MA374 Financial Engineering Lab
Assignment - 7

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Question - 1

In order to calculate the price of the European call and Put option in the classical Black Scholes Merton framework, we use the below formulae for the call option price:-

$$C(t,s) = sN(d_1) - ke^{-r\tau}N(d_2)$$

$$d_1 = \frac{1}{\sigma\sqrt{(\tau)}}\left(\log\left(\frac{s}{k}\right) + (r + \sigma^2/2)\,\tau\right)$$

$$d2 = d1 - \sigma\sqrt{(\tau)}$$

$$\tau = T - t$$

Now from the above relations we can calculate the price of a European Call option in the classical BSM framework. For put option we use the put-call parity:-

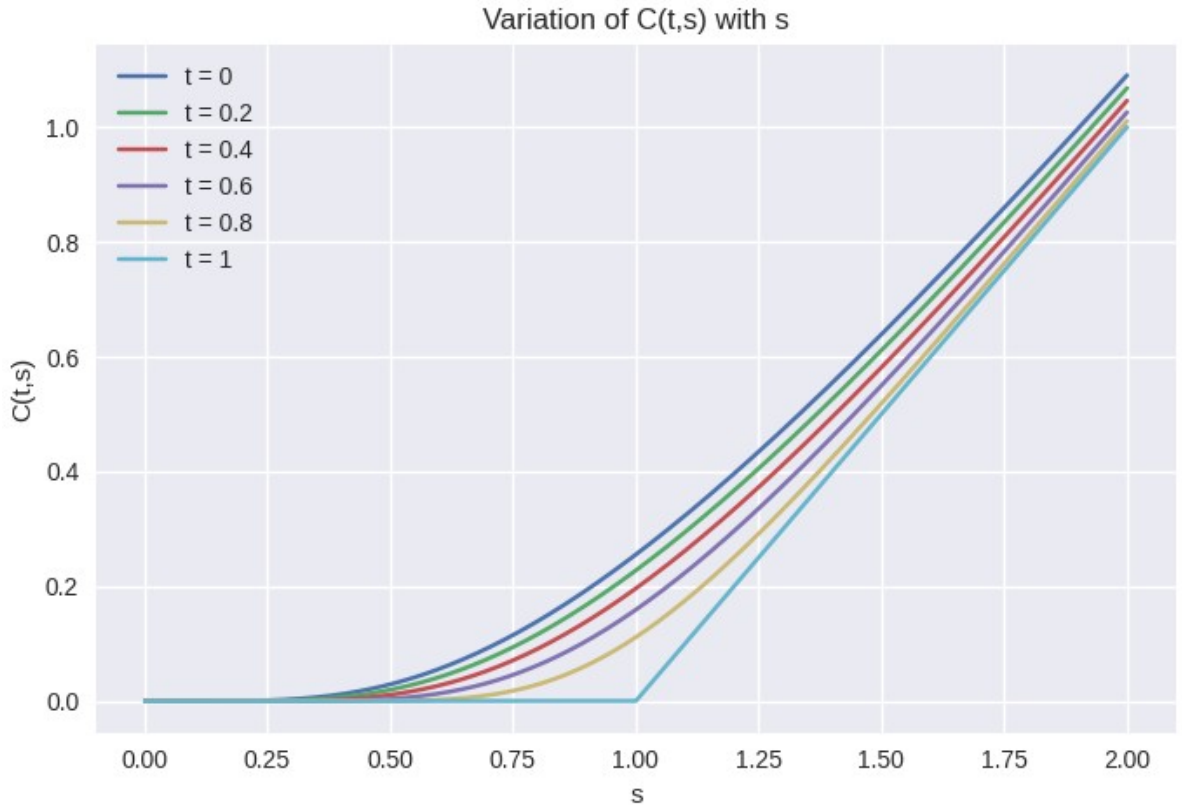
$$C(t,s) - P(t,s) = s - Ke^{-r\tau}$$

I implemented the below formuales in my program and calculated the price of a European call and put option in the classical BSM framework. The paramters chosen were as follows:-
t = 0,s = 1,k=1, $\sigma = 0.6$ *, r = 0.05 , T = 1*
The price of European Call and Put option were as follows:-

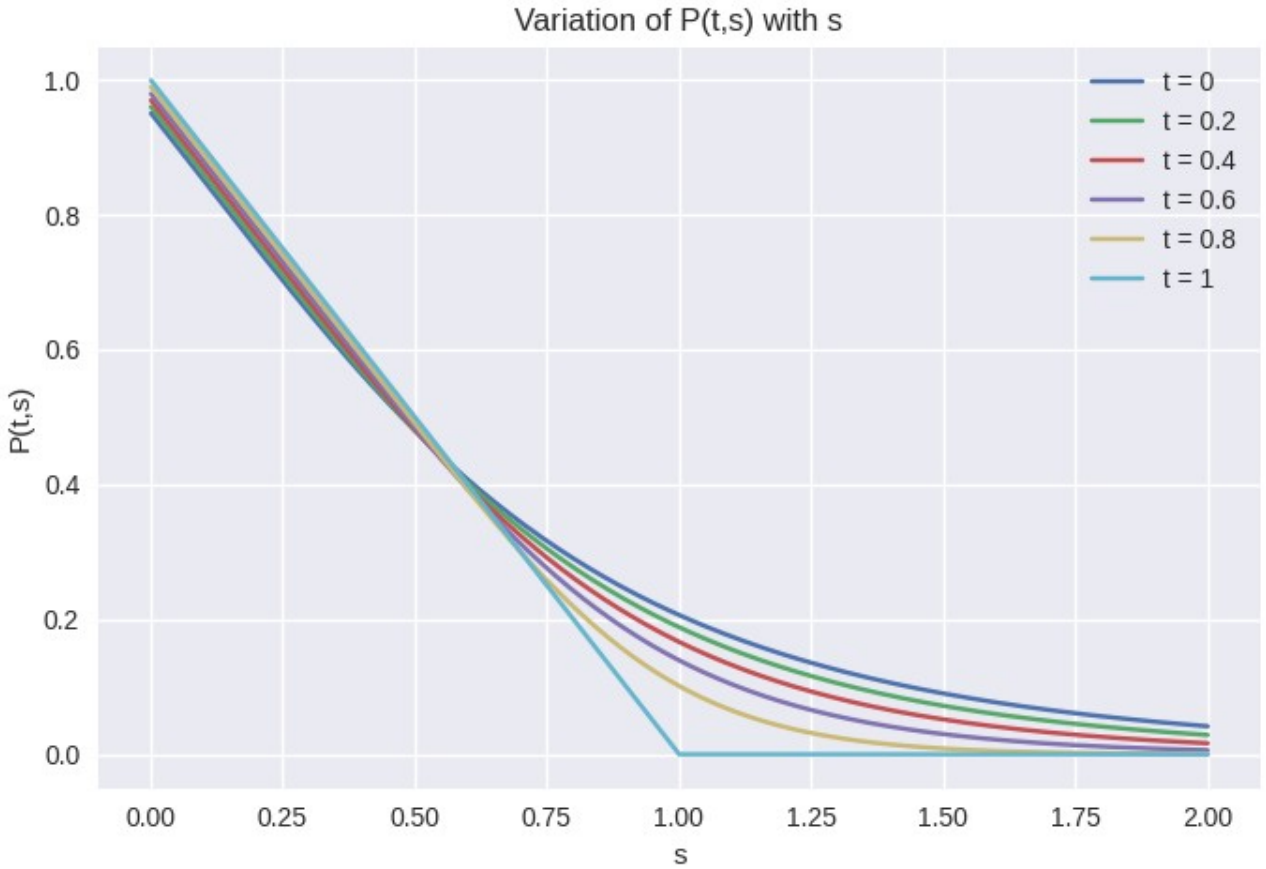
C(t,s) = 0.255232 ***P(t,s) = 0.206461***

Question - 2

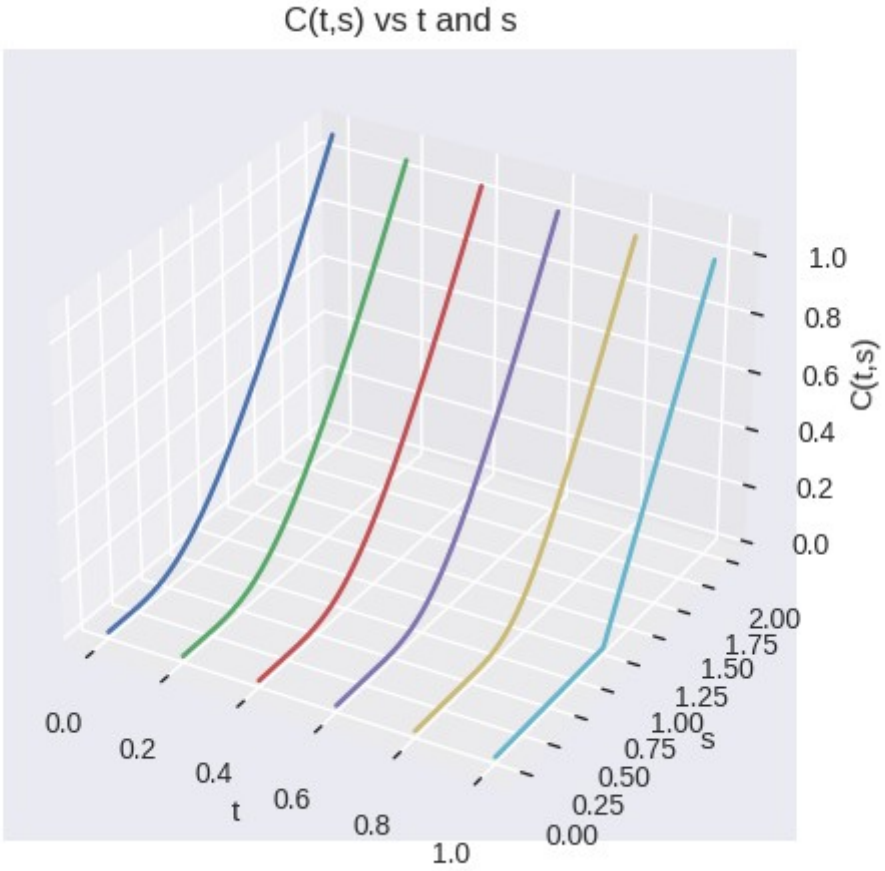
Plot of C(t,s) as a function of t alone for given values of t



