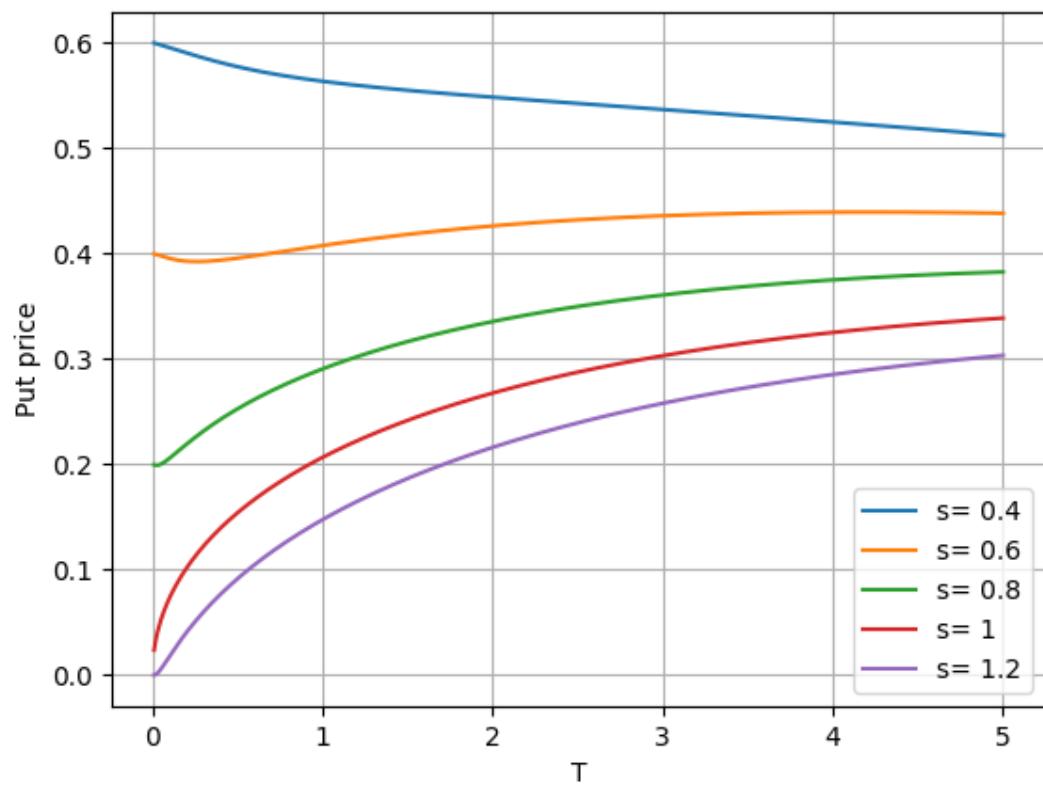
r	C(t,S(t))	P(t,S(t))
0.098	0.152134	0.258783
0.198	0.181038	0.201408
0.298	0.212075	0.154376
0.398	0.244772	0.116434
0.498	0.278598	0.086343
0.598	0.312995	0.062905
0.698	0.347413	0.044993
0.798	0.381344	0.0315727
0.898	0.414339	0.0217228
0.998	0.446029	0.0146454