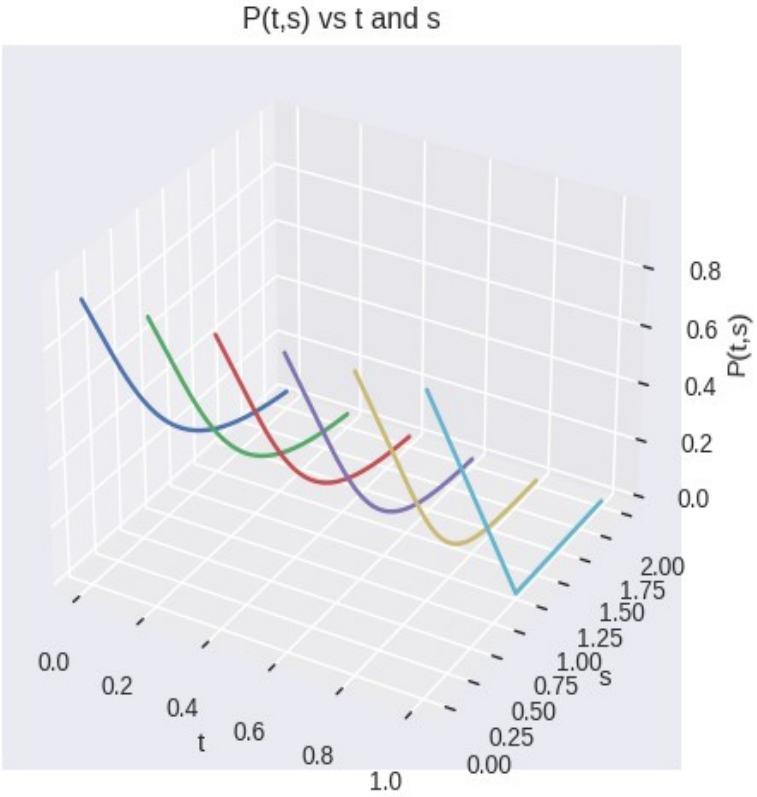
Plot of P(t,s) as a function of t alone for given values of t



Plot of C(t,s) as a function of t alone for given values of t (3D)

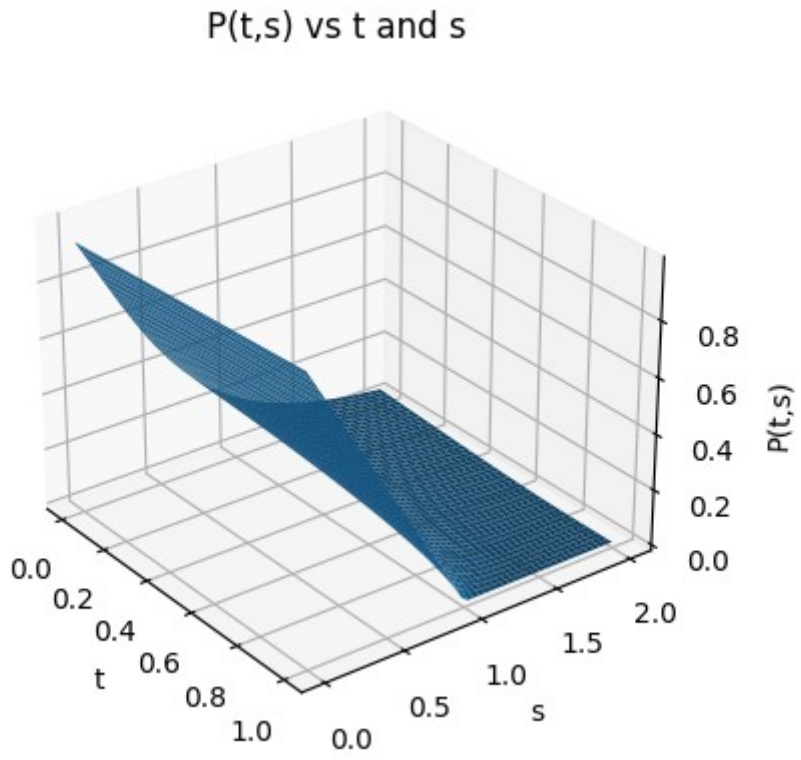


Plot of P(t,s) as a function of t alone for given values of t (3D)