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

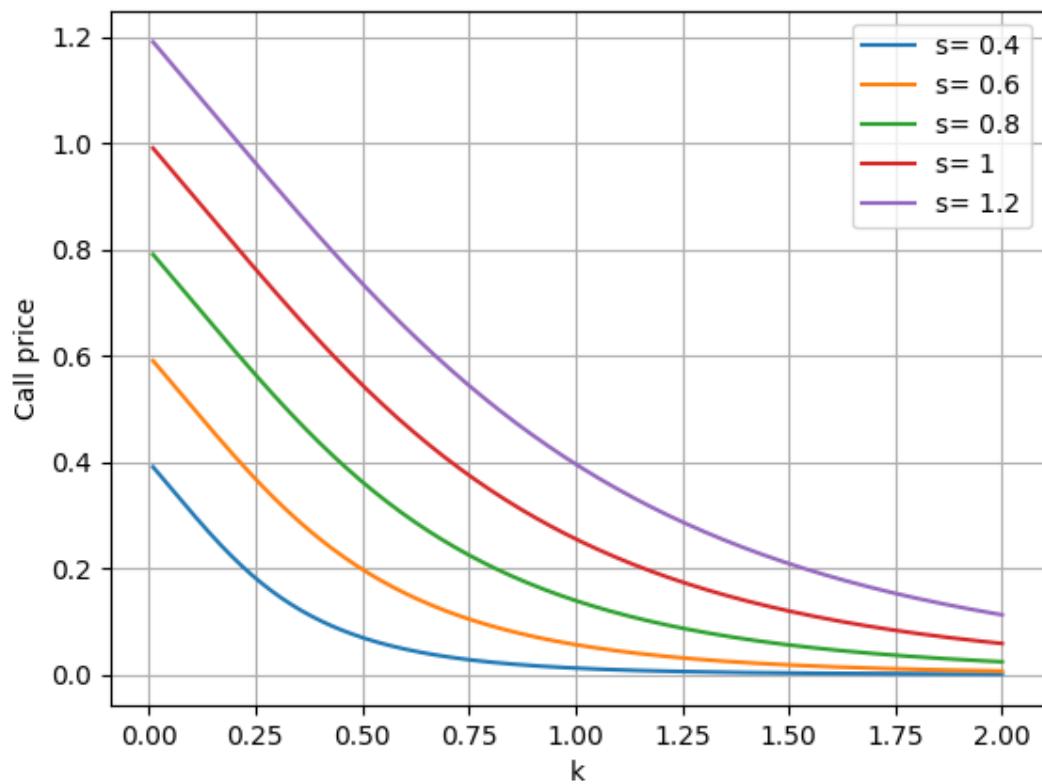
Variation of  $C(t, S(t))$  wrt  $T$



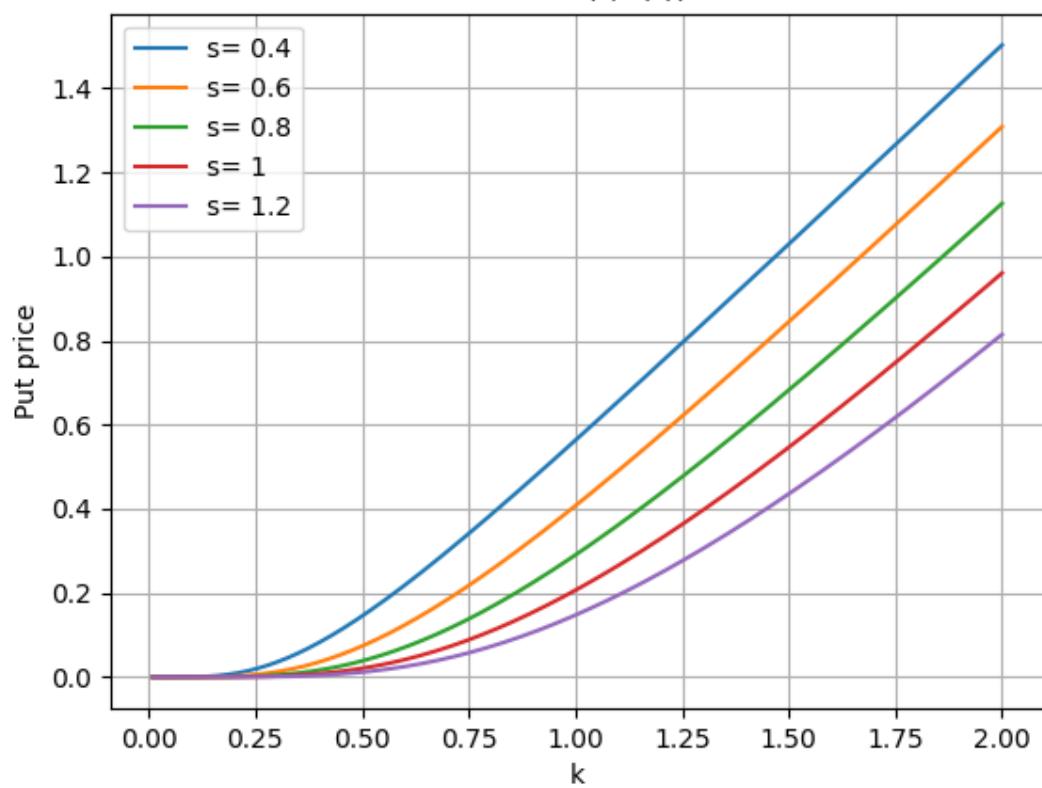
Variation of  $P(t, S(t))$  wrt  $T$



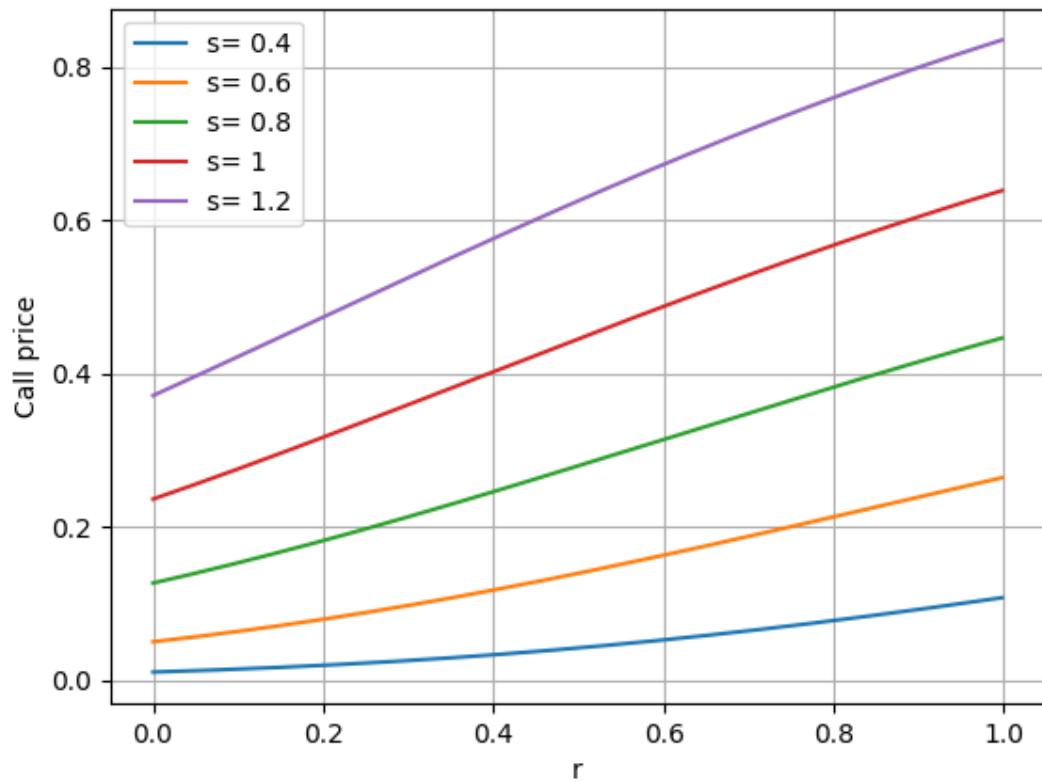
Variation of  $C(t, S(t))$  wrt  $k$



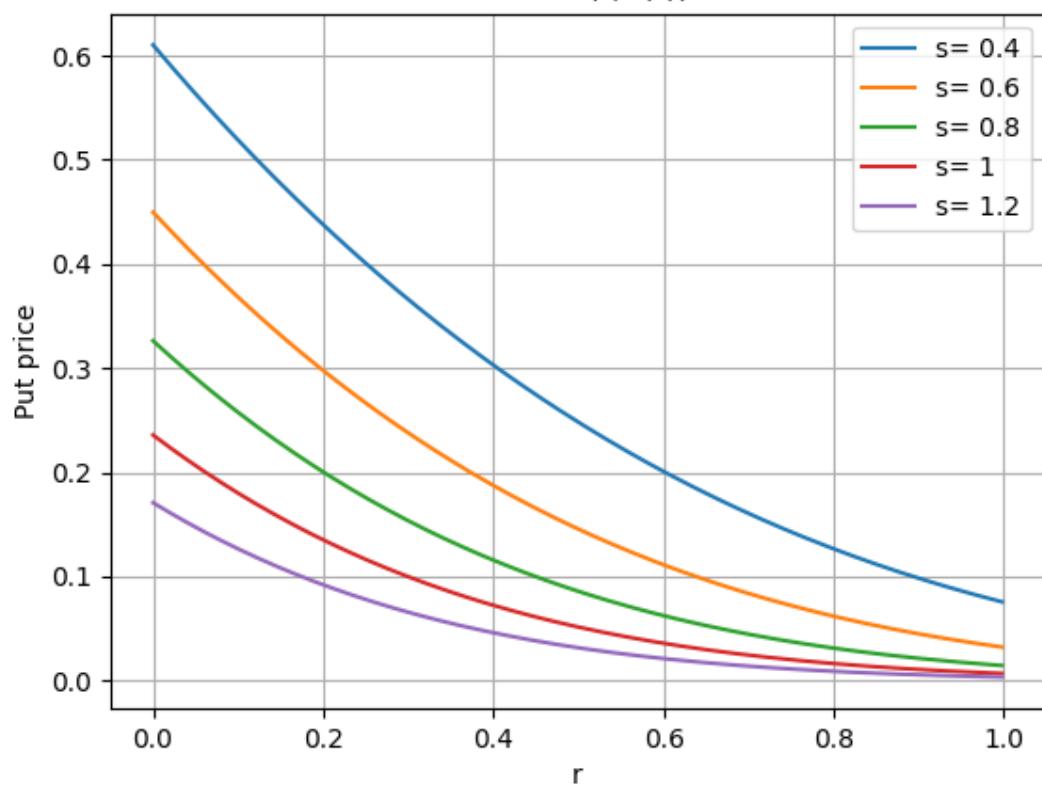
Variation of  $P(t, S(t))$  wrt  $k$



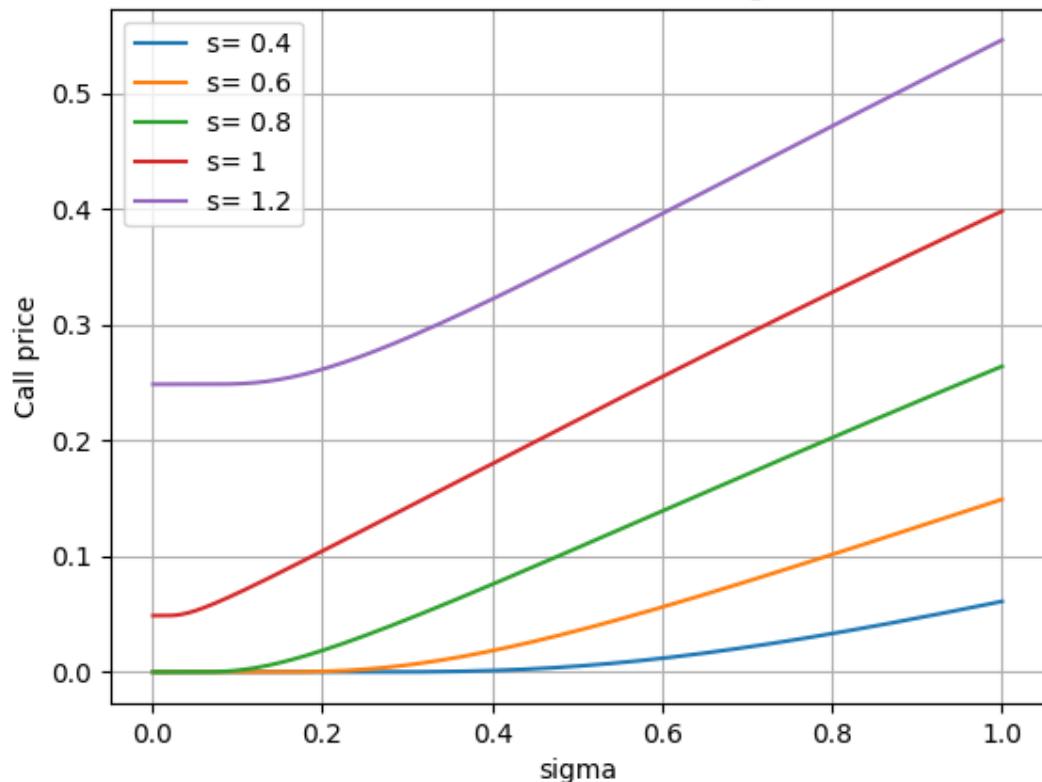
Variation of  $C(t, S(t))$  wrt  $r$



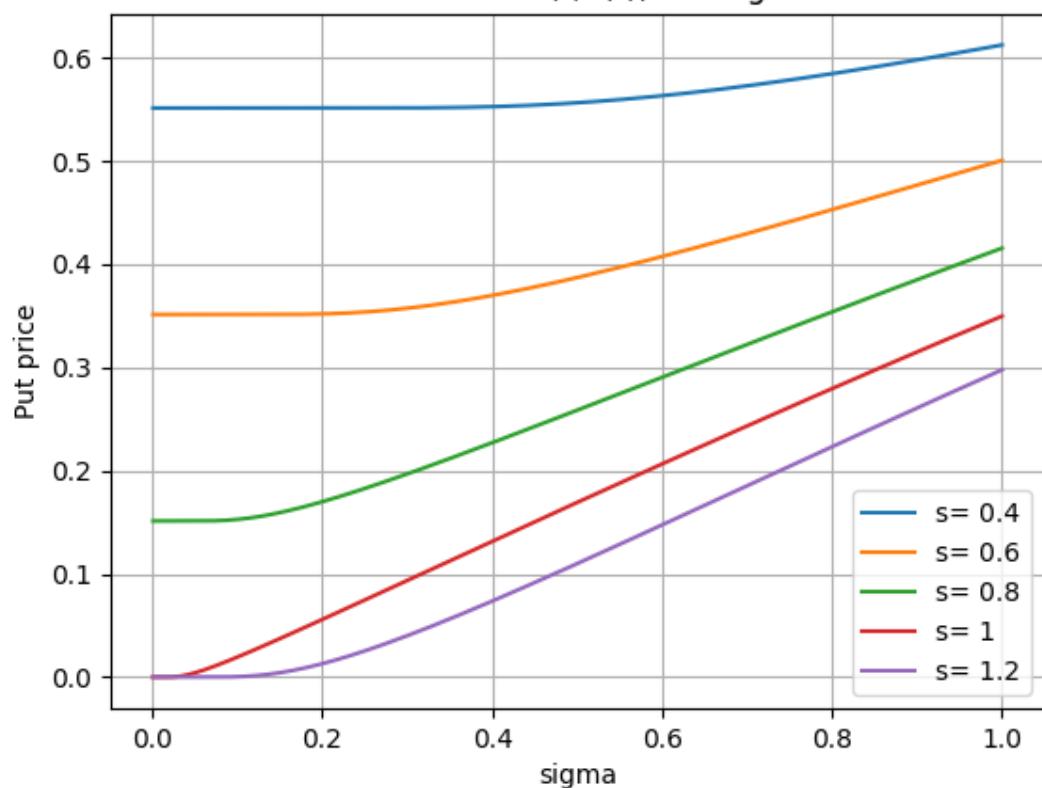
Variation of  $P(t, S(t))$  wrt  $r$



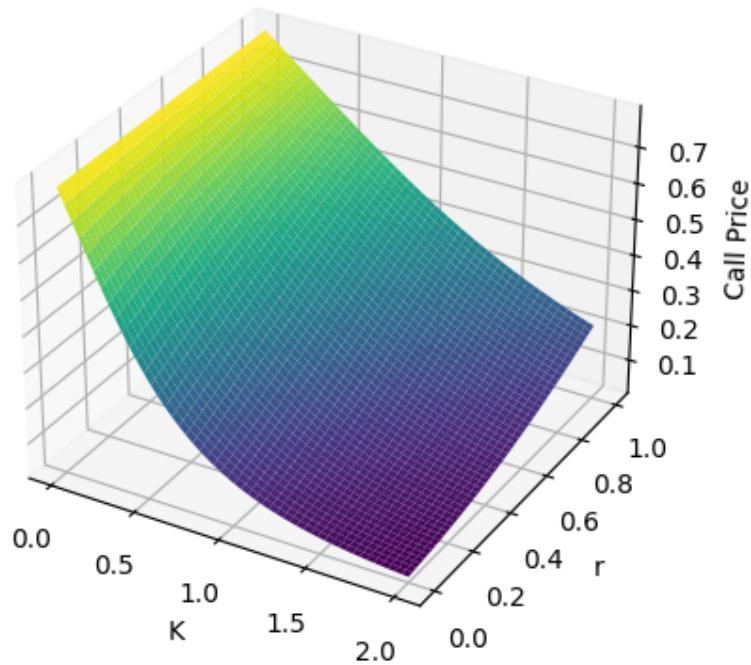
Variation of  $C(t, S(t))$  wrt sigma



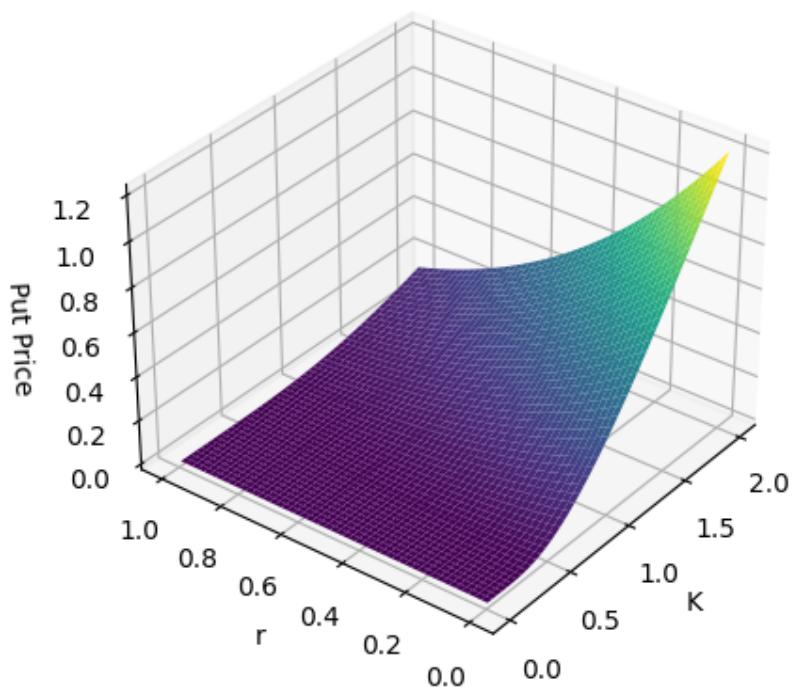
Variation of  $P(t, S(t))$  wrt sigma



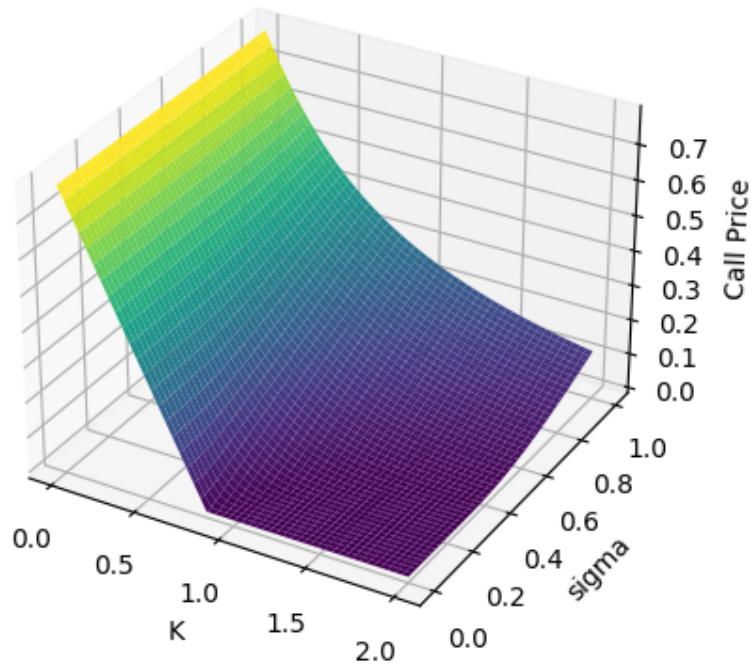
Variation of  $C(t, S(t))$  for change in  $k$  and  $r$



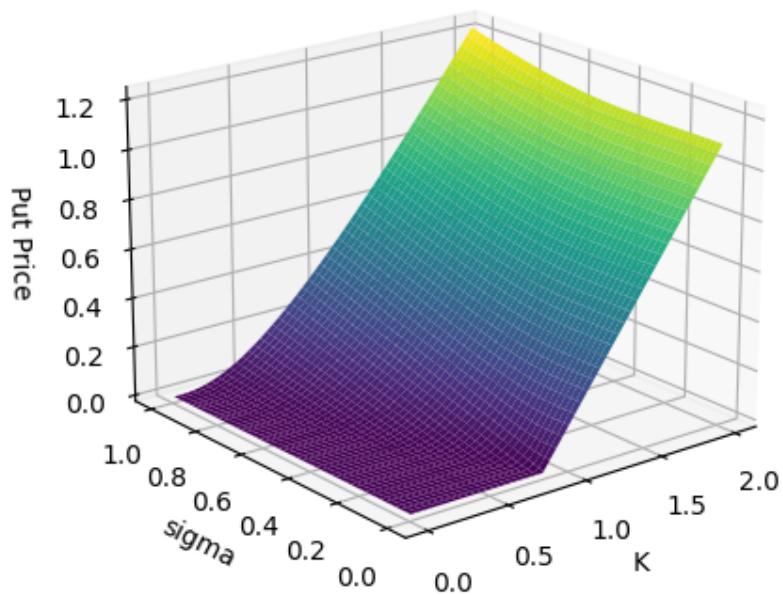
Variation of  $P(t, S(t))$  for change in  $k$  and  $r$



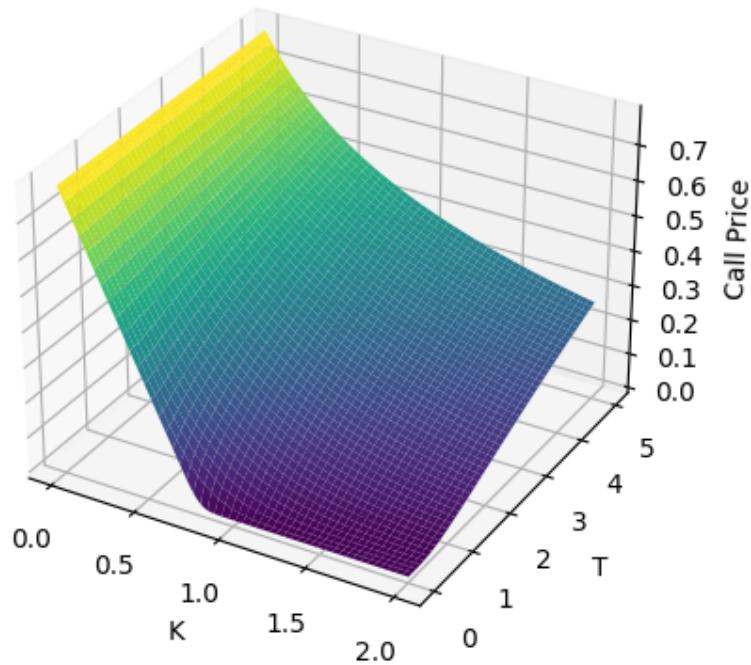
Variation of  $C(t, S(t))$  for change in  $k$  and  $\sigma$



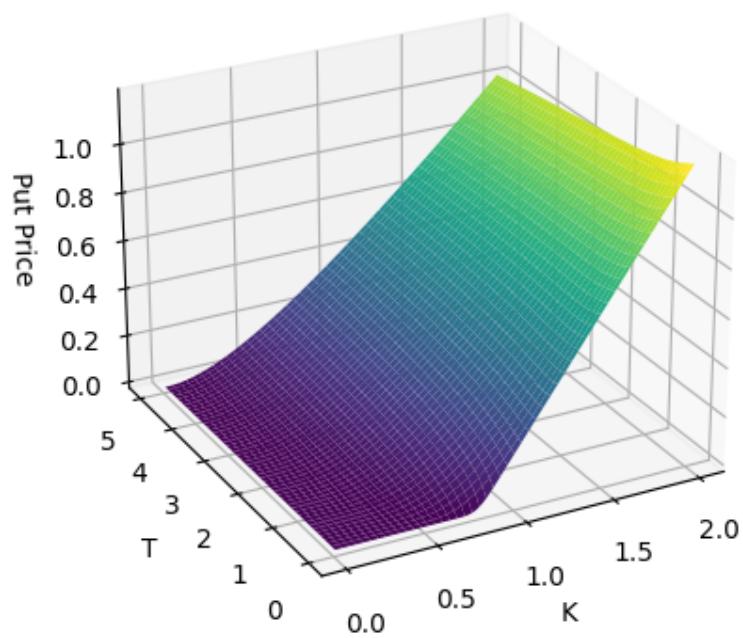
Variation of  $P(t, S(t))$  for change in  $k$  and  $\sigma$



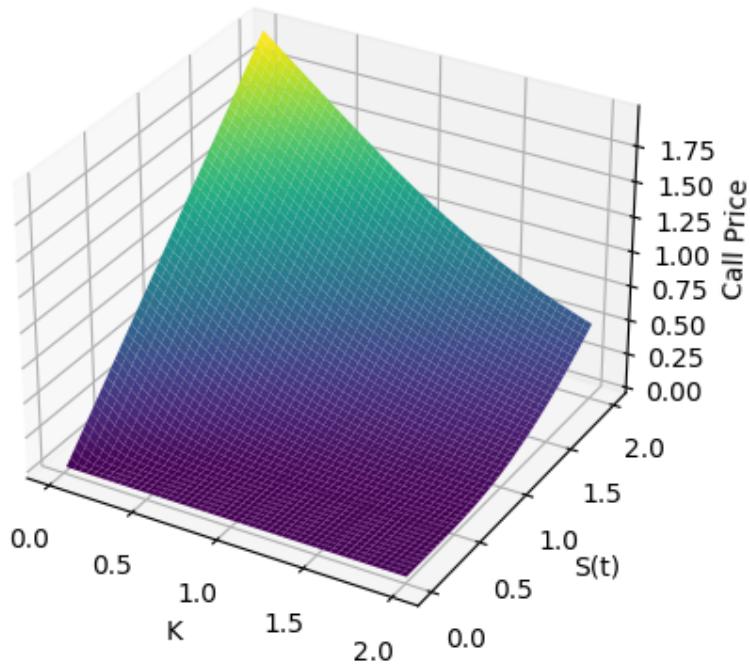
Variation of  $C(t, S(t))$  for change in  $k$  and  $T$



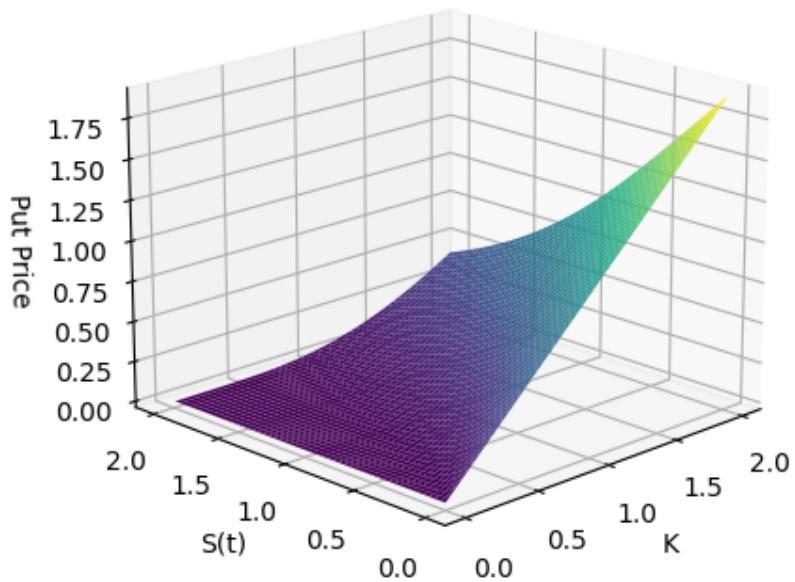
Variation of  $P(t, S(t))$  for change in  $k$  and  $T$



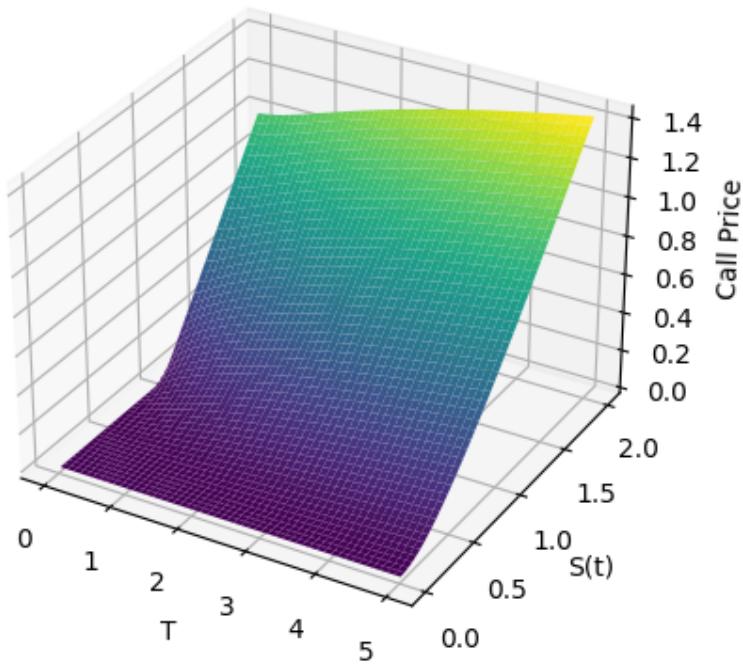
Variation of  $C(t, S(t))$  for change in  $k$  and  $S(t)$



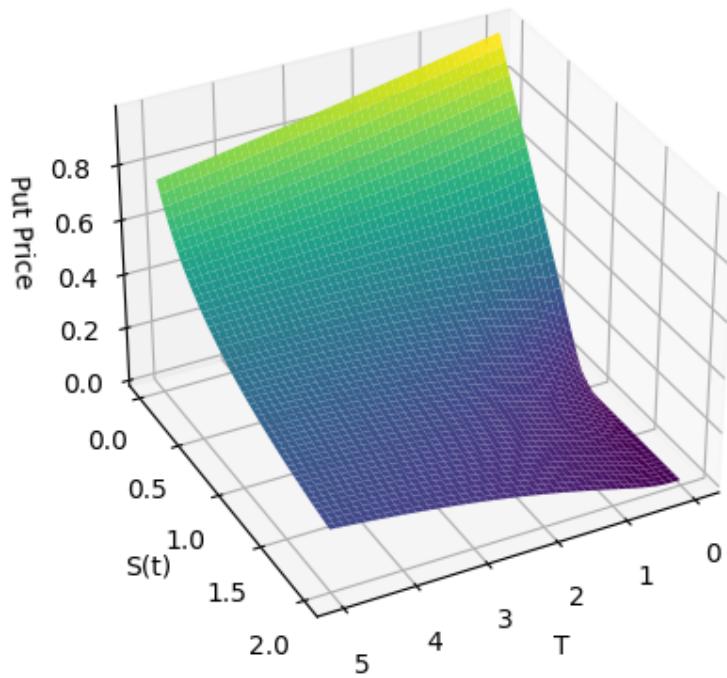
Variation of  $P(t, S(t))$  for change in  $k$  and  $S(t)$



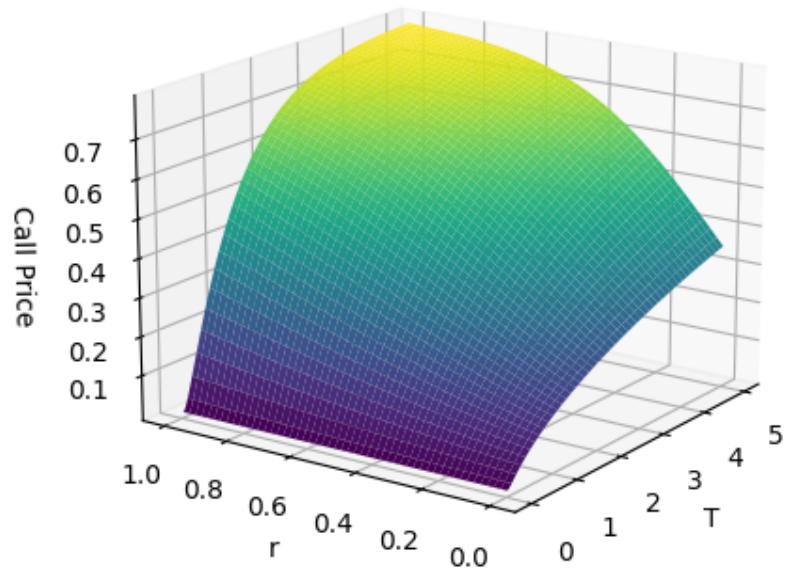
Variation of  $C(t, S(t))$  for change in  $T$  and  $S(t)$



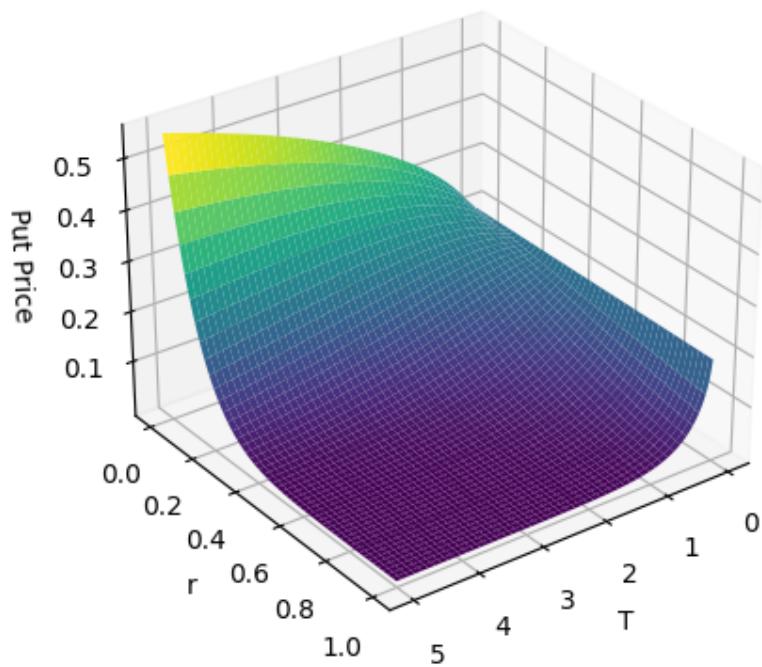
Variation of  $P(t, S(t))$  for change in  $T$  and  $S(t)$



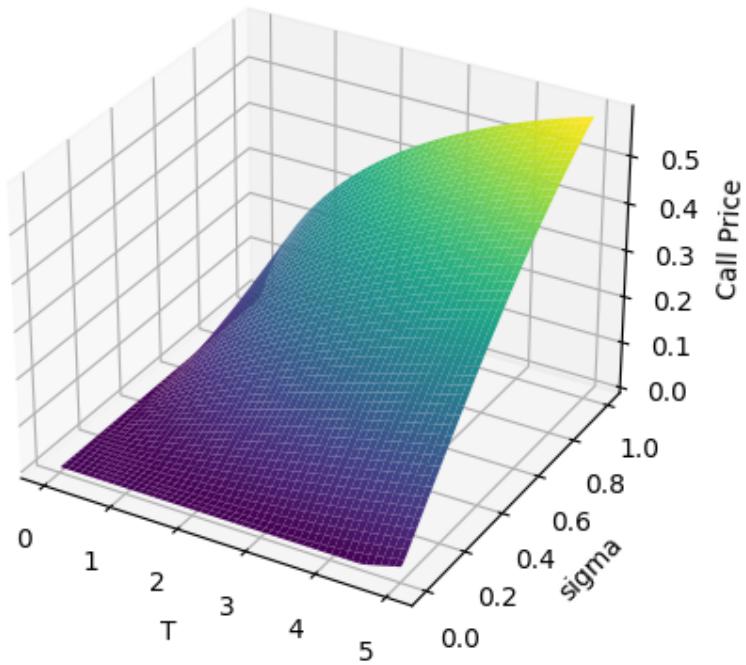
Variation of  $C(t, S(t))$  for change in  $T$  and  $r$



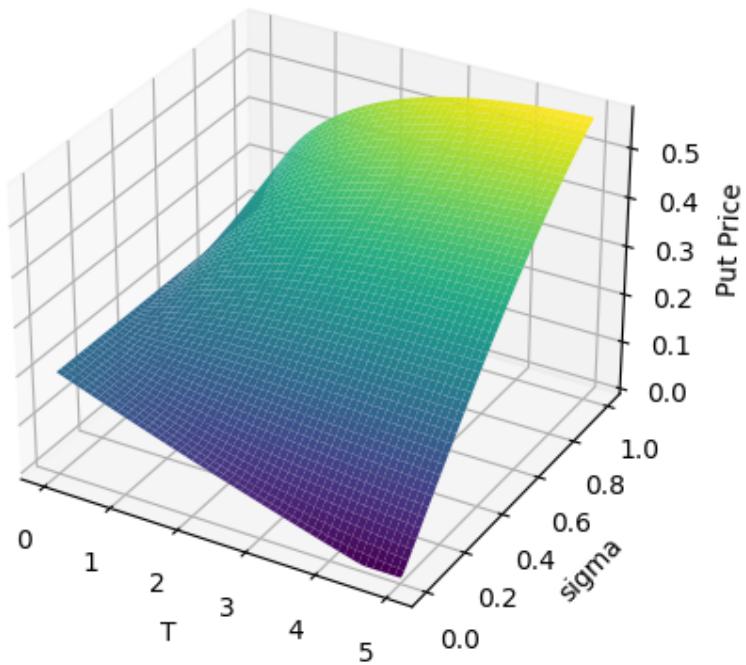
Variation of  $P(t, S(t))$  for change in  $T$  and  $r$



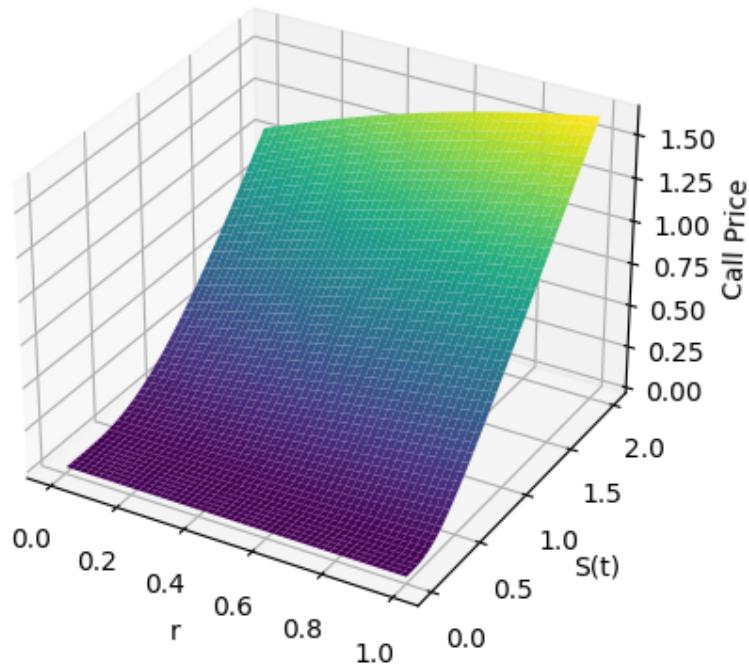
Variation of  $C(t, S(t))$  for change in  $T$  and sigma



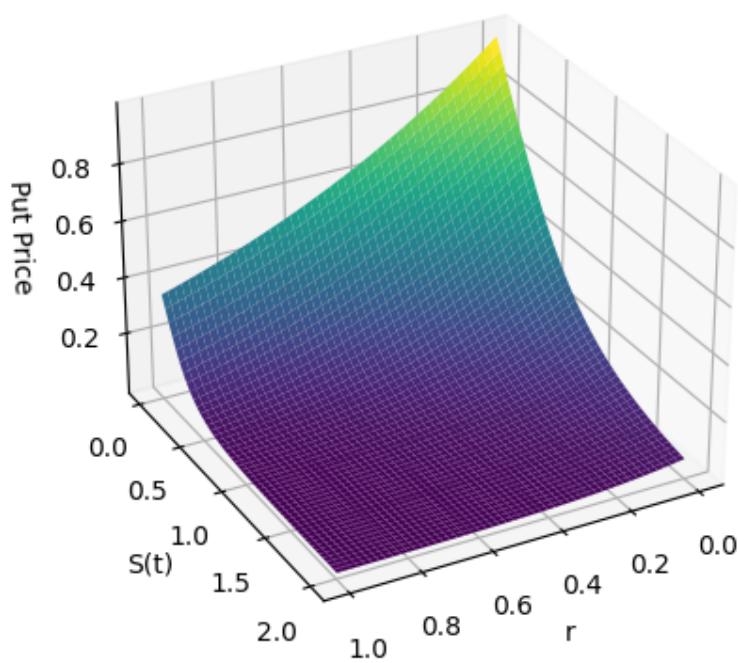
Variation of  $P(t, S(t))$  for change in  $T$  and sigma



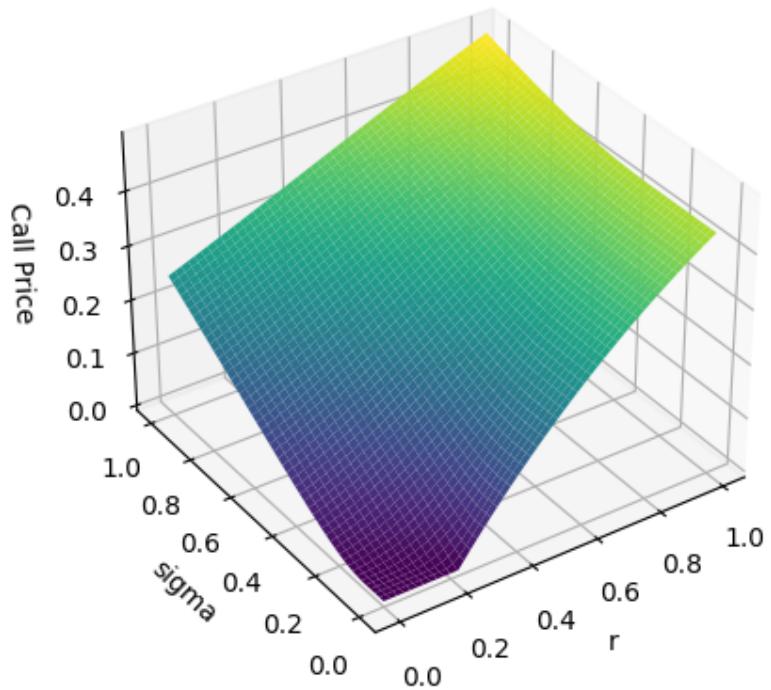
Variation of  $C(t, S(t))$  for change in  $r$  and  $S(t)$



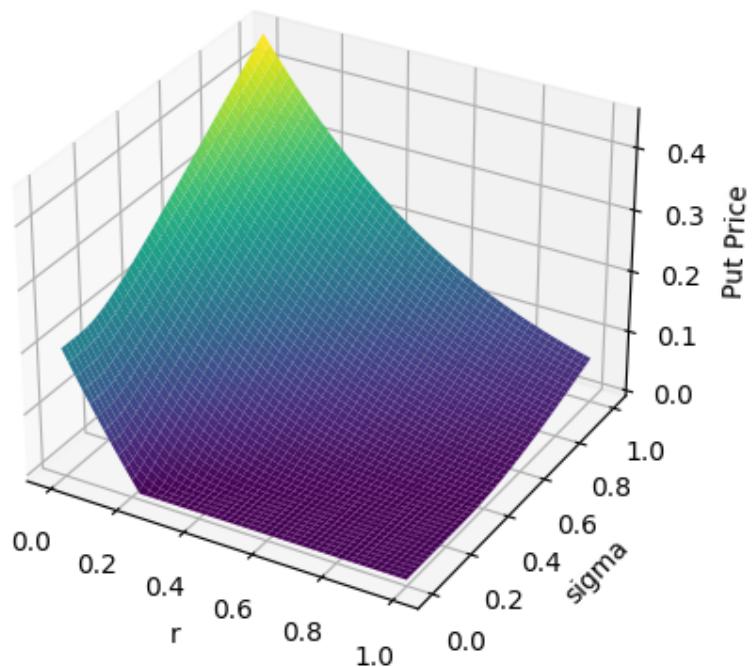
Variation of  $P(t, S(t))$  for change in  $r$  and  $S(t)$



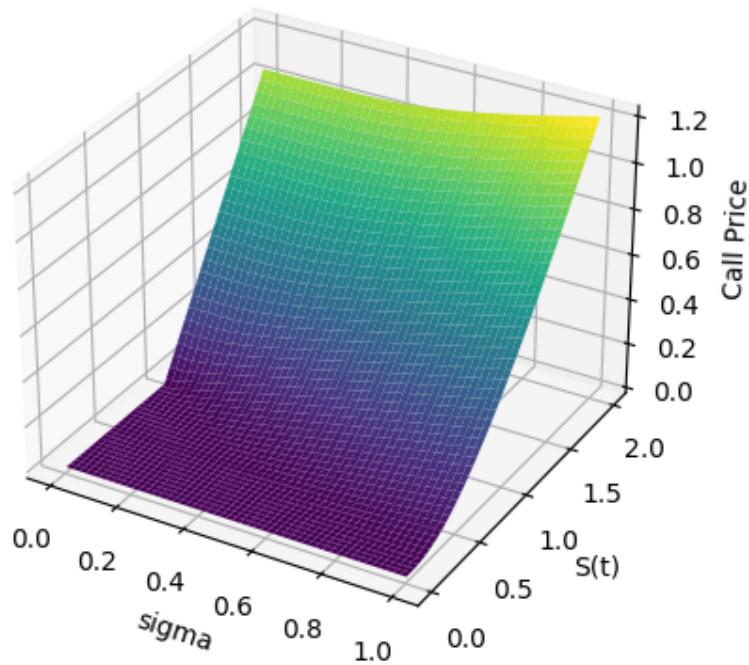
Variation of  $C(t, S(t))$  for change in  $r$  and  $\sigma$