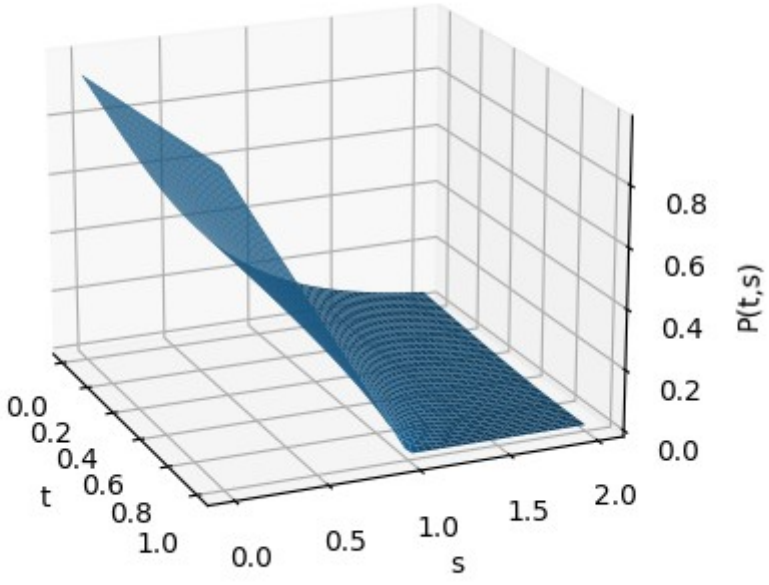


Question - 3

C(t,s) as a smooth surface over t,s plane

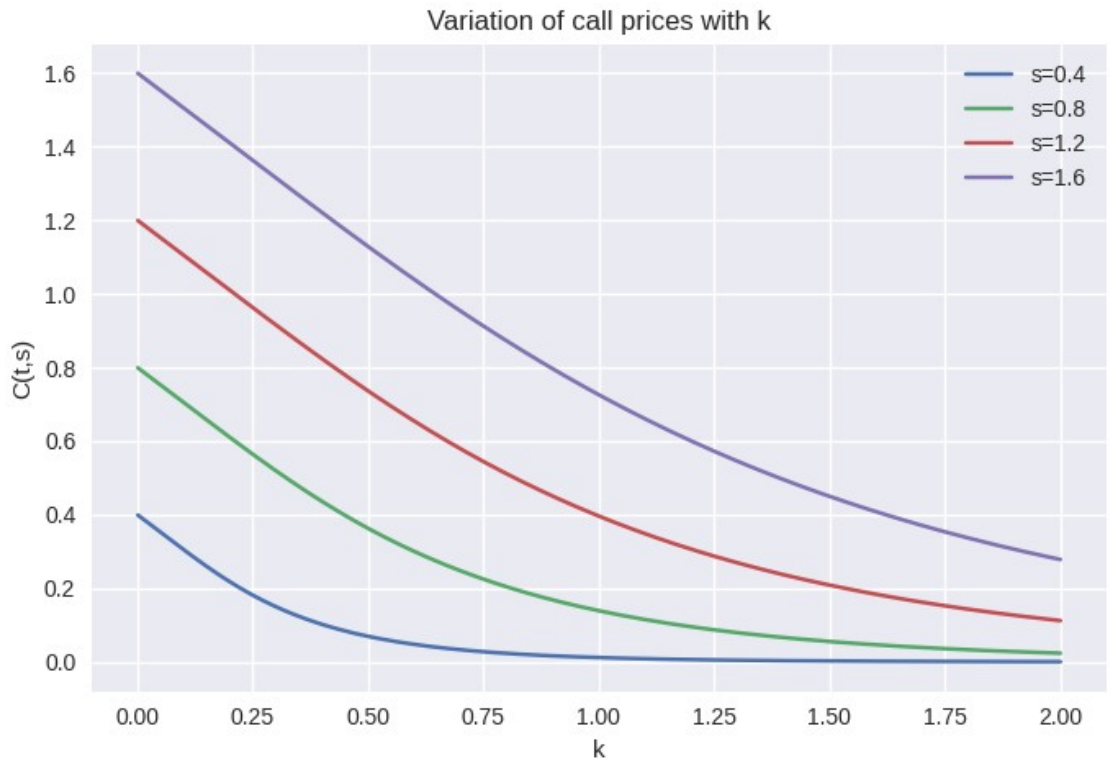


P(t,s) as a smooth surface over t,s plane

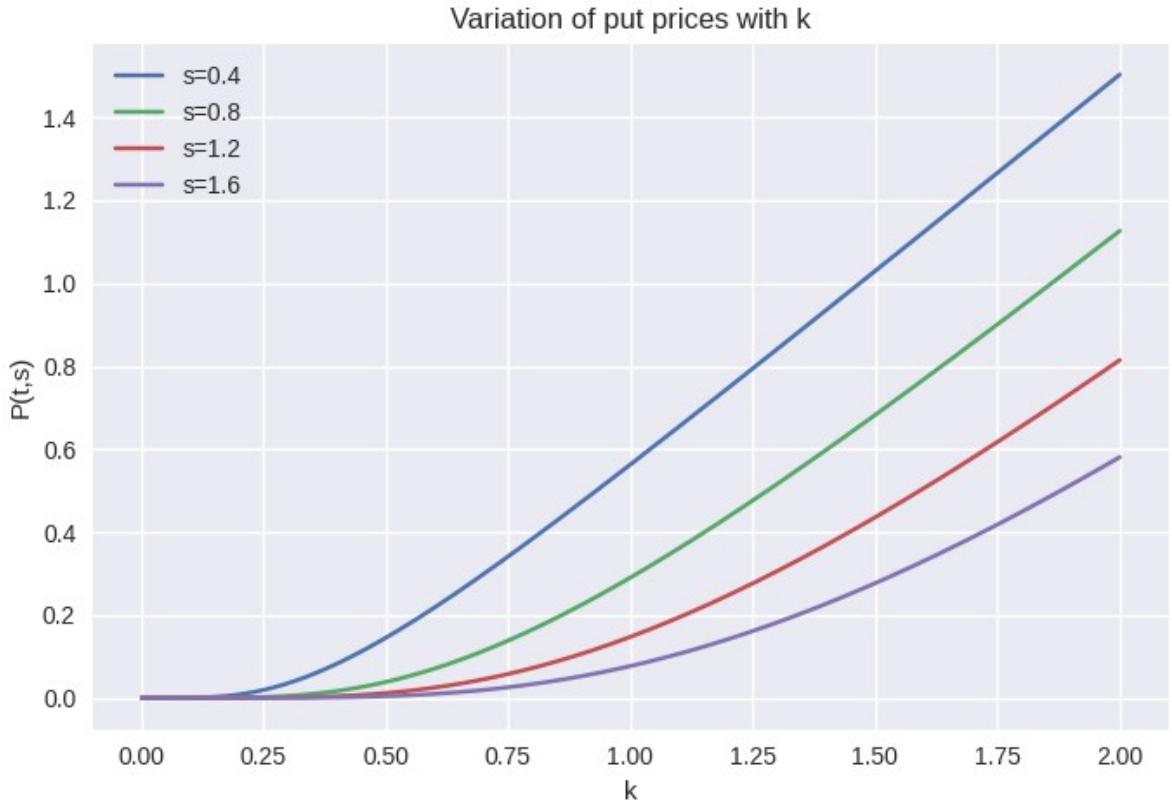


Question - 4

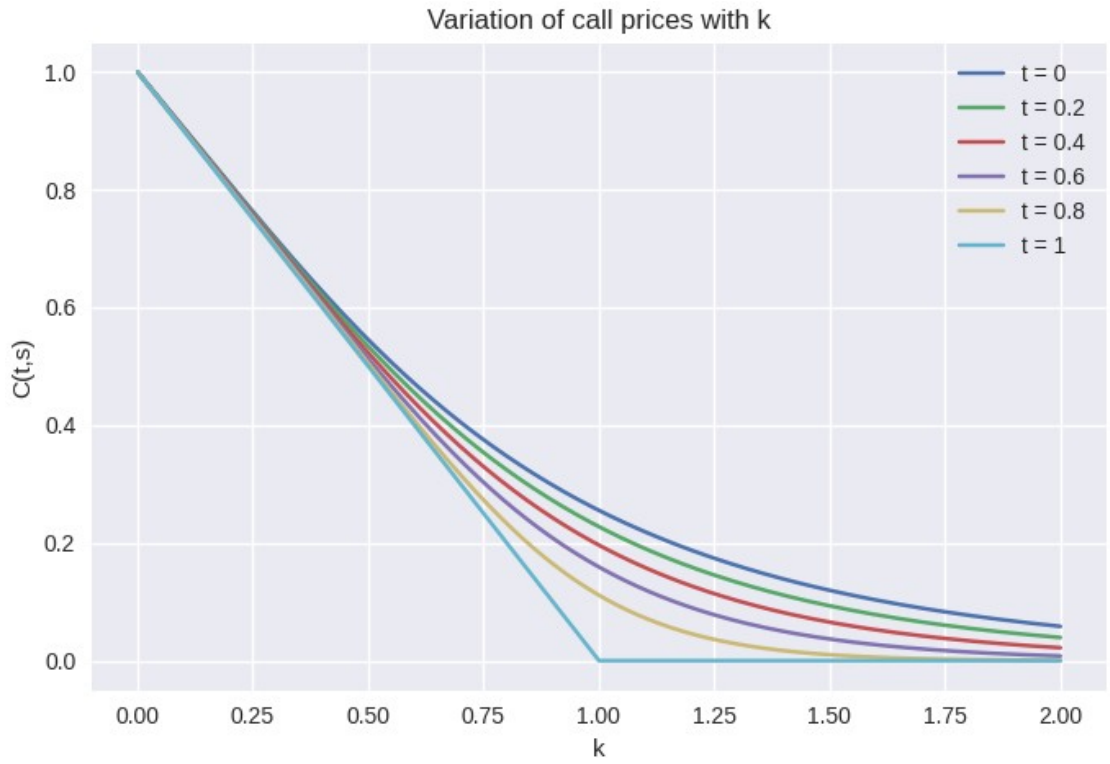
Plot of C(t,s) with k for different values of s



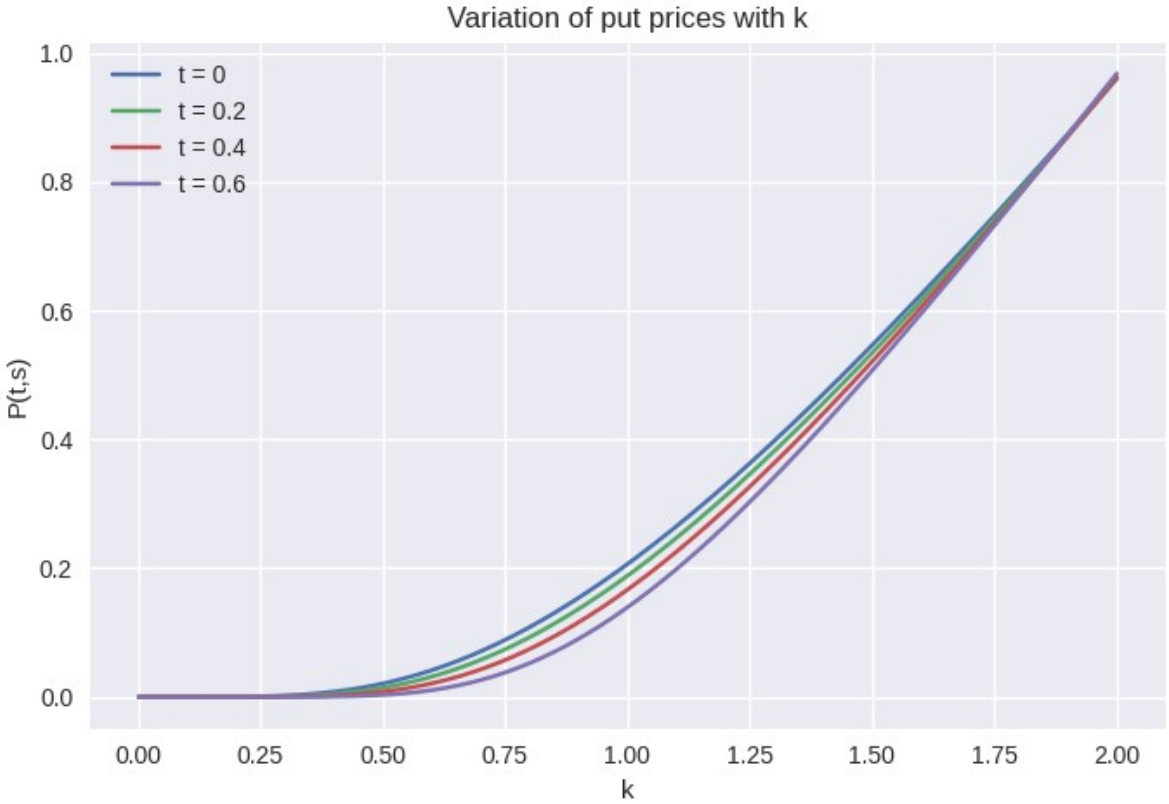
Plot of P(t,s) with k for different values of s



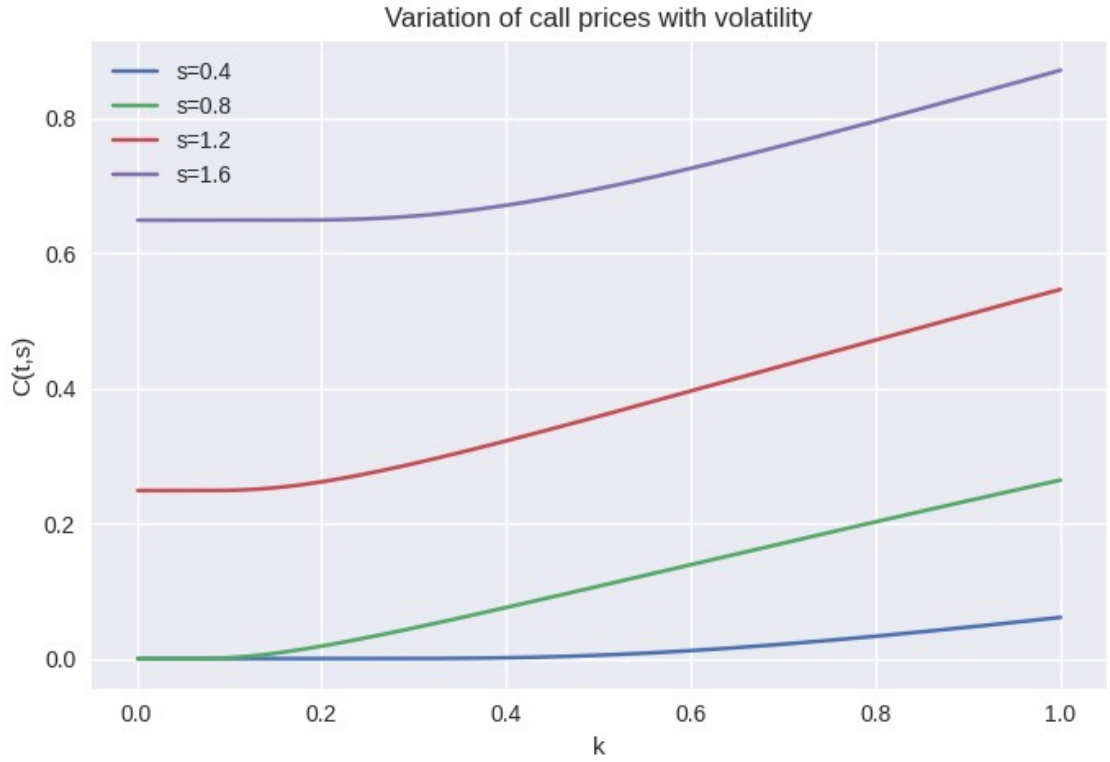
Plot of C(t,s) with k for different values of t