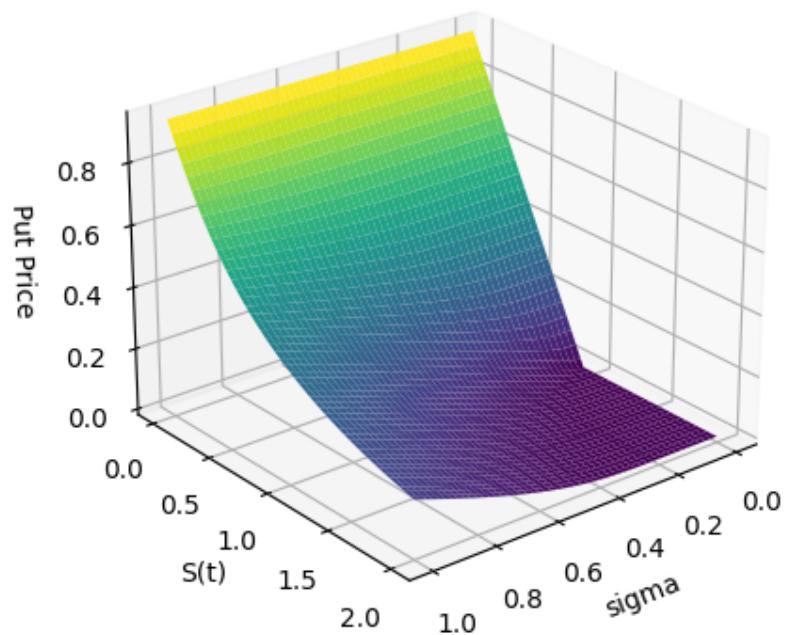
Variation of  $P(t, S(t))$  for change in  $r$  and  $\sigma$



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



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



### **Question 5:**

The price of European Call and Put Option with continuously paying dividend at the rate  $a$  given by BSM framework is:

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

Where,

$$d_1 = \frac{\log(\frac{x}{K}) + (r-a+\frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$

$$d_2 = \frac{\log(\frac{x}{K}) + (r-a-\frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}}$$

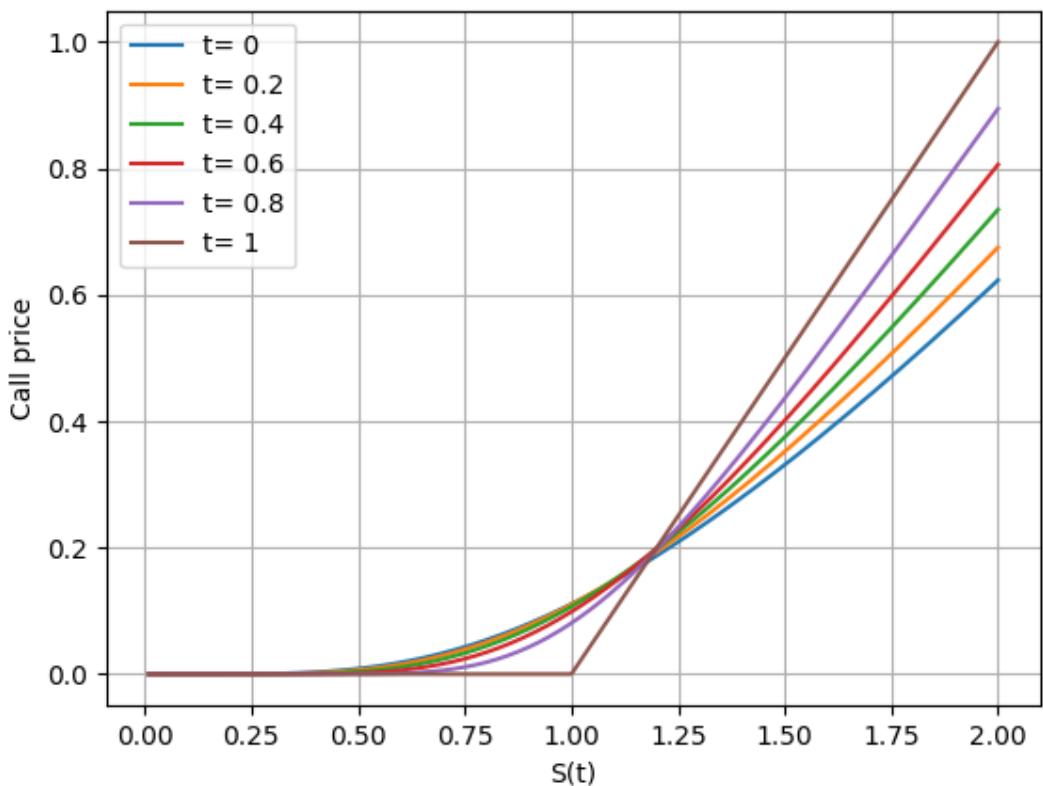
$$N(x) = \int_{-\infty}^x \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-x^2}{2}} dx$$

For the sensitivity analysis as Qsn 4, the parameters values are varied accordingly, and where some particular values of parameters are required, they are taken from the following:

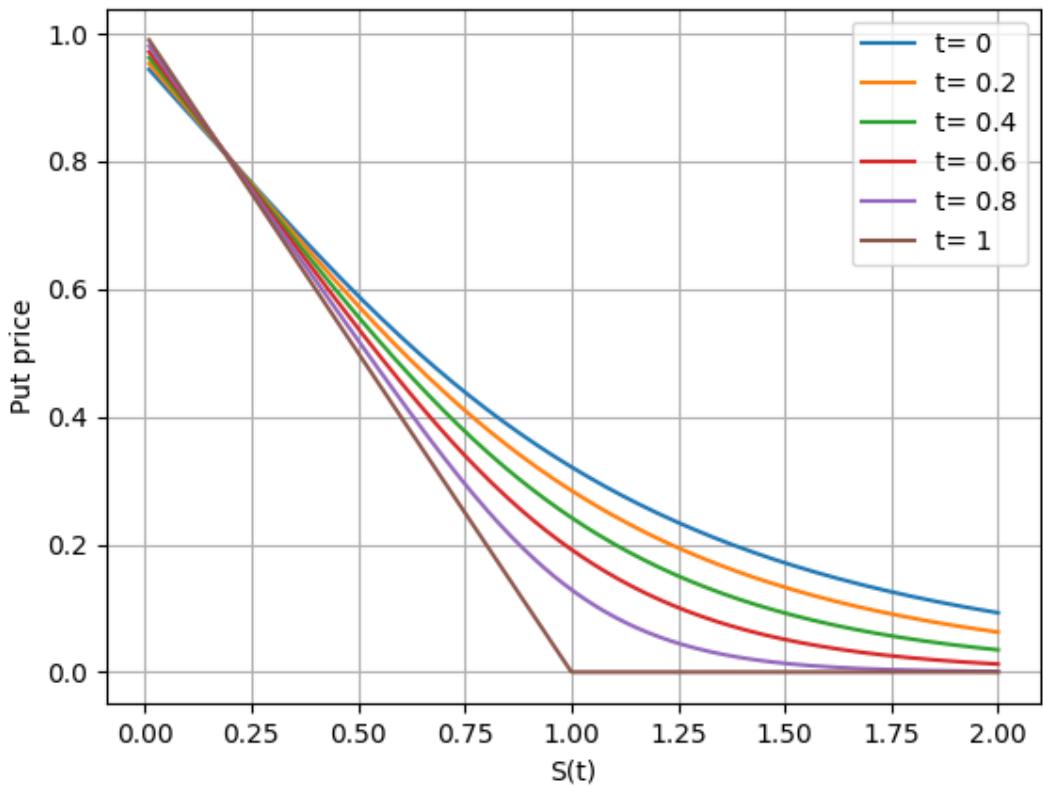
$$s = 0.8, a = 0.3, t = 0, T = 1, k = 1, r = 0.05, \sigma = 0.6$$

All the plots are attached below :

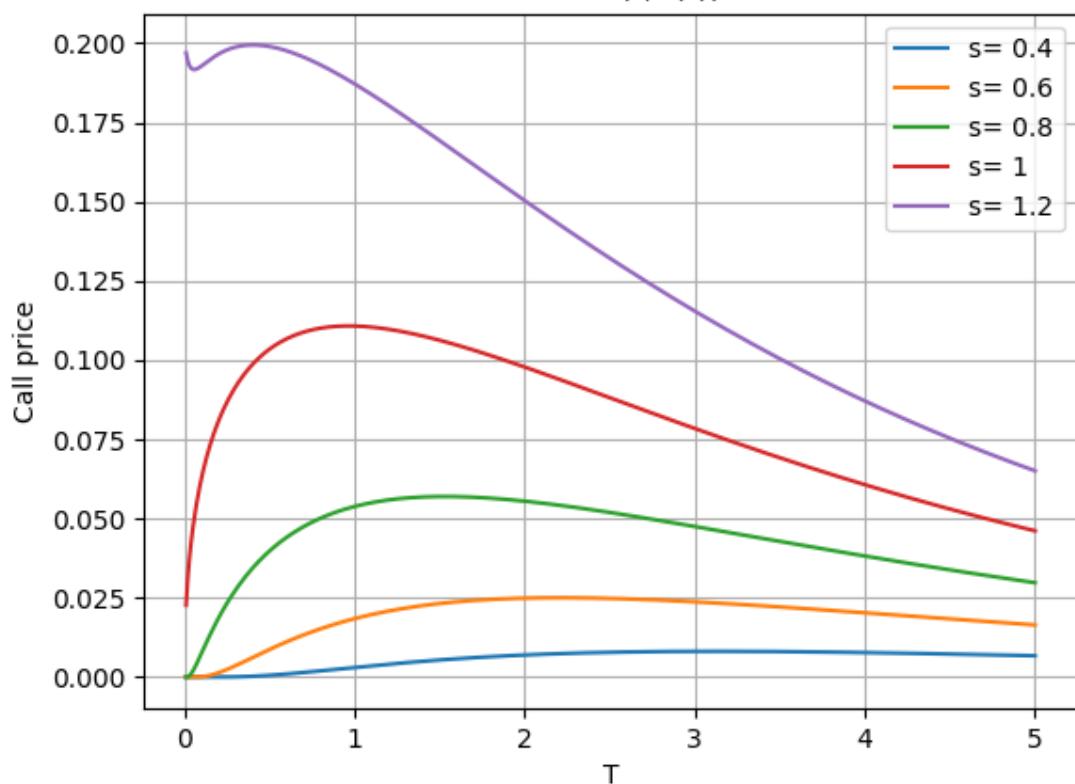
### Variation of $C(t, S(t))$ wrt $S(t)$



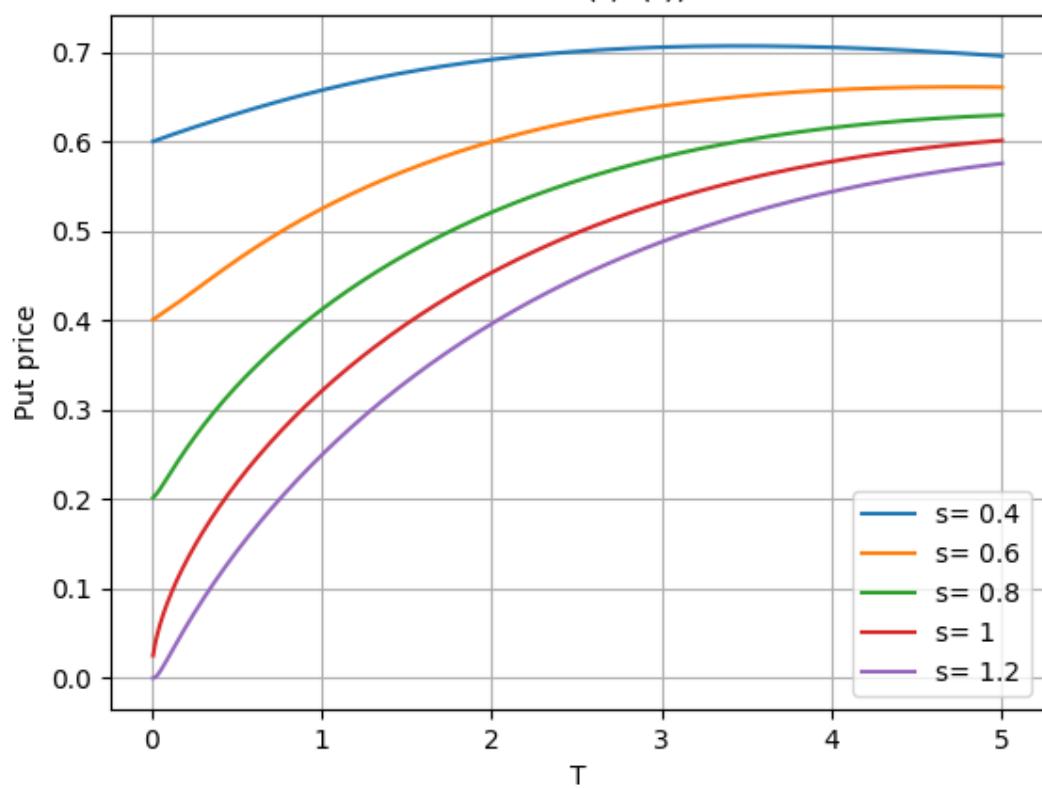
### Variation of $P(t, S(t))$ wrt $S(t)$



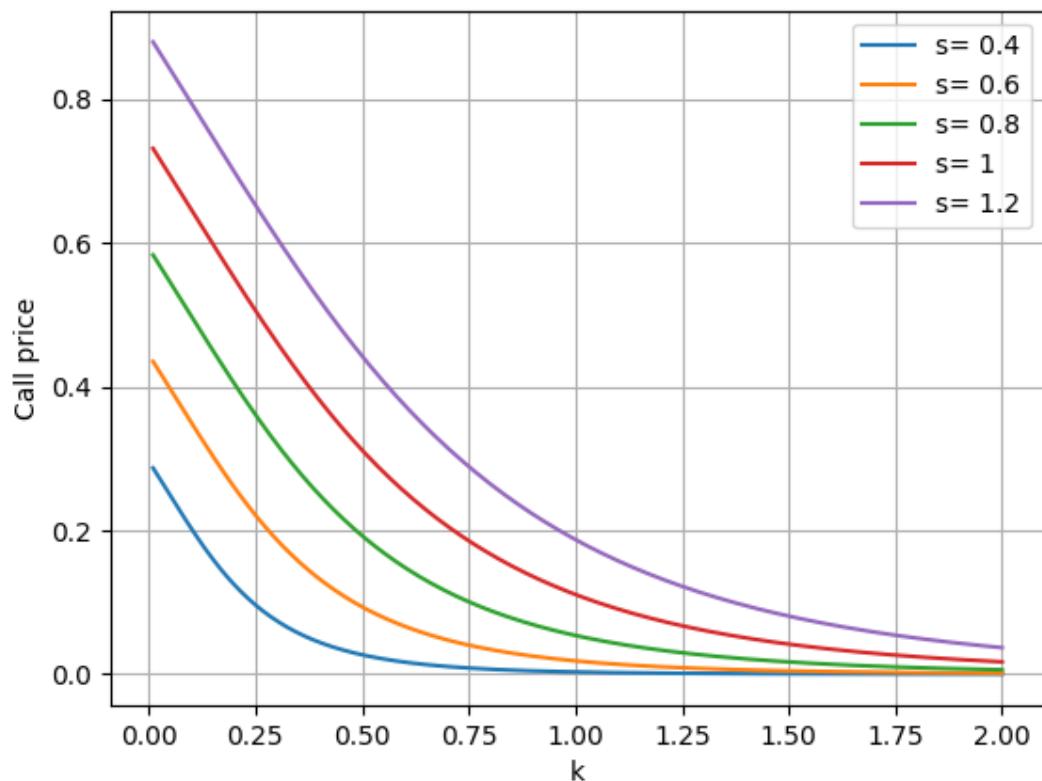
Variation of  $C(t, S(t))$  wrt  $T$



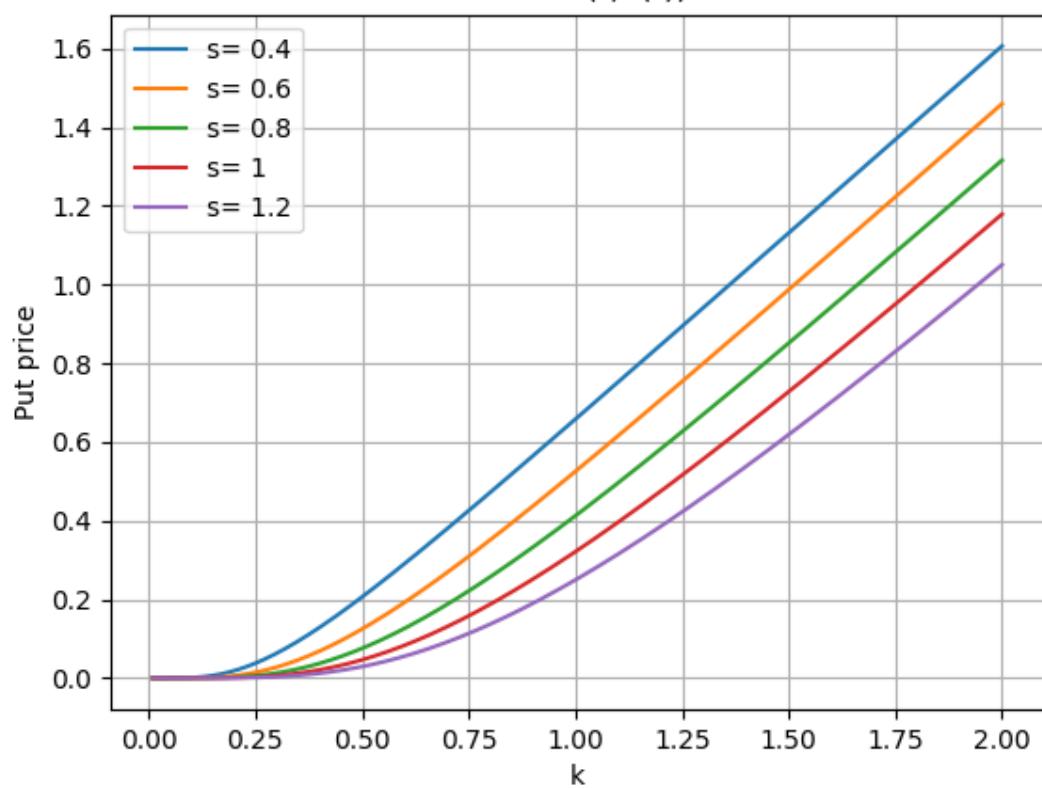
Variation of  $P(t, S(t))$  wrt  $T$



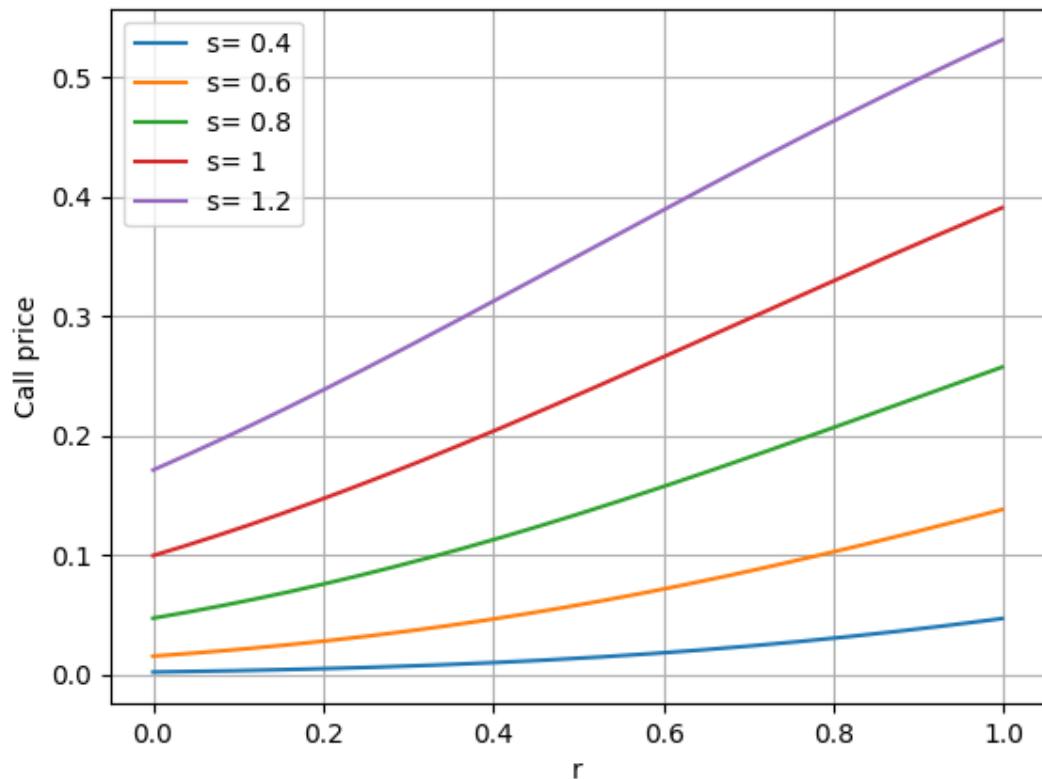
Variation of  $C(t, S(t))$  wrt  $k$



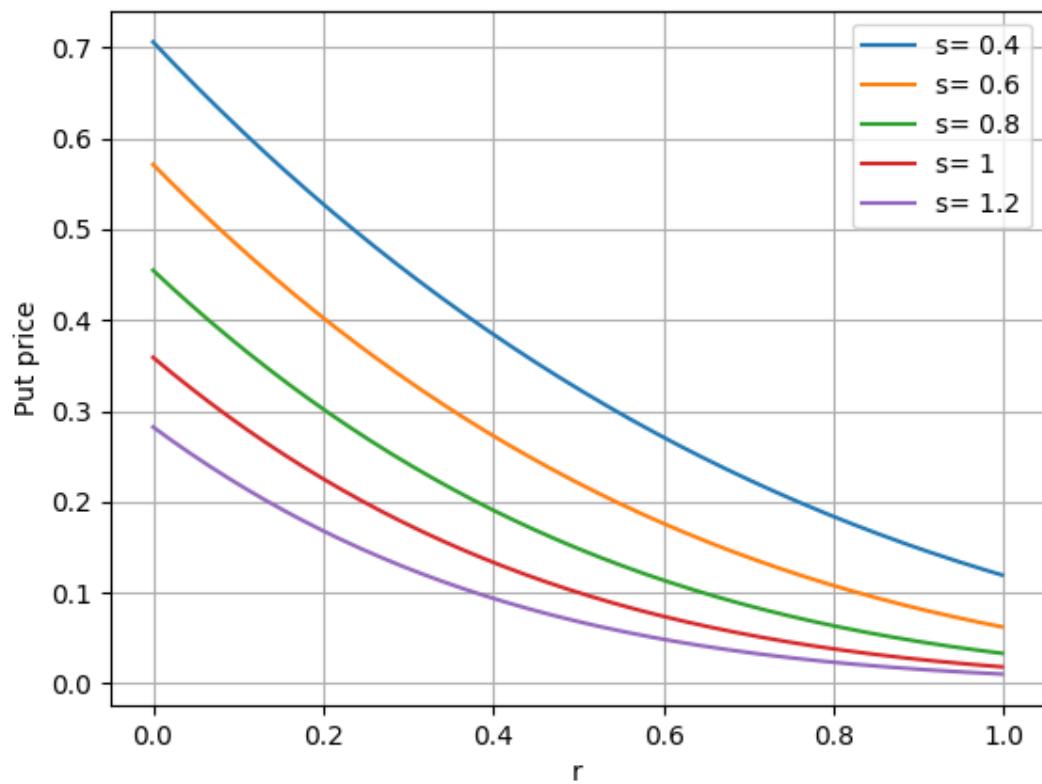
Variation of  $P(t, S(t))$  wrt  $k$



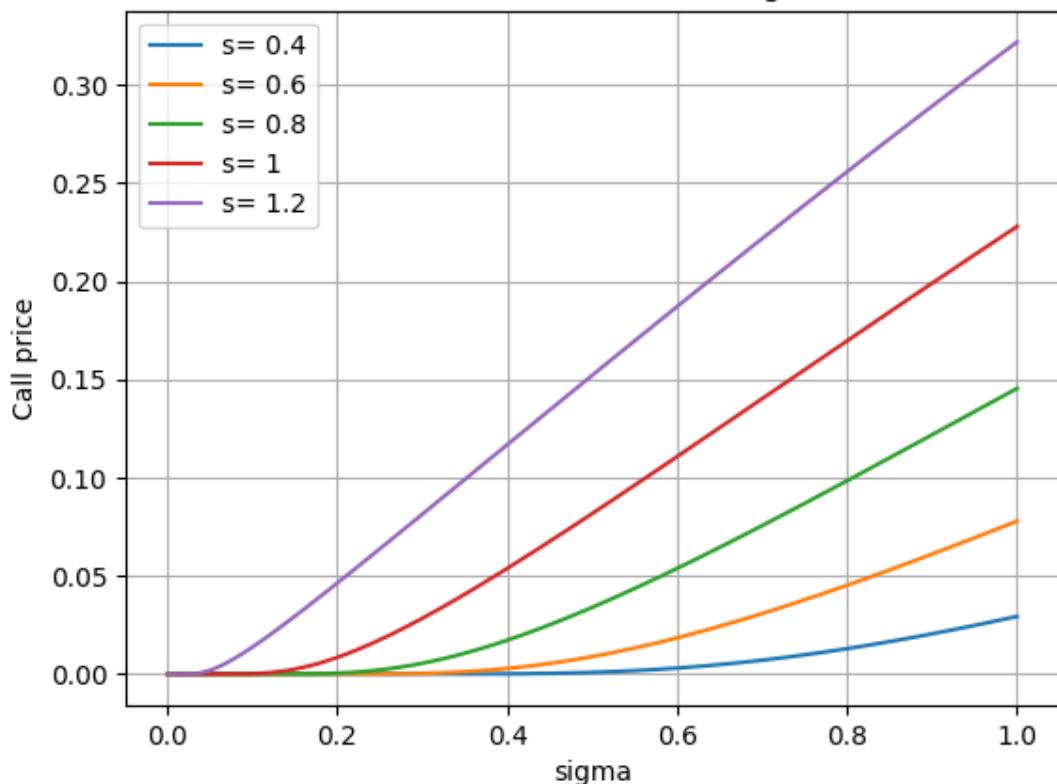
Variation of  $C(t, S(t))$  wrt  $r$



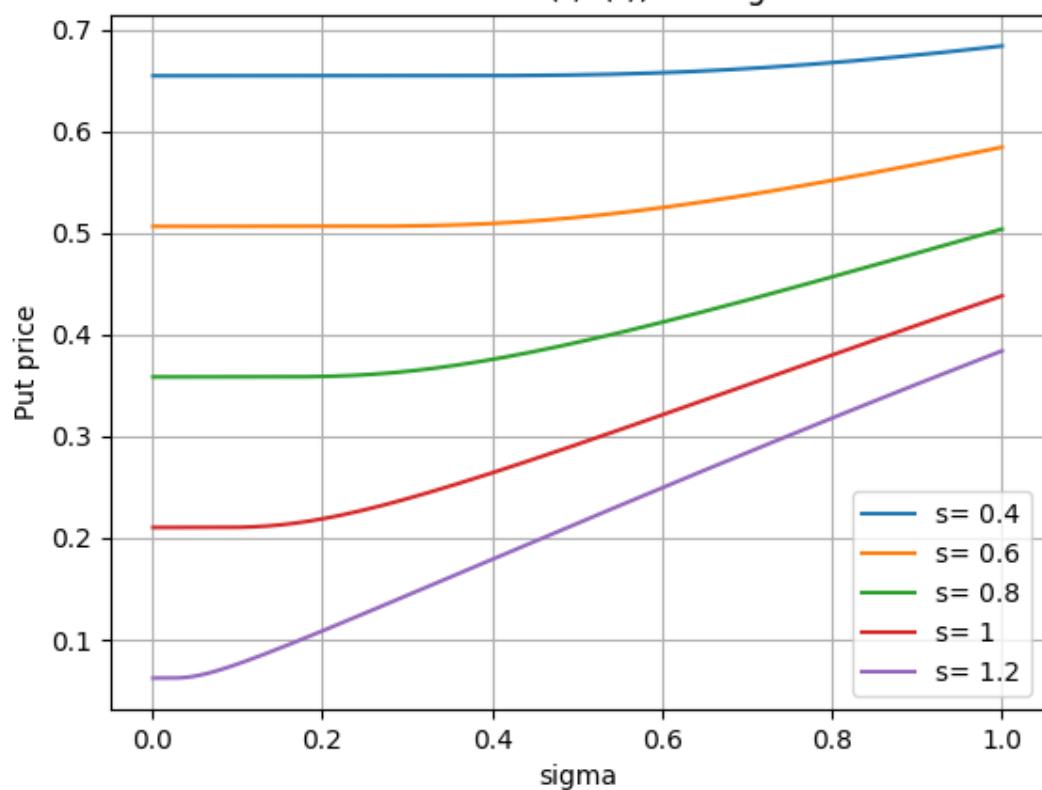
Variation of  $P(t, S(t))$  wrt  $r$



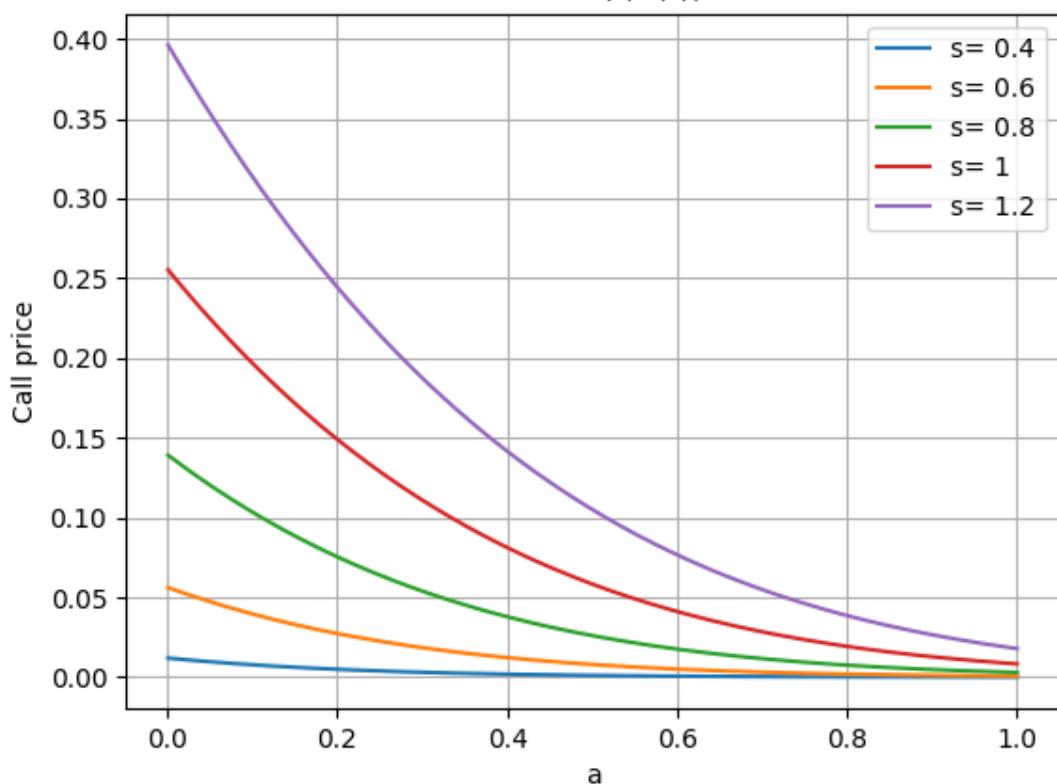
Variation of  $C(t, S(t))$  wrt sigma



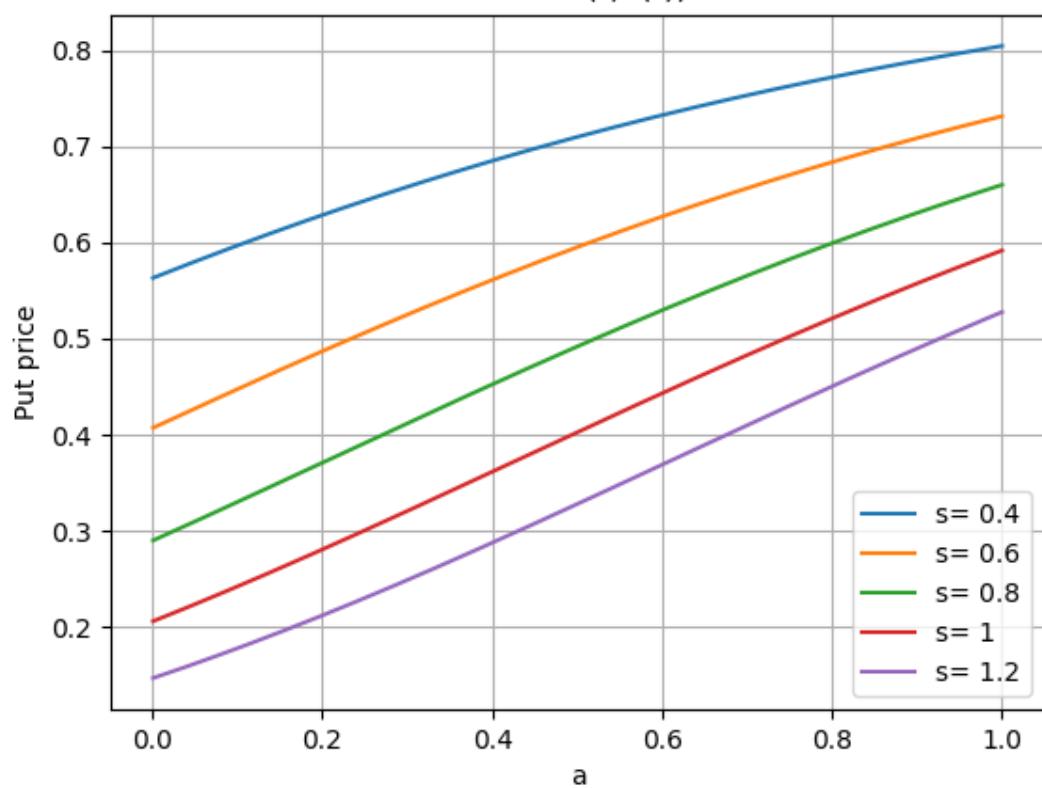
Variation of  $P(t, S(t))$  wrt sigma



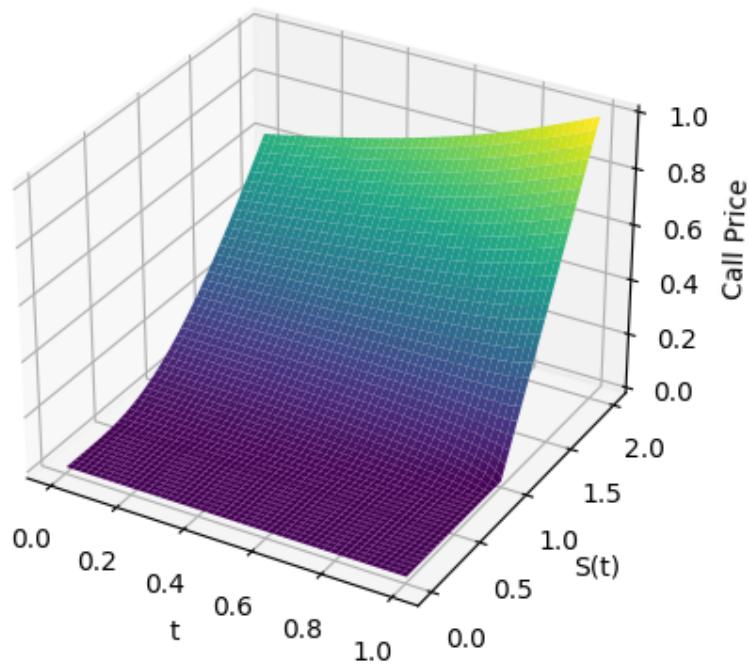
Variation of  $C(t, S(t))$  wrt  $a$



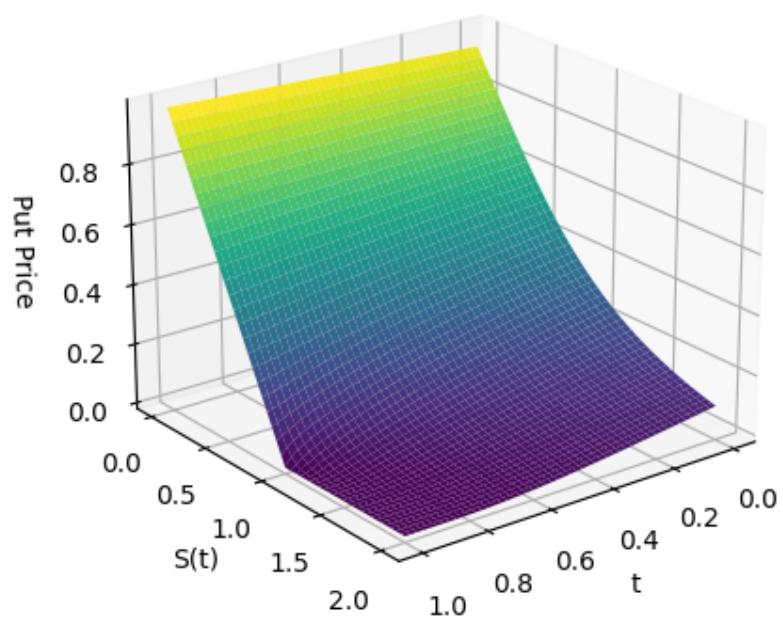
Variation of  $P(t, S(t))$  wrt  $a$