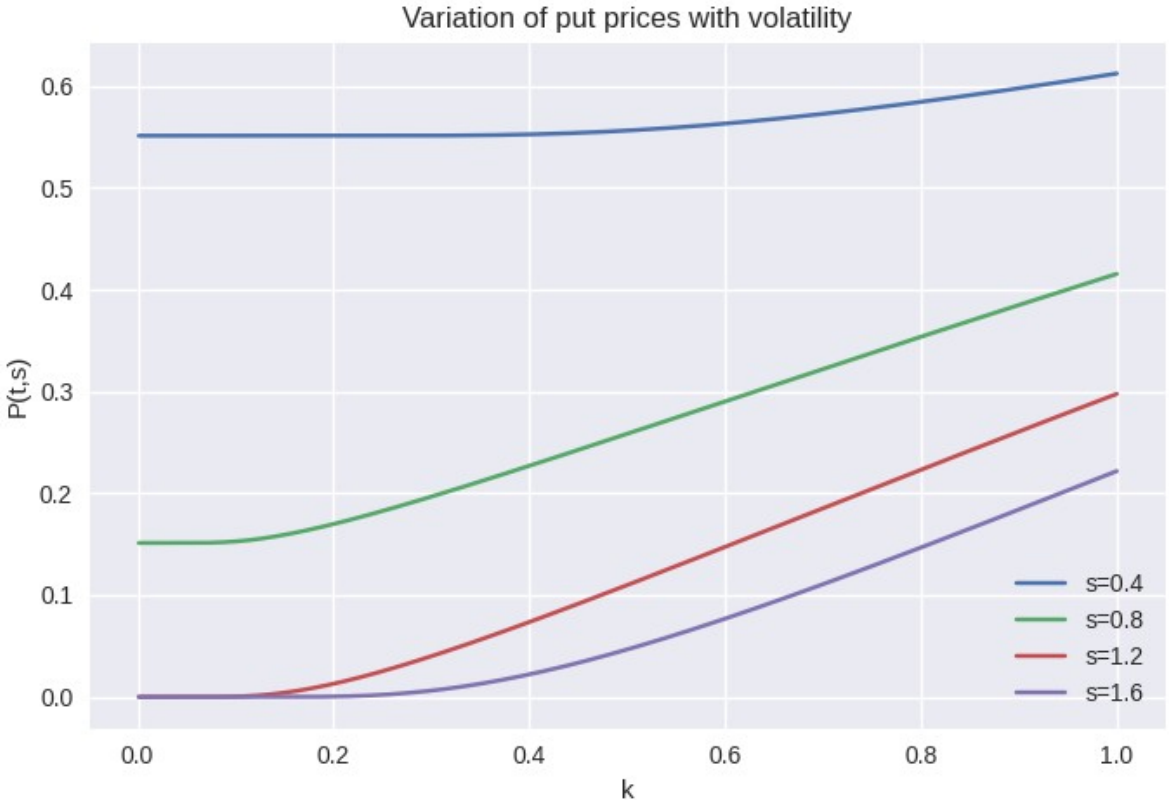
Plot of P(t,s) with k for different values of t



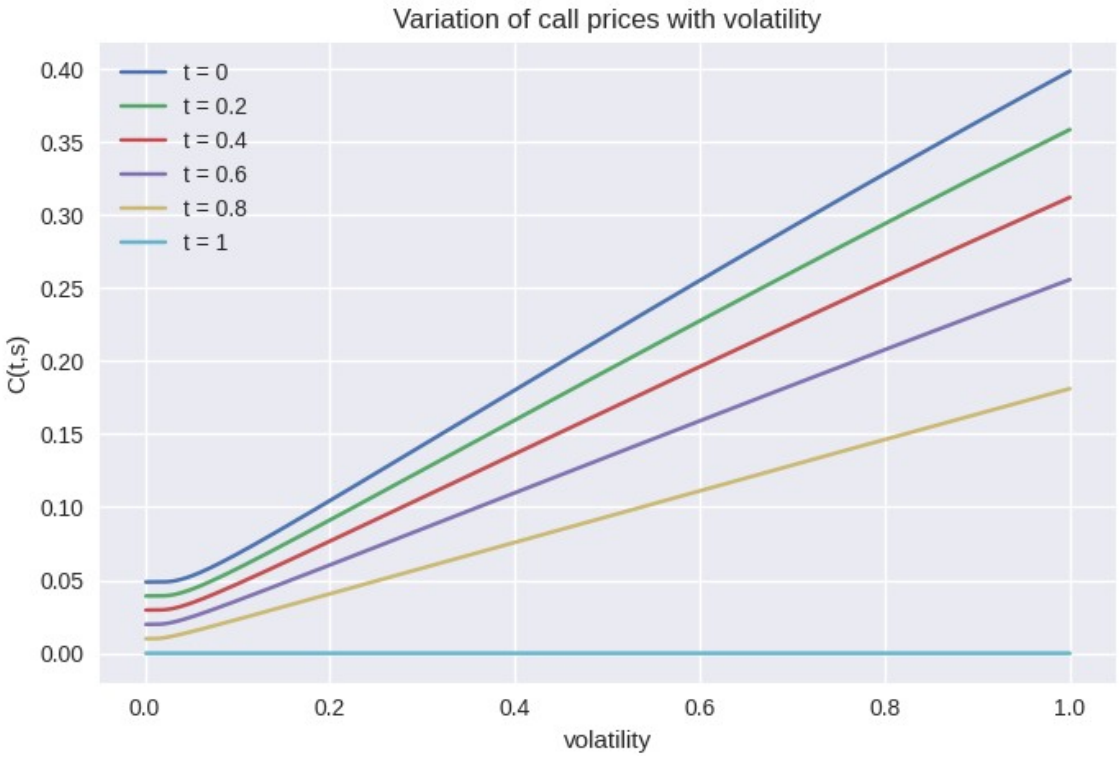
Plot of C(t,s) with σ for different values of s



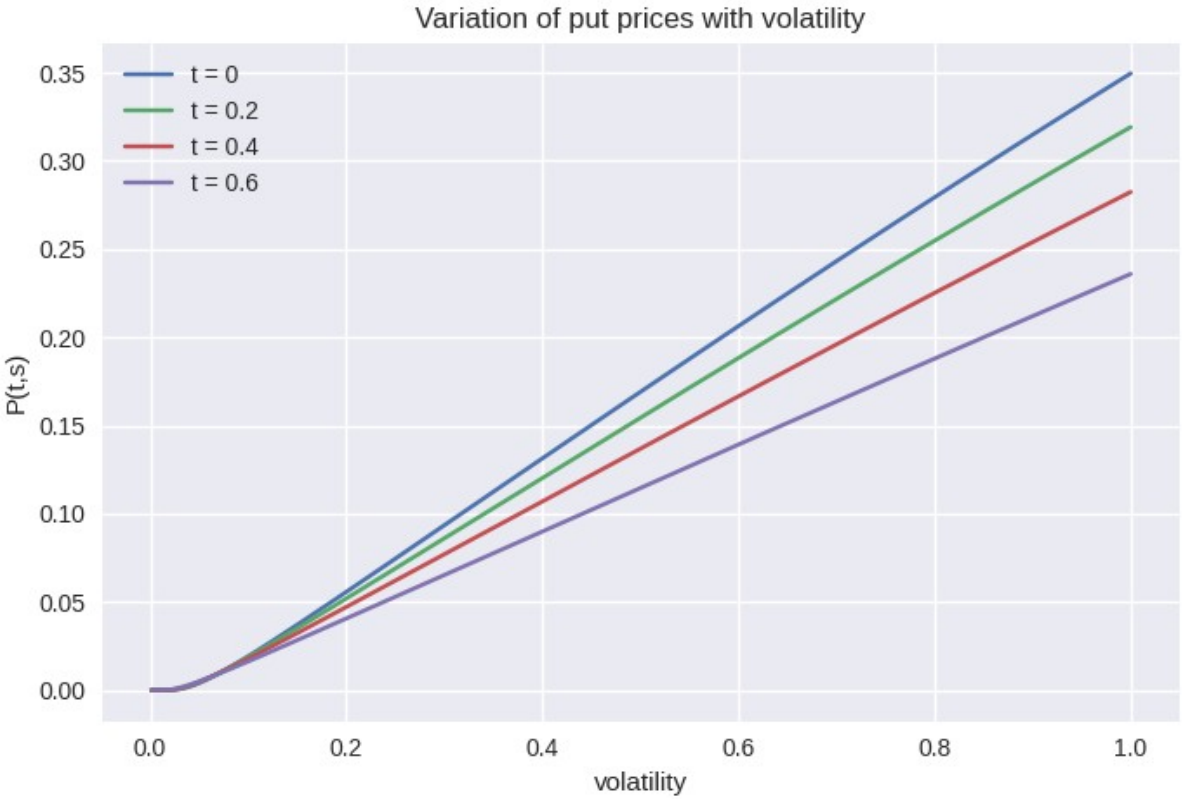
Plot of P(t,s) with σ for different values of s