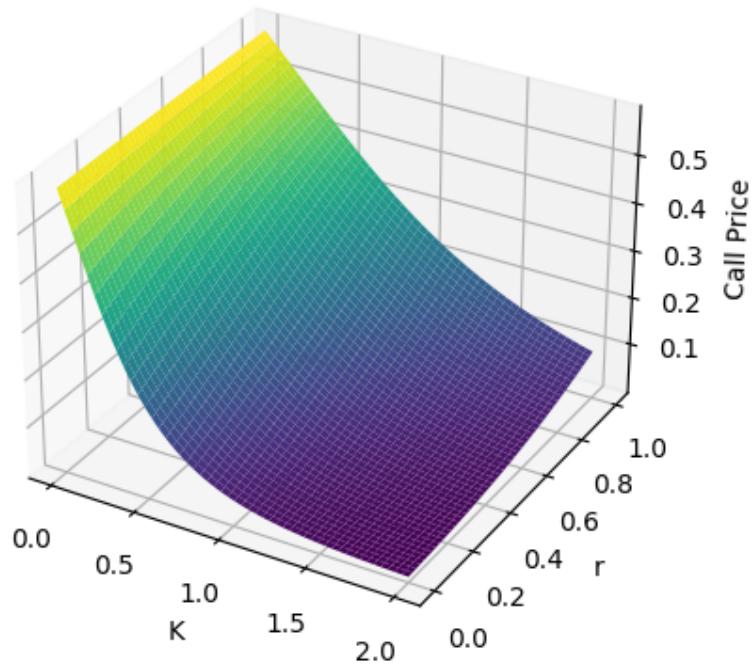
Variation of  $C(t, S(t))$  for change in  $t$  and  $S(t)$



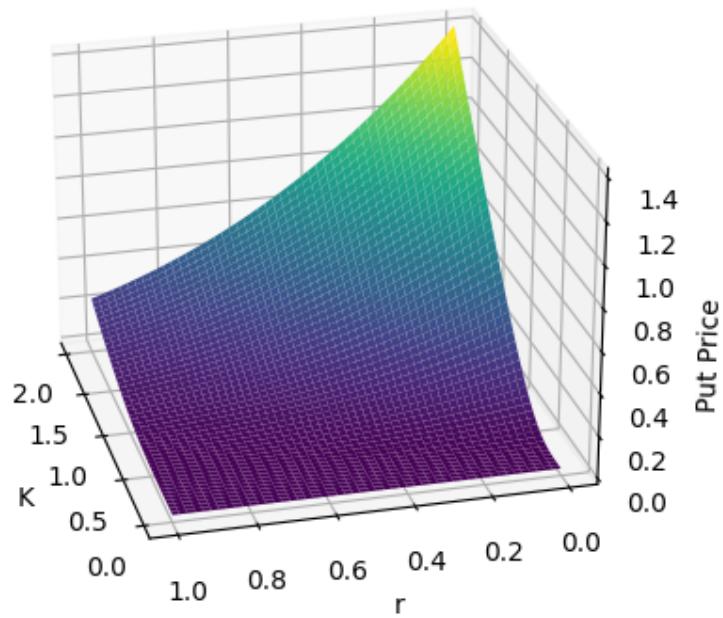
Variation of  $P(t, S(t))$  for change in  $t$  and  $S(t)$



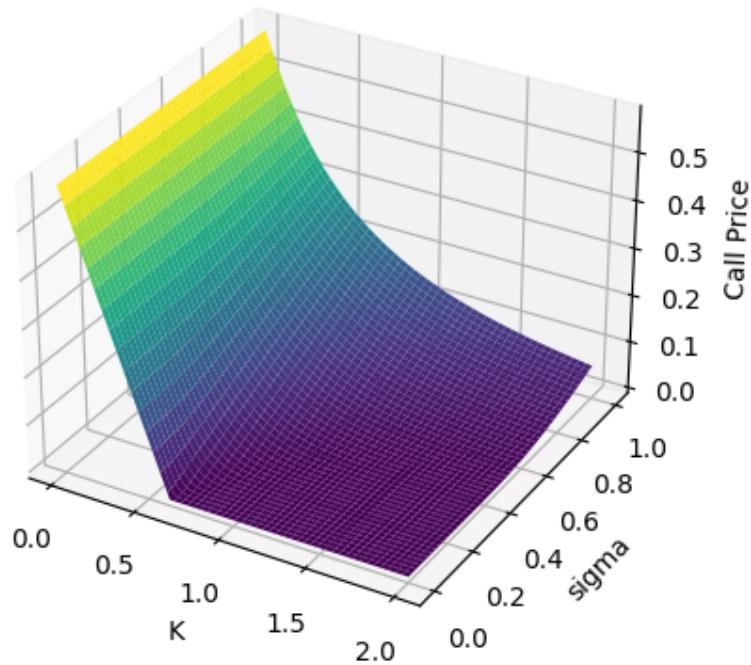
Variation of  $C(t, S(t))$  for change in  $k$  and  $r$



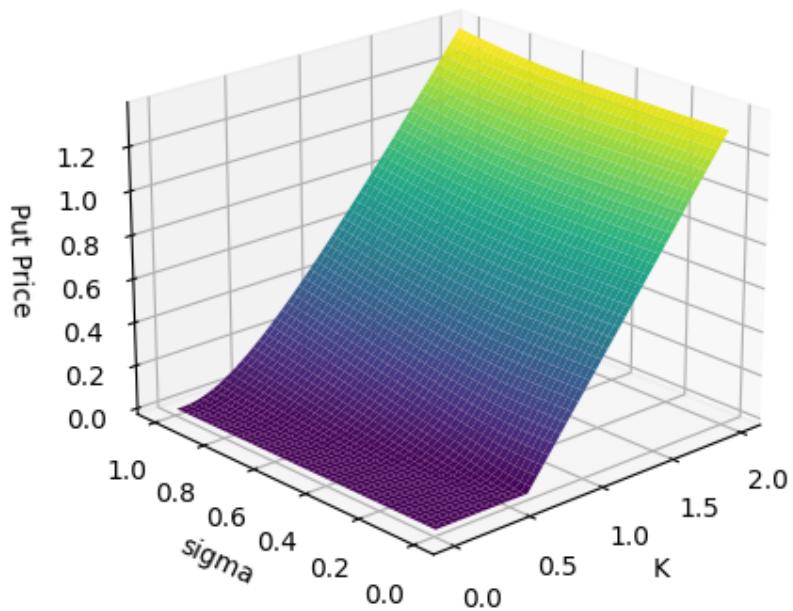
Variation of  $P(t, S(t))$  for change in  $k$  and  $r$



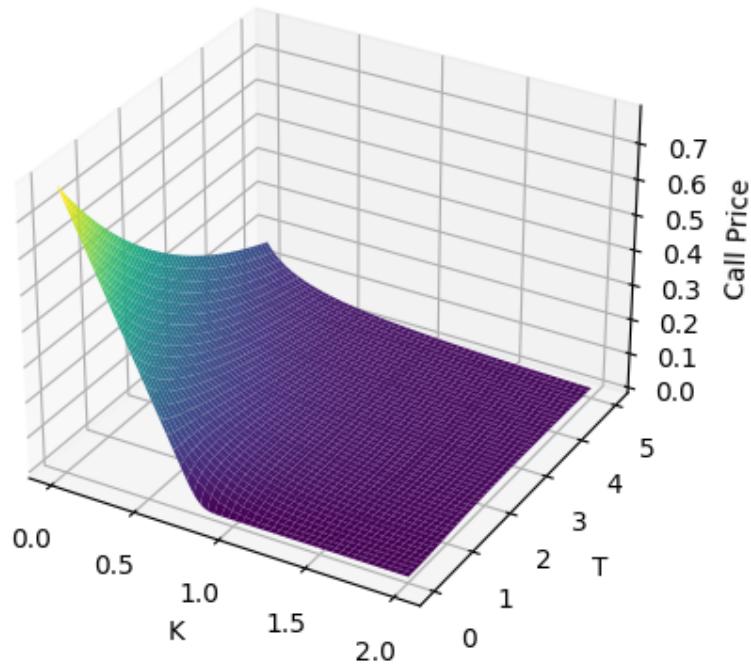
Variation of  $C(t, S(t))$  for change in  $k$  and  $\sigma$



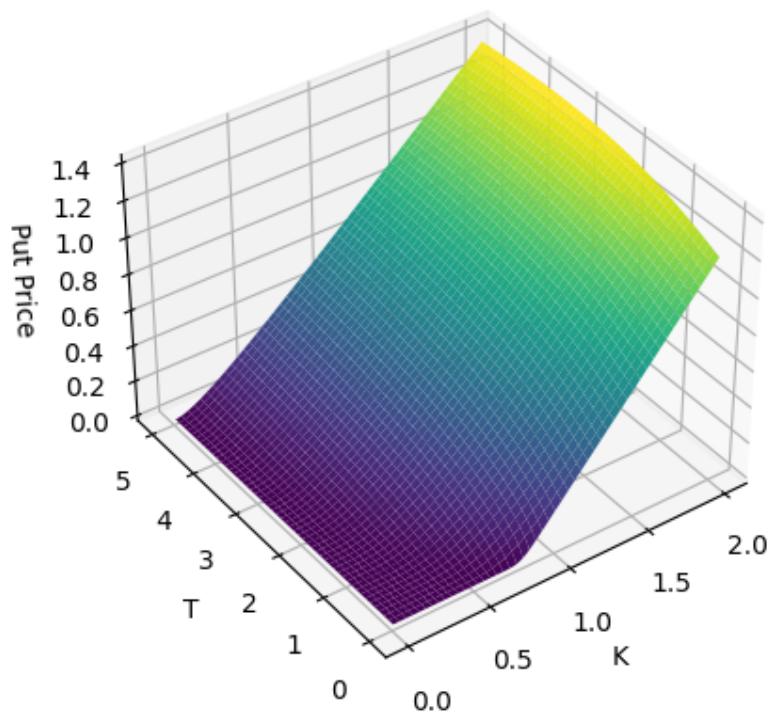
Variation of  $P(t, S(t))$  for change in  $k$  and  $\sigma$



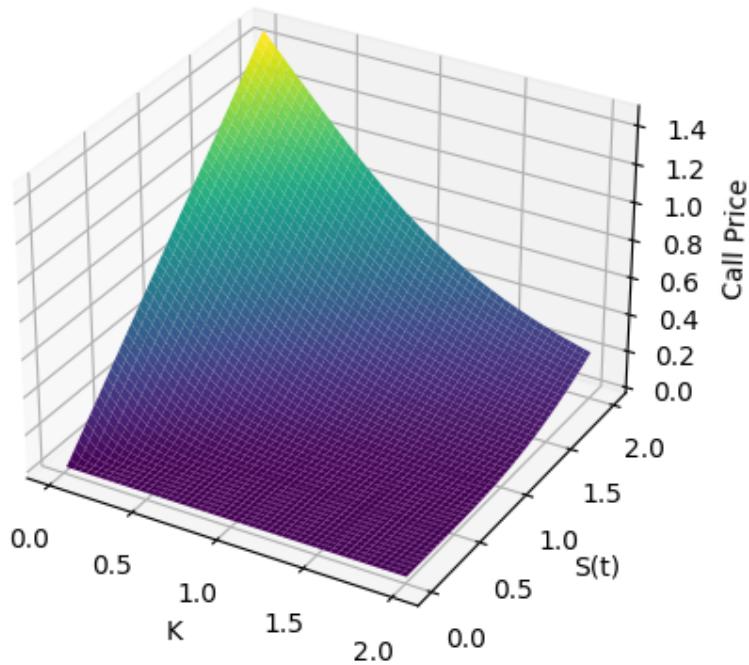
Variation of  $C(t, S(t))$  for change in  $k$  and  $T$



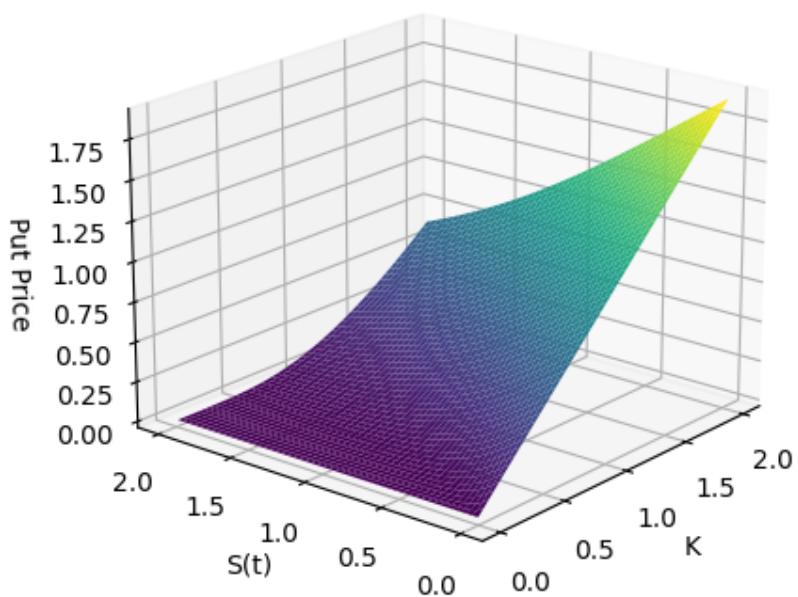
Variation of  $P(t, S(t))$  for change in  $k$  and  $T$