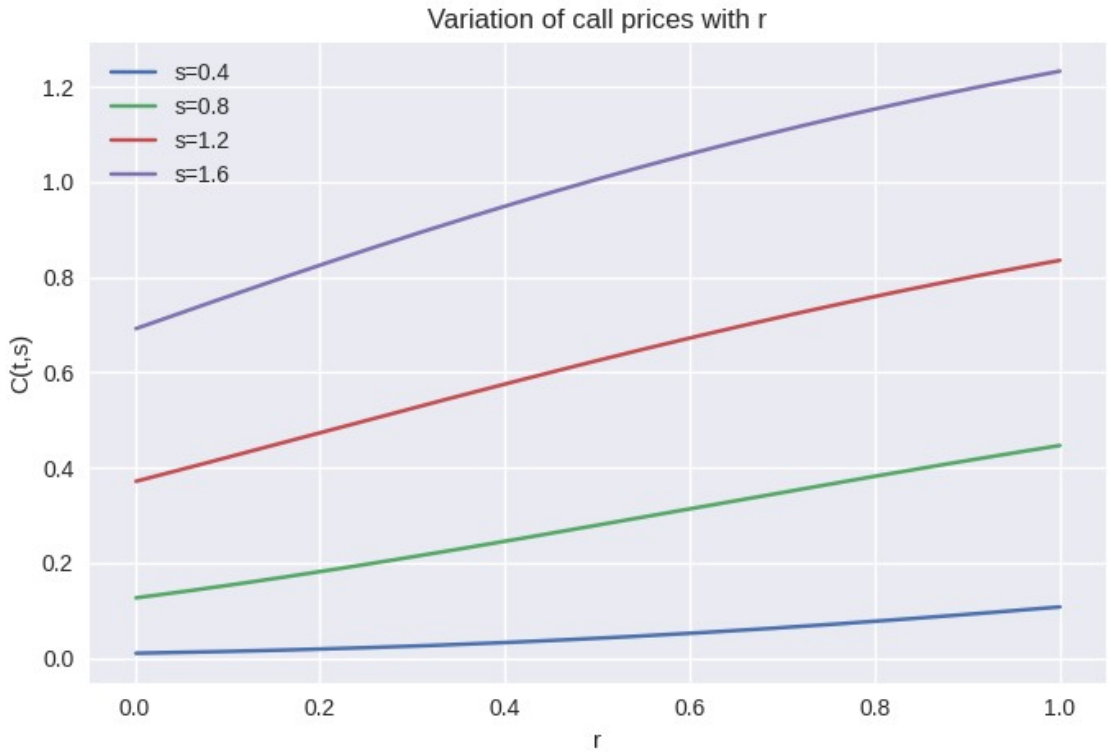
Plot of C(t,s) with σ for different values of t



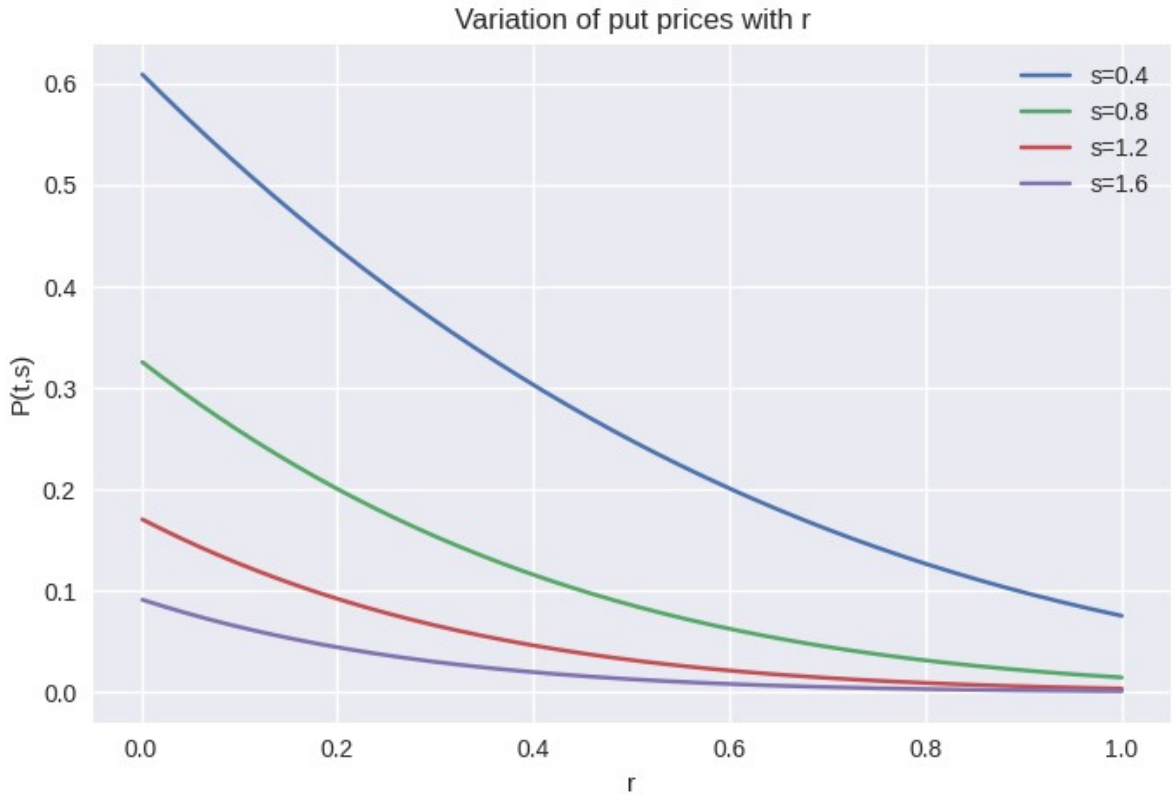
Plot of P(t,s) with σ for different values of t



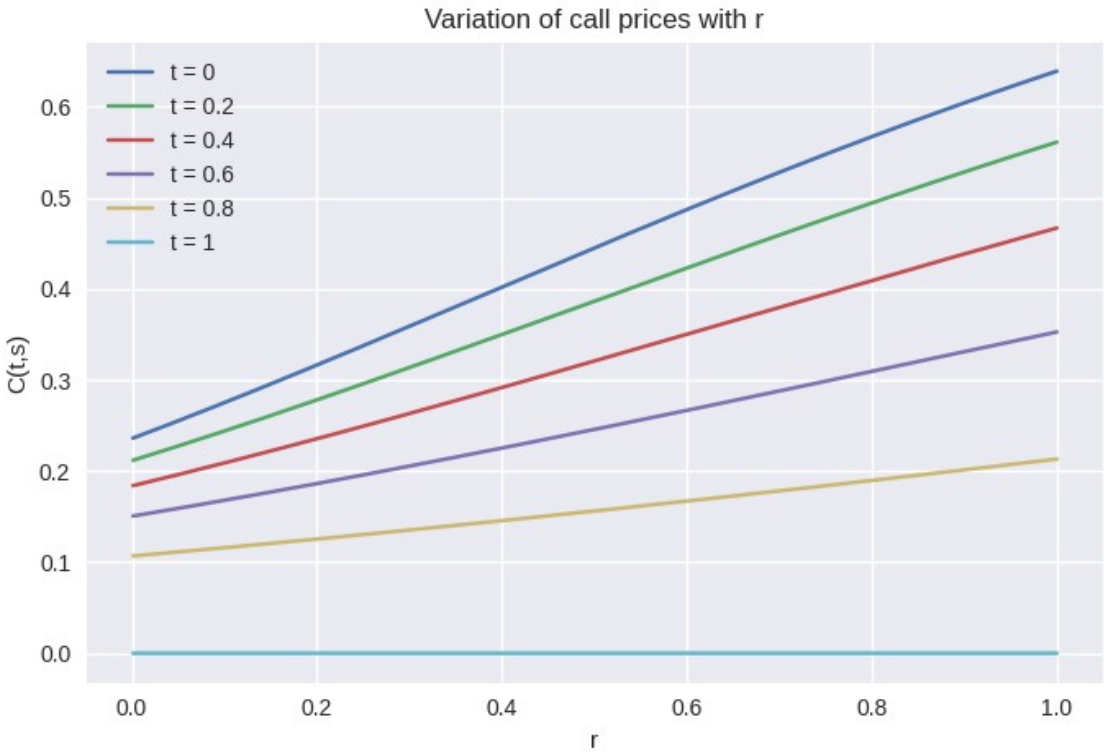
Plot of C(t,s) with r for different values of s



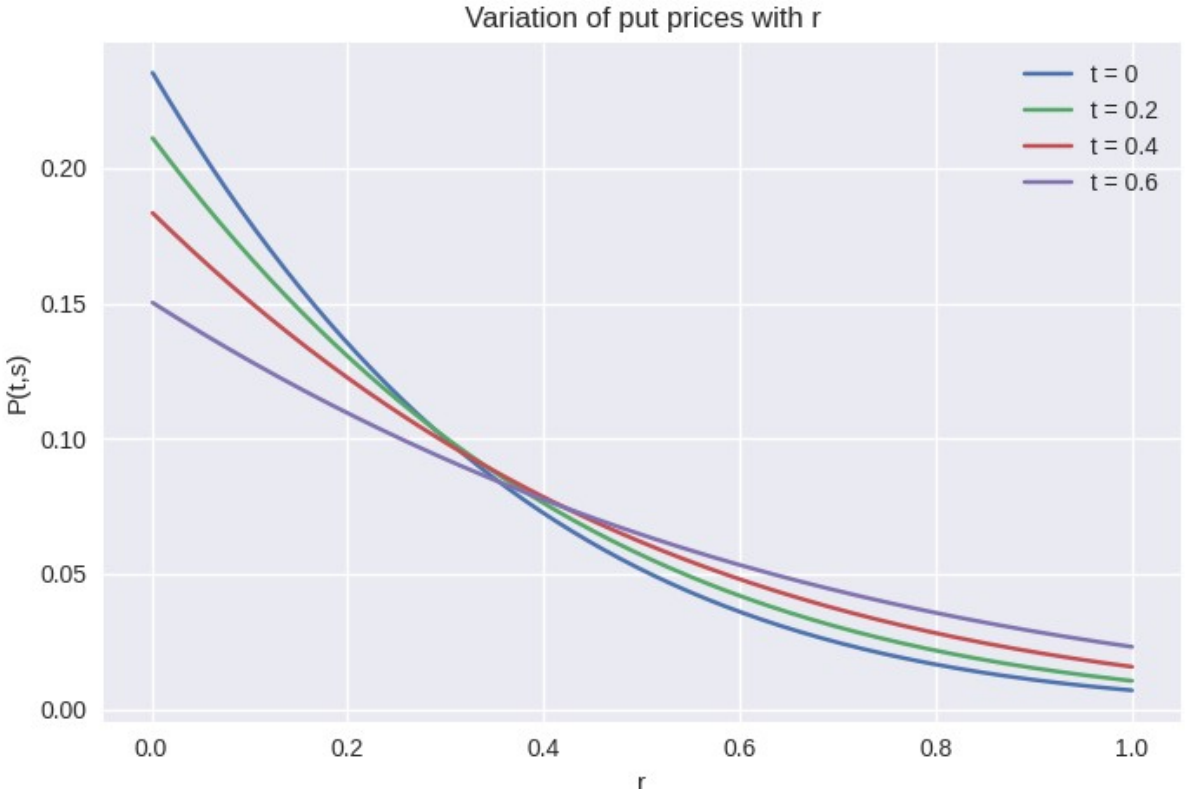
Plot of P(t,s) with r for different values of s



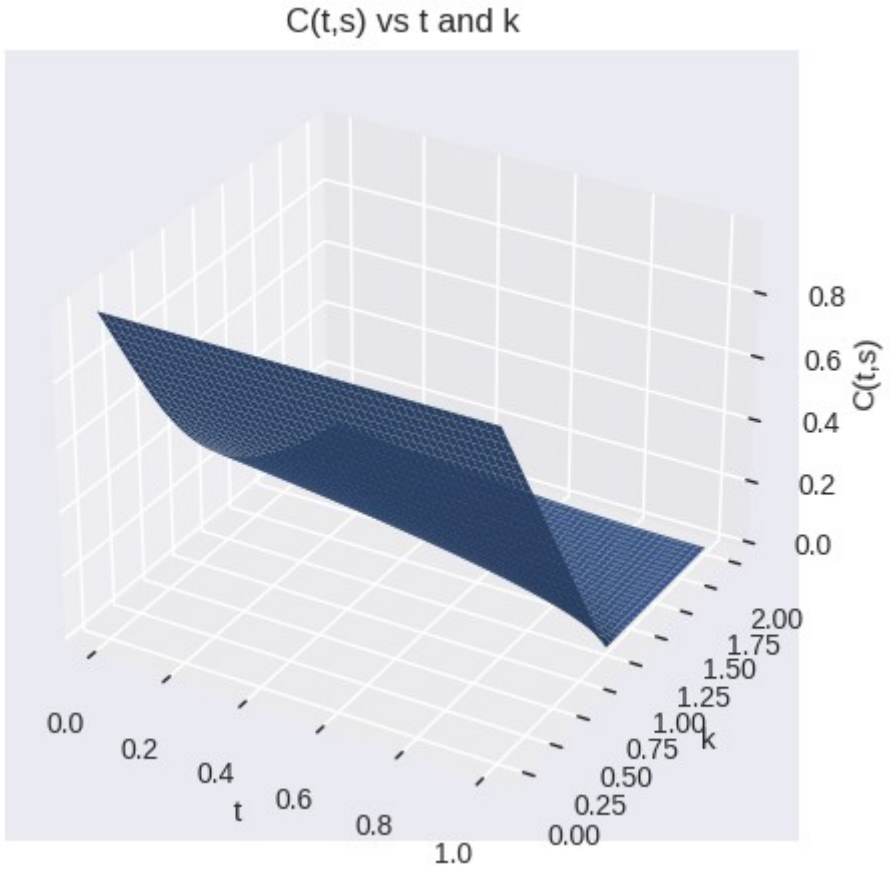
Plot of C(t,s) with r for different values of t



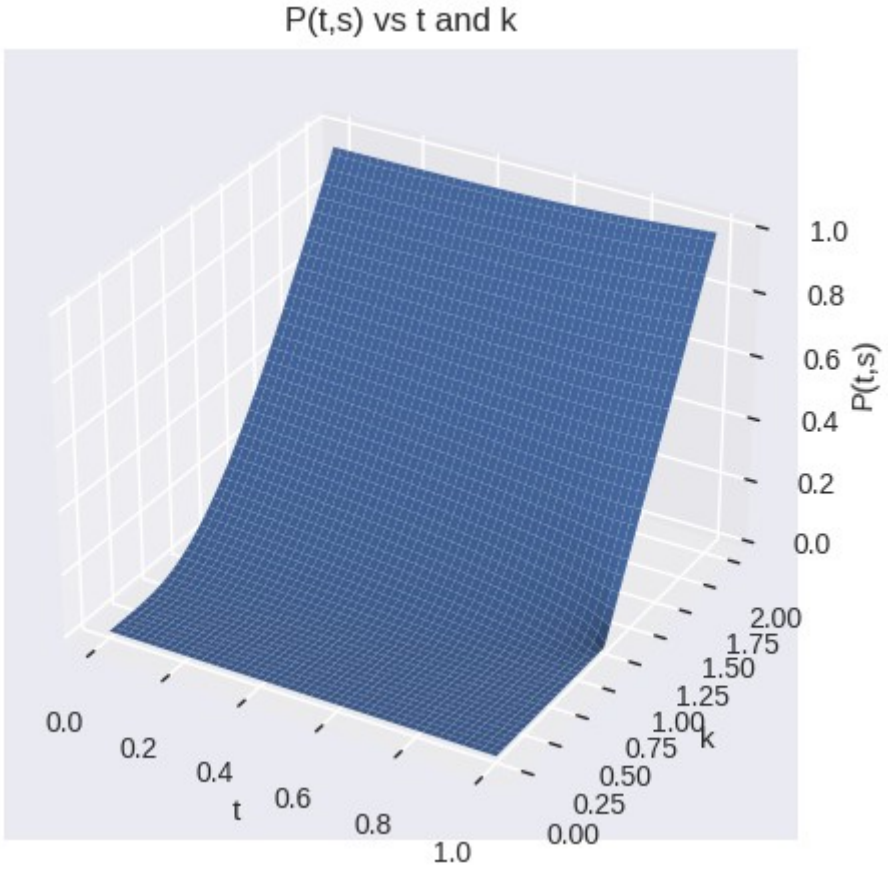
Plot of P(t,s) with r for different values of t