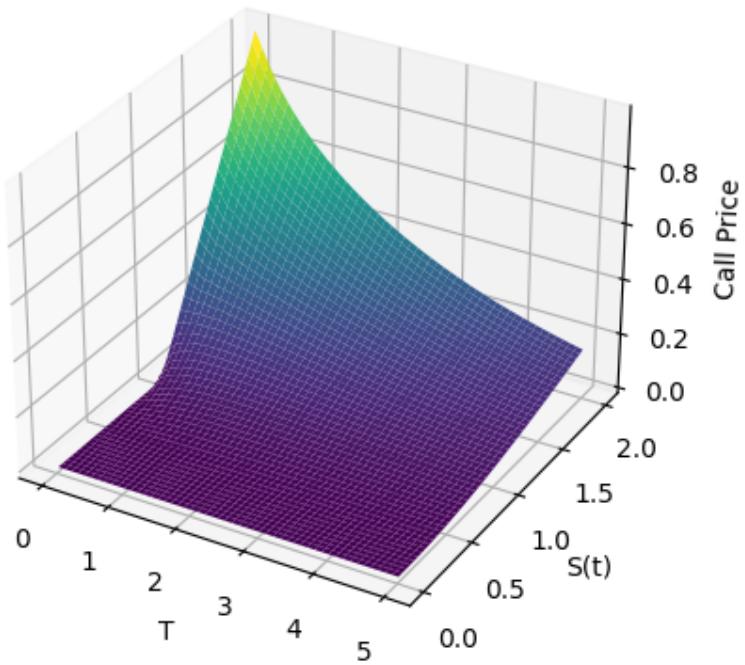
Variation of  $C(t, S(t))$  for change in  $k$  and  $S(t)$



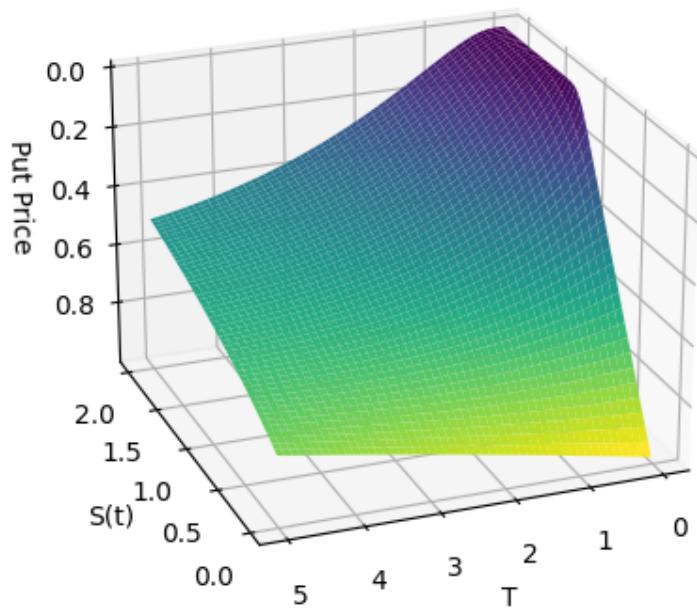
Variation of  $P(t, S(t))$  for change in  $k$  and  $S(t)$



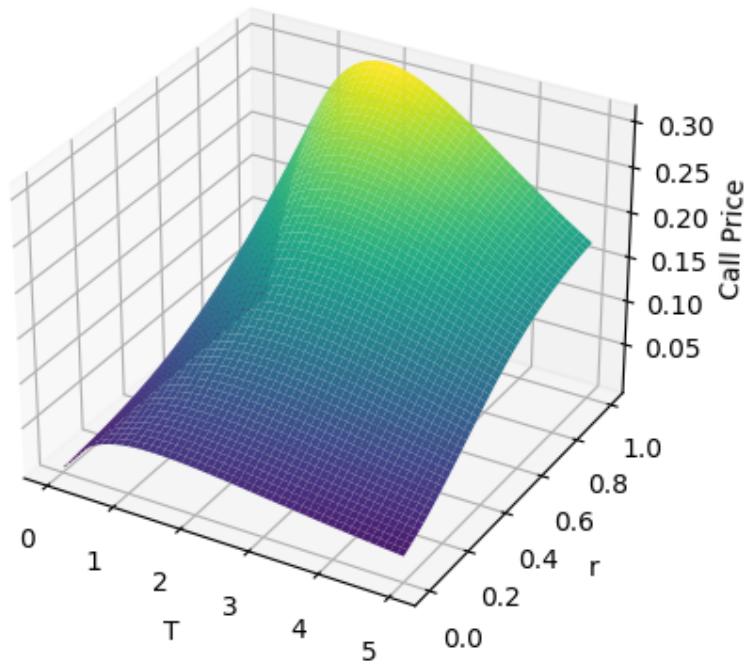
Variation of  $C(t, S(t))$  for change in  $T$  and  $S(t)$



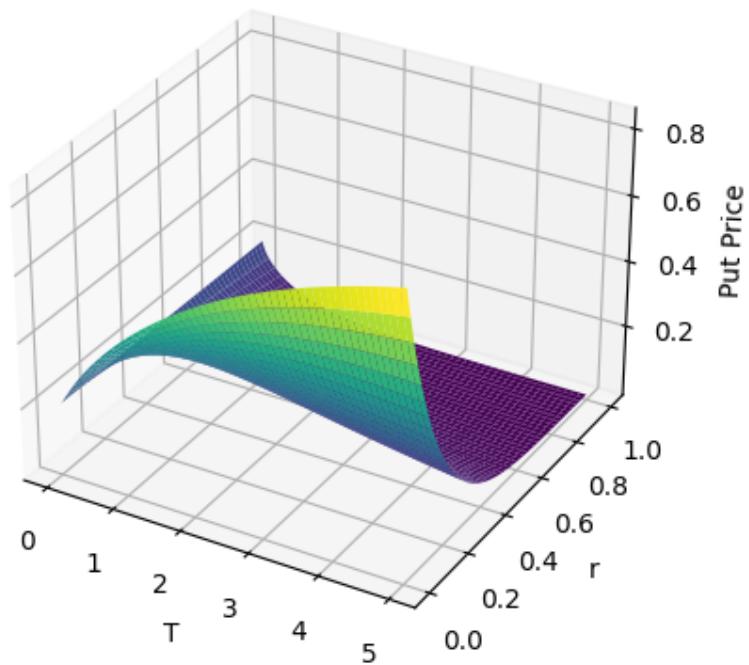
Variation of  $P(t, S(t))$  for change in  $T$  and  $S(t)$



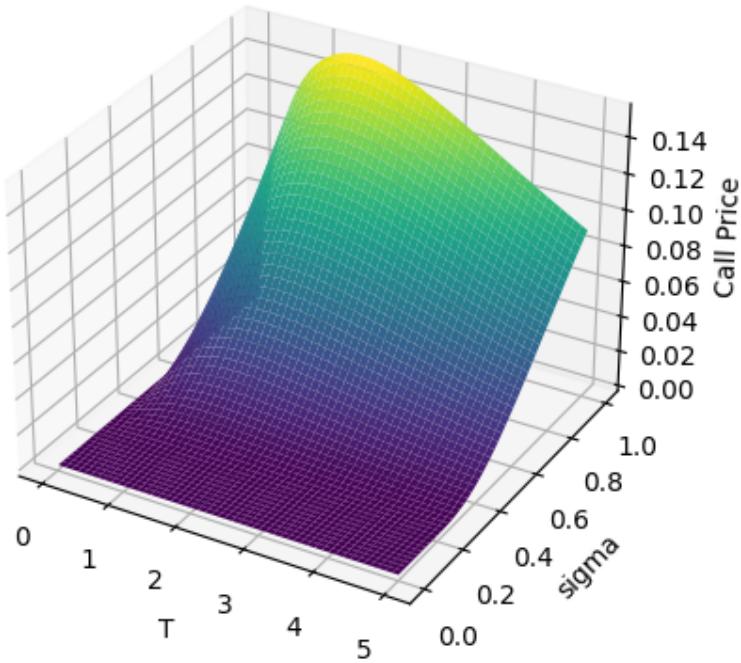
Variation of  $C(t, S(t))$  for change in  $T$  and  $r$



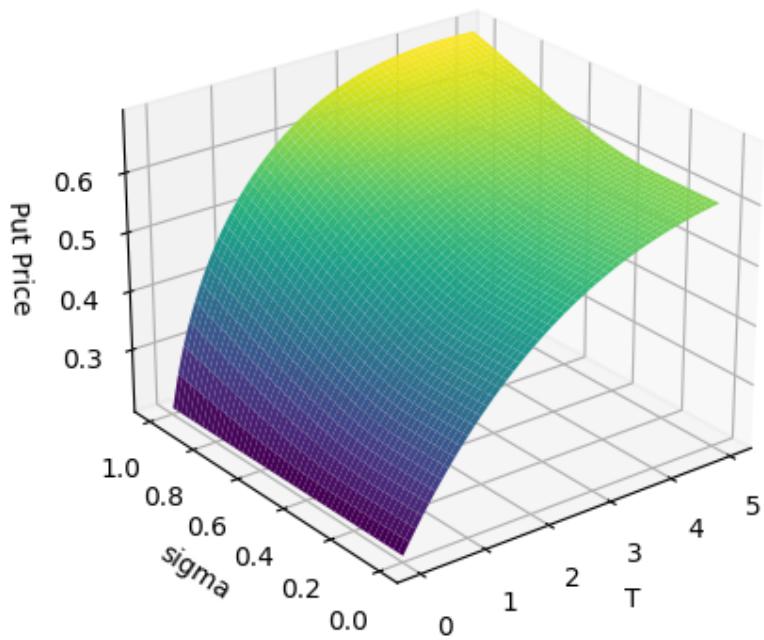
Variation of  $P(t, S(t))$  for change in  $T$  and  $r$



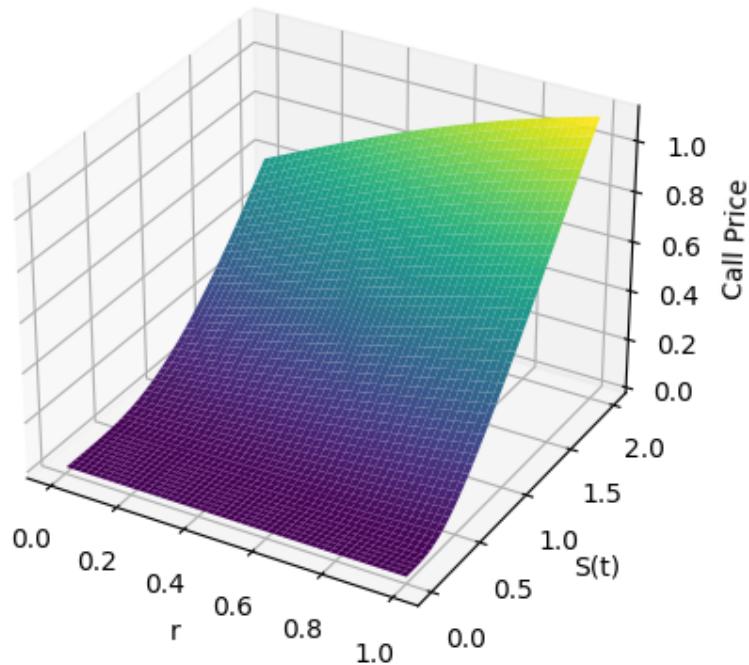
Variation of  $C(t, S(t))$  for change in  $T$  and  $\sigma$



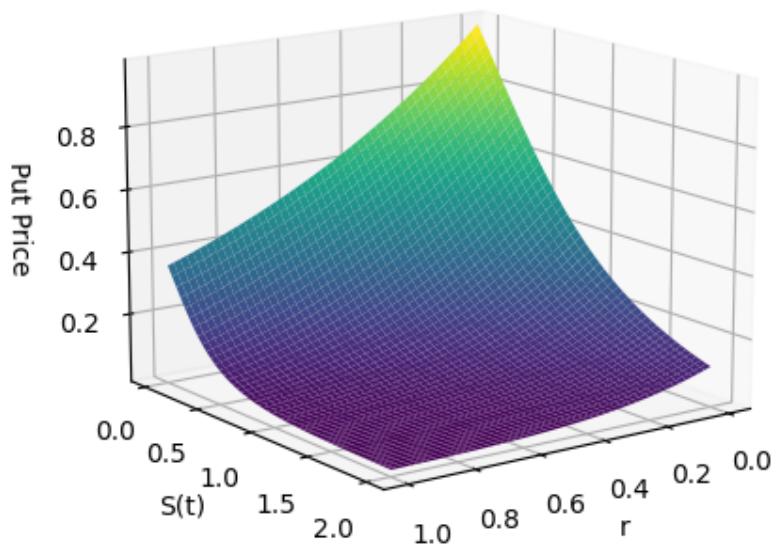
Variation of  $P(t, S(t))$  for change in  $T$  and  $\sigma$



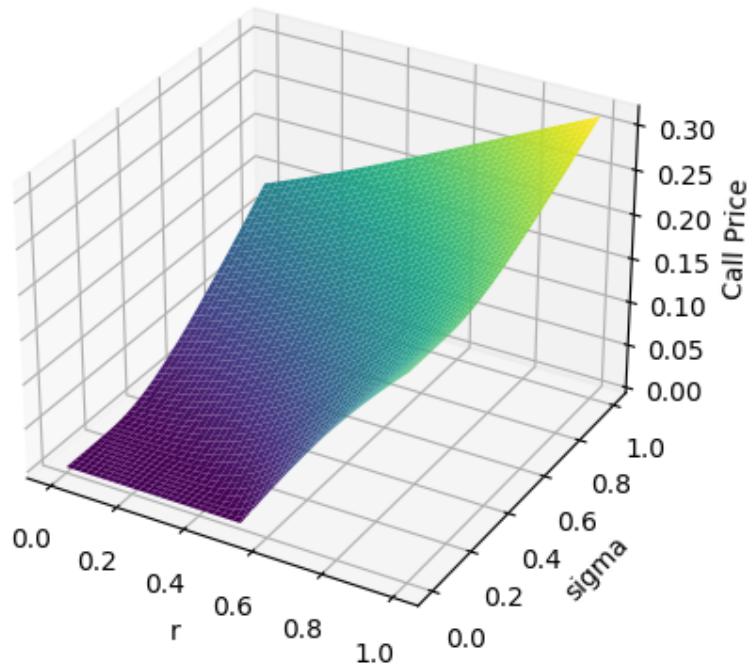
Variation of  $C(t, S(t))$  for change in  $r$  and  $S(t)$



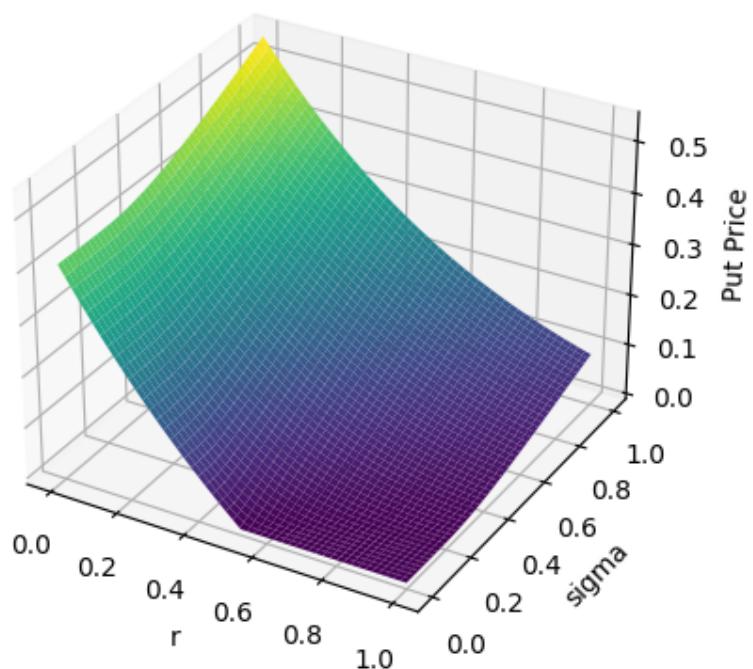
Variation of  $P(t, S(t))$  for change in  $r$  and  $S(t)$



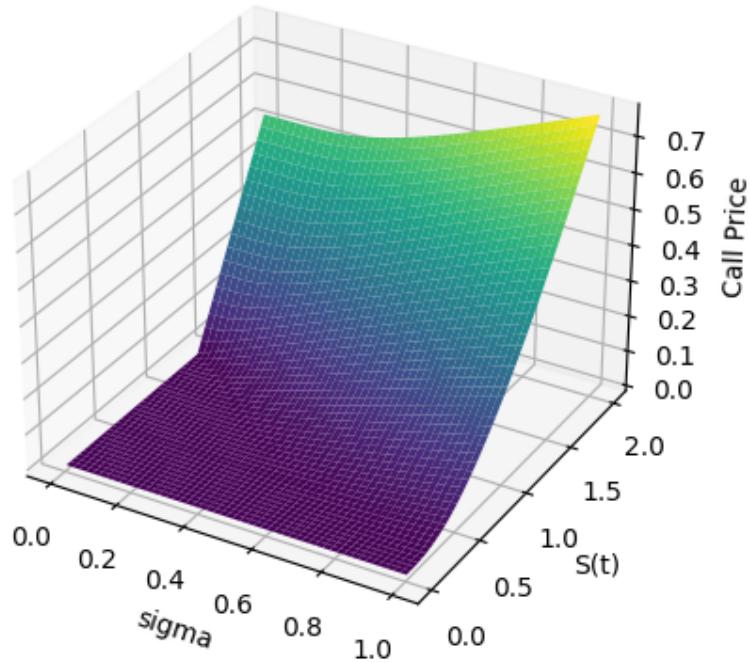
Variation of  $C(t, S(t))$  for change in  $r$  and sigma