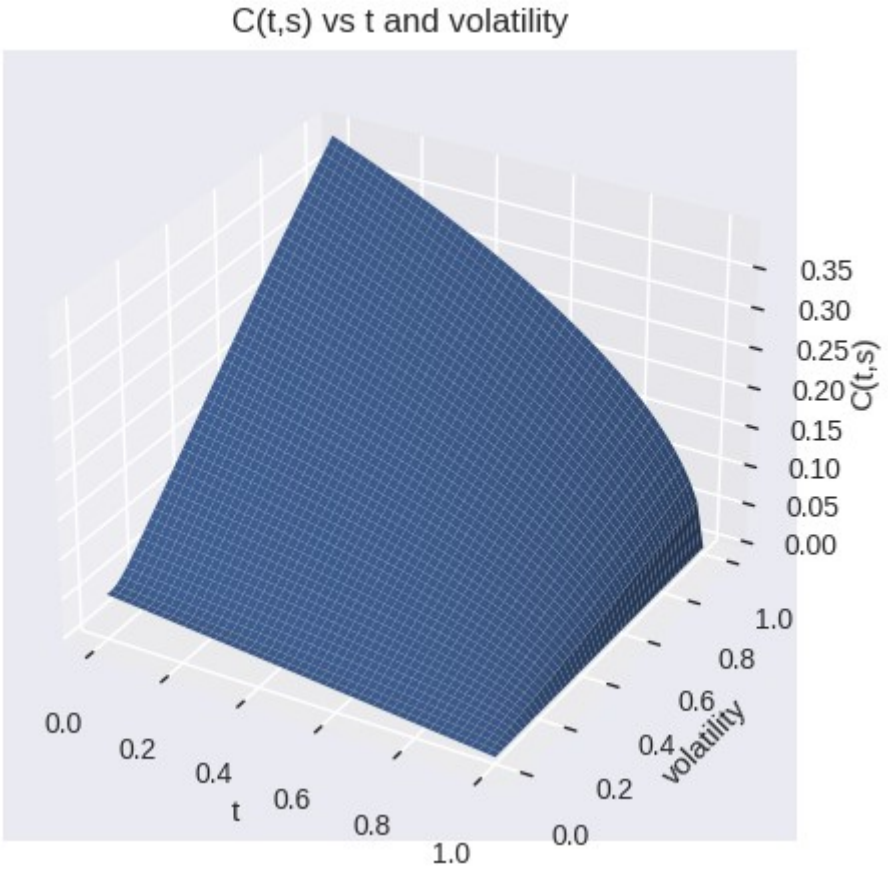
Surface plot of C(t,s) vs t and k



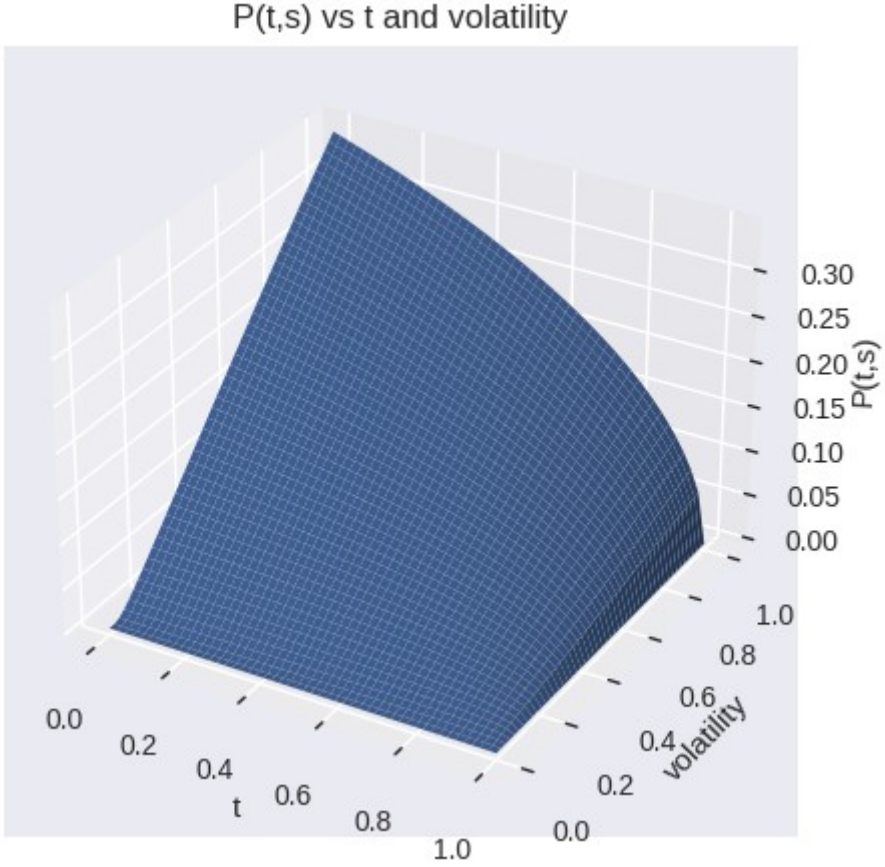
Surface plot of P(t,s) vs t and k



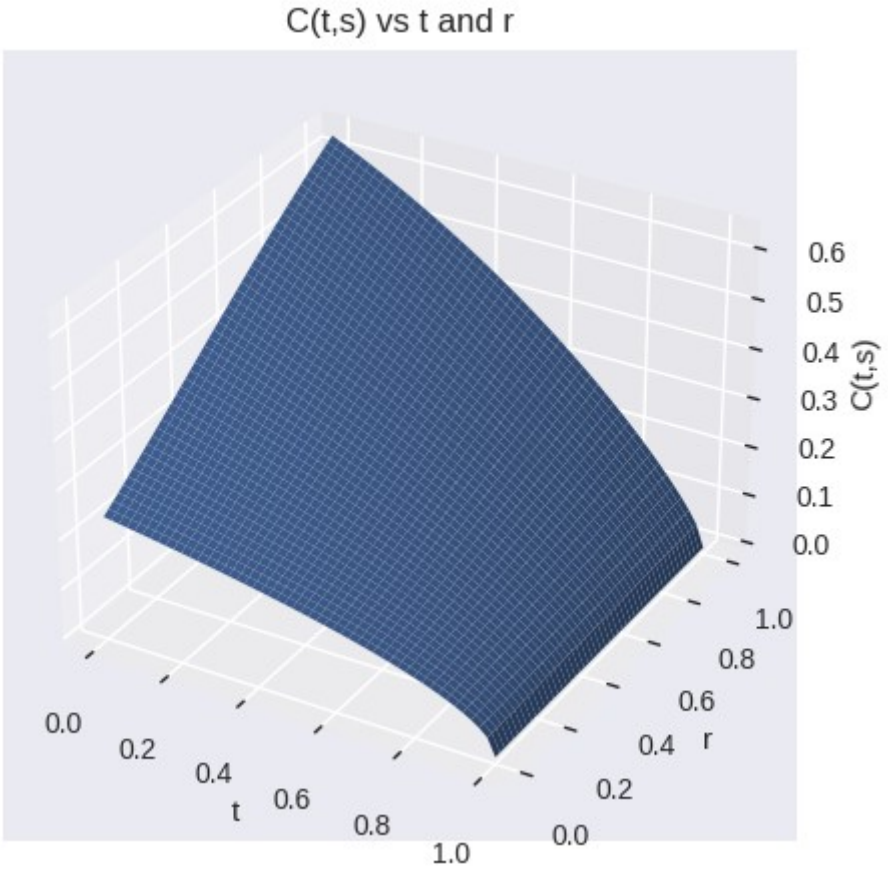
Surface plot of C(t,s) vs t and σ



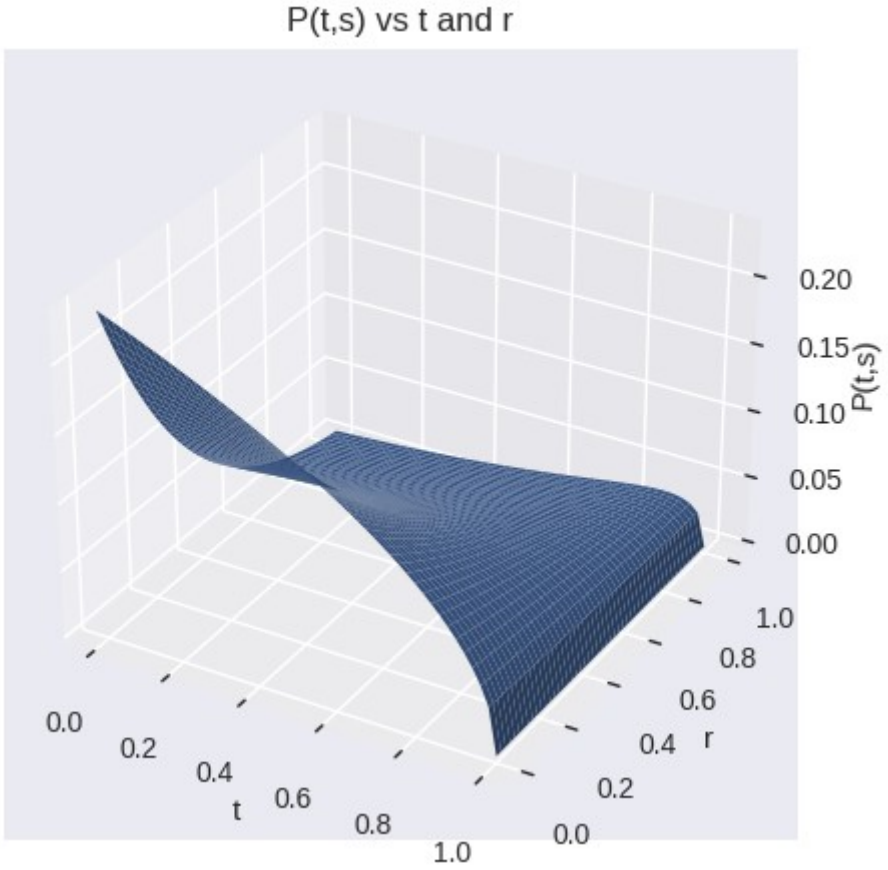
Surface plot of P(t,s) vs t and σ



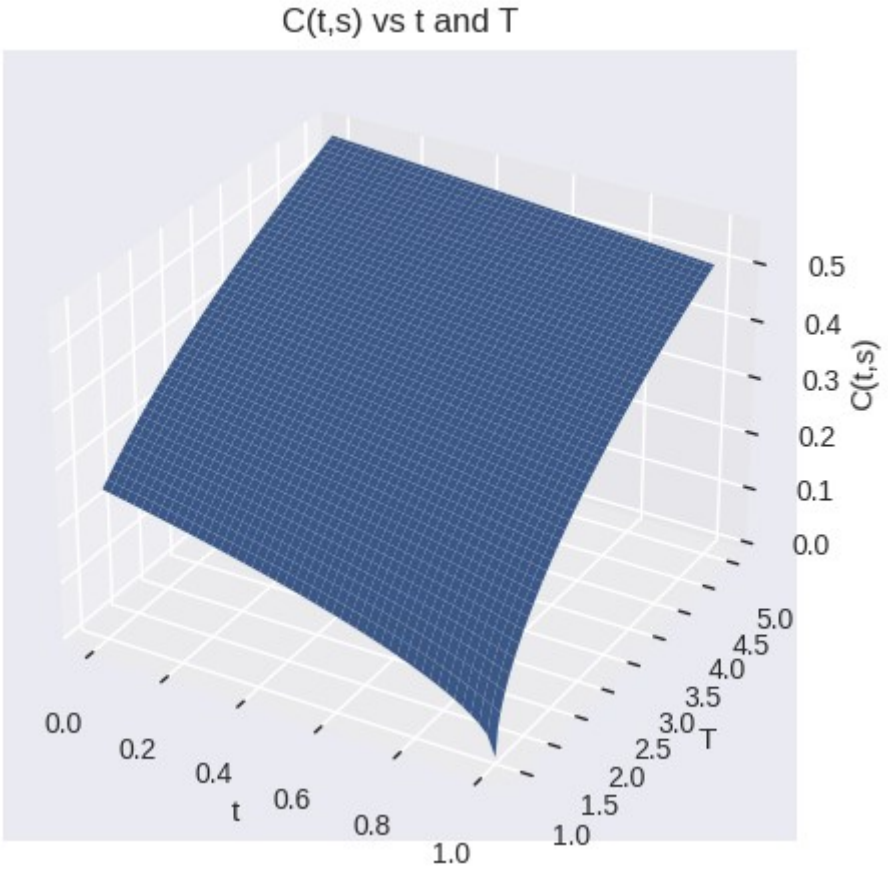