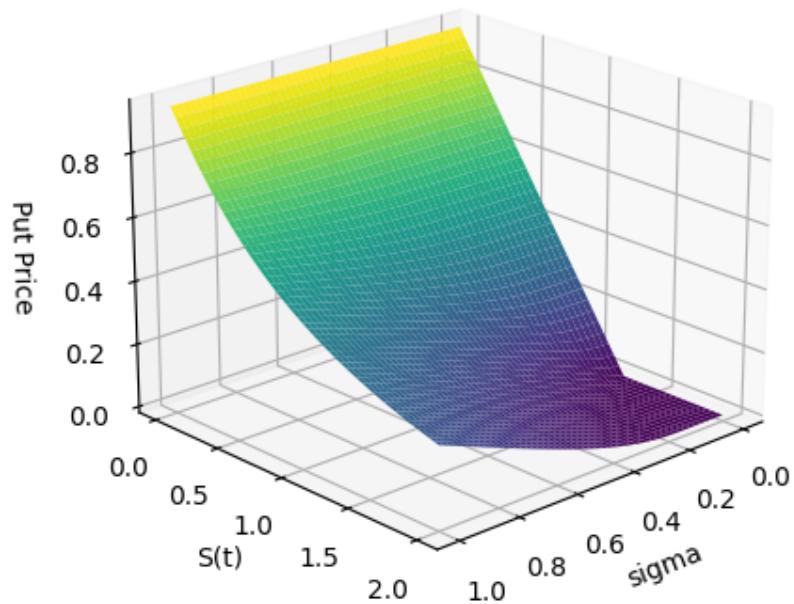
Variation of  $P(t, S(t))$  for change in  $r$  and sigma



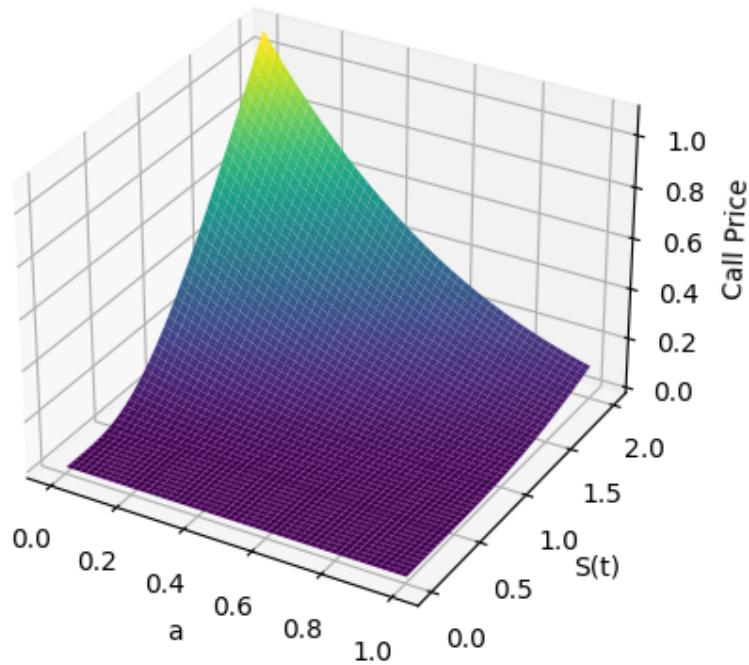
Variation of  $C(t, S(t))$  for change in sigma and  $S(t)$



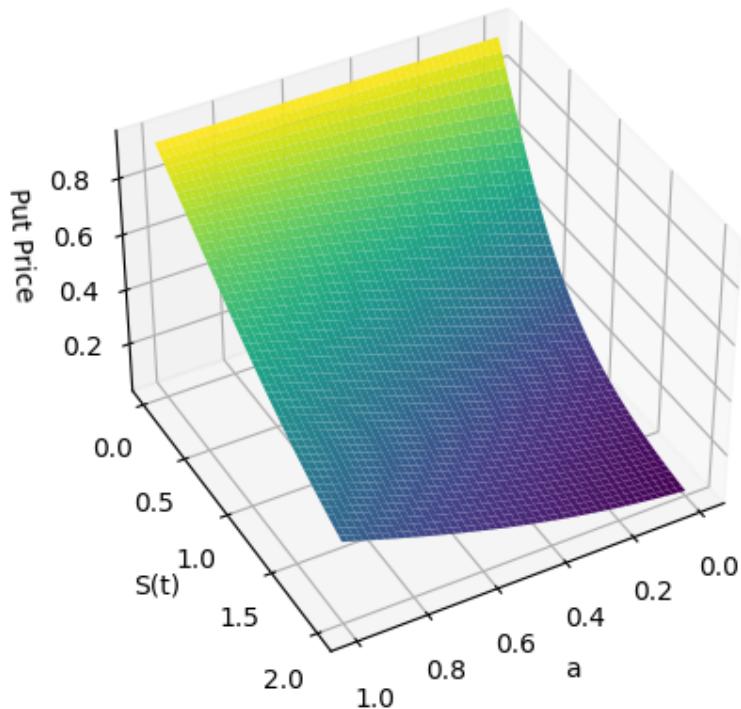
Variation of  $P(t, S(t))$  for change in sigma and  $S(t)$



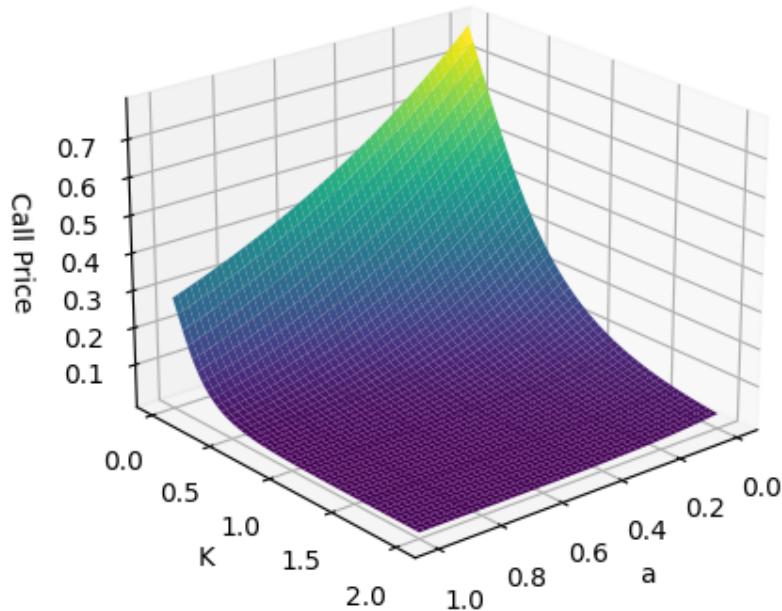
Variation of  $C(t, S(t))$  for change in  $a$  and  $S(t)$



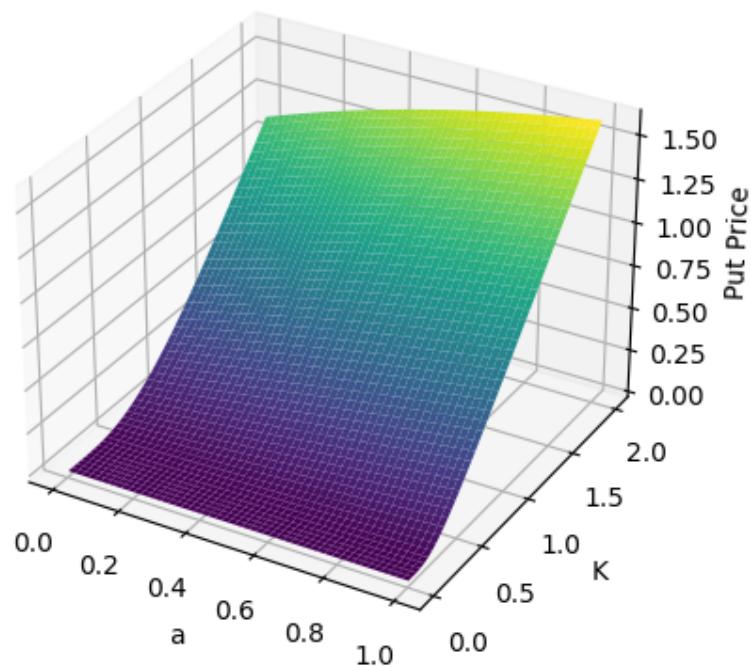
Variation of  $P(t, S(t))$  for change in  $a$  and  $S(t)$



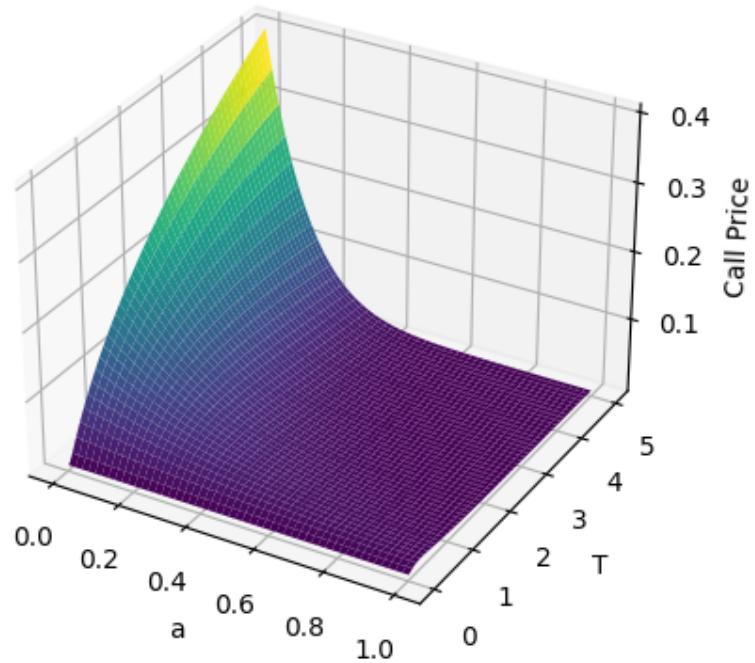
Variation of  $C(t, S(t))$  for change in  $a$  and  $k$



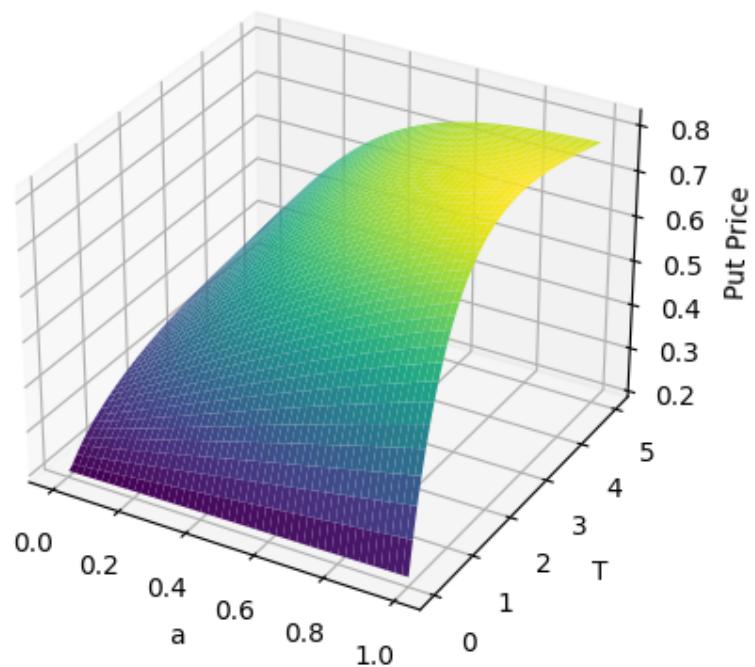
Variation of  $P(t, S(t))$  for change in  $a$  and  $k$



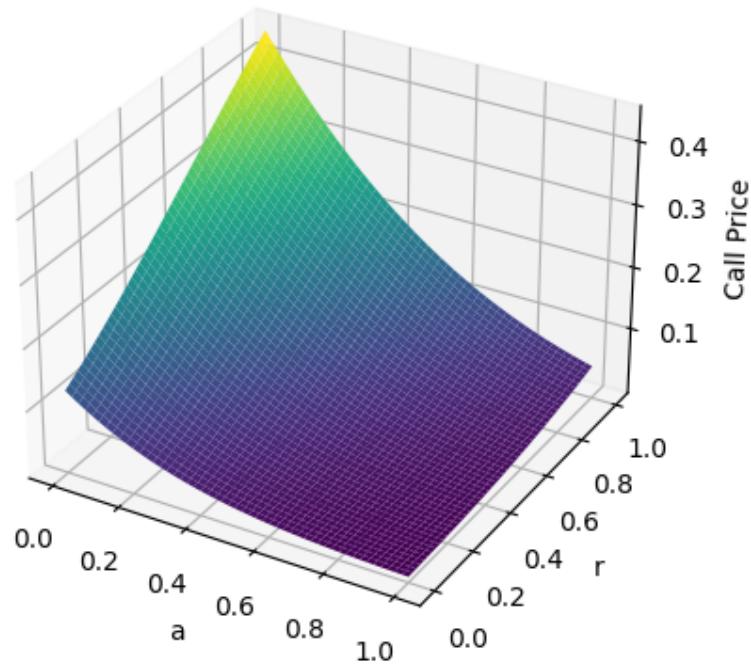
Variation of  $C(t, S(t))$  for change in  $a$  and  $T$



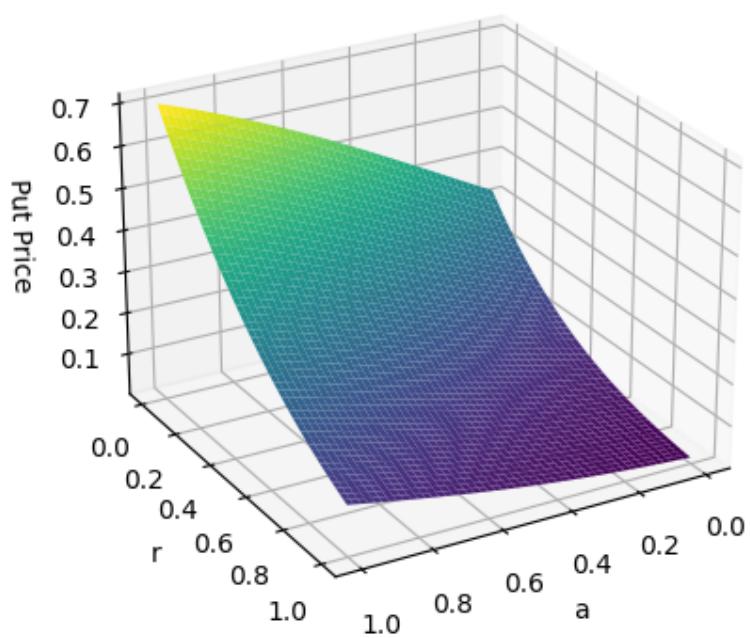
Variation of  $P(t, S(t))$  for change in  $a$  and  $T$



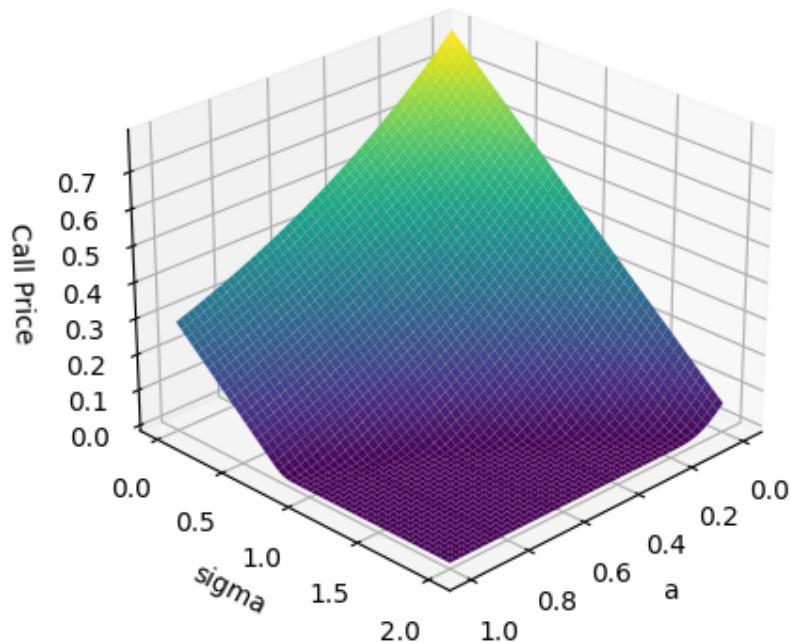
Variation of  $C(t, S(t))$  for change in  $a$  and  $r$



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



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



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