Surface plot of C(t,s) vs t and r



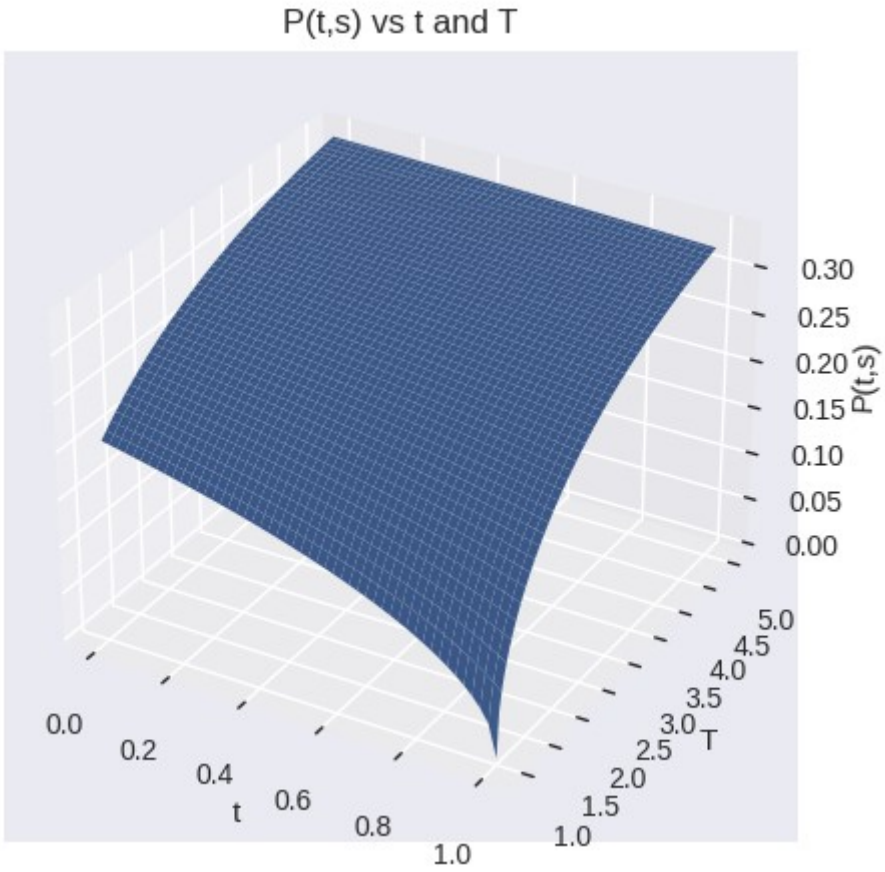
Surface plot of P(t,s) vs t and r



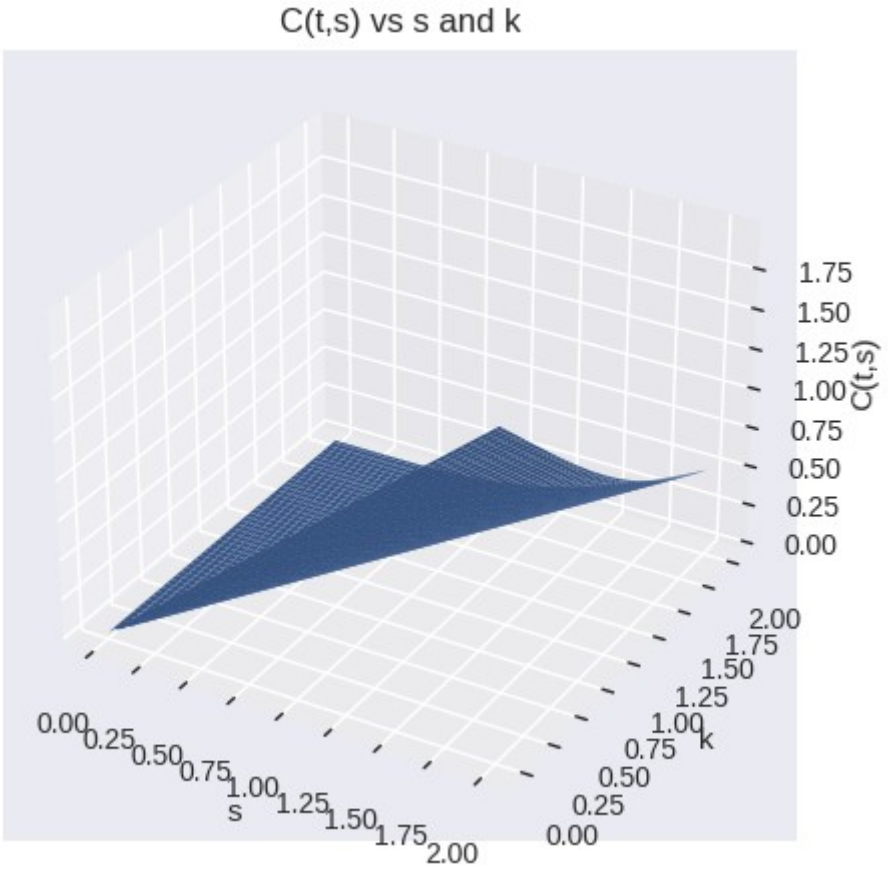
Surface plot of C(t,s) vs t and T



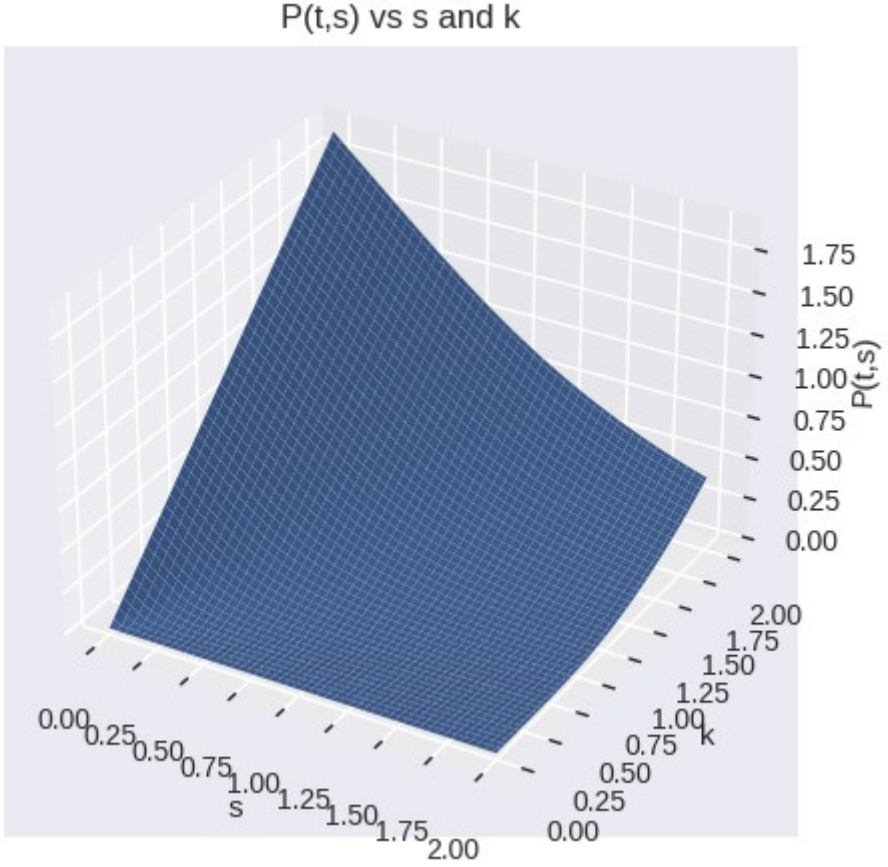
Surface plot of P(t,s) vs t and T



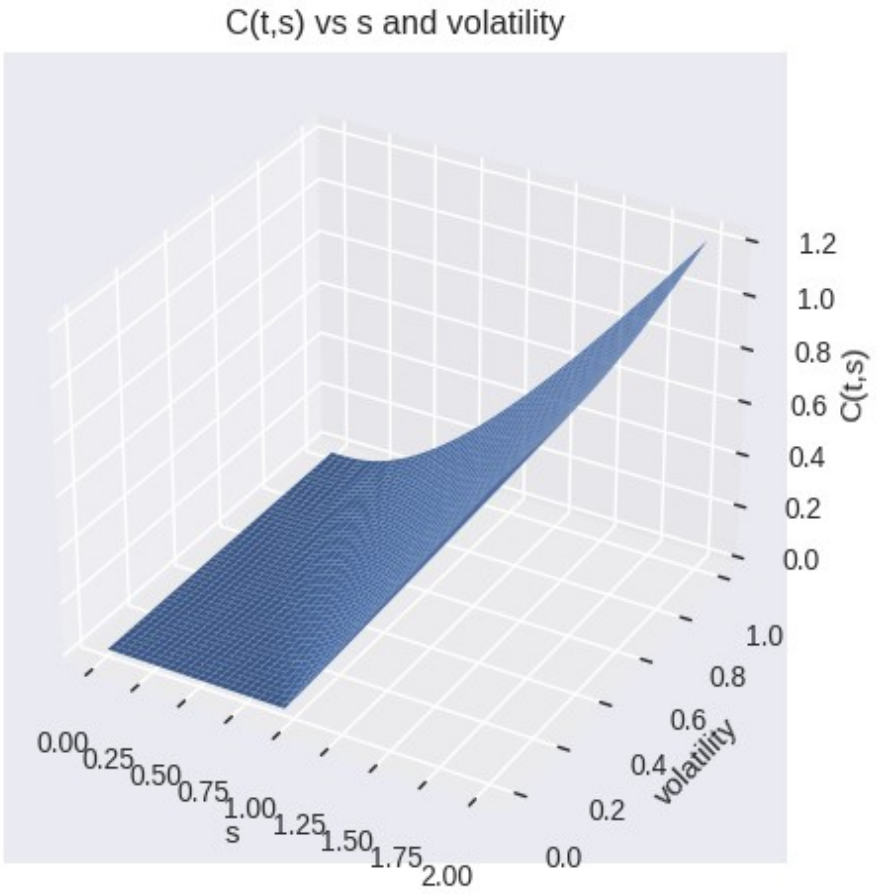
Surface plot of C(t,s) vs s and k



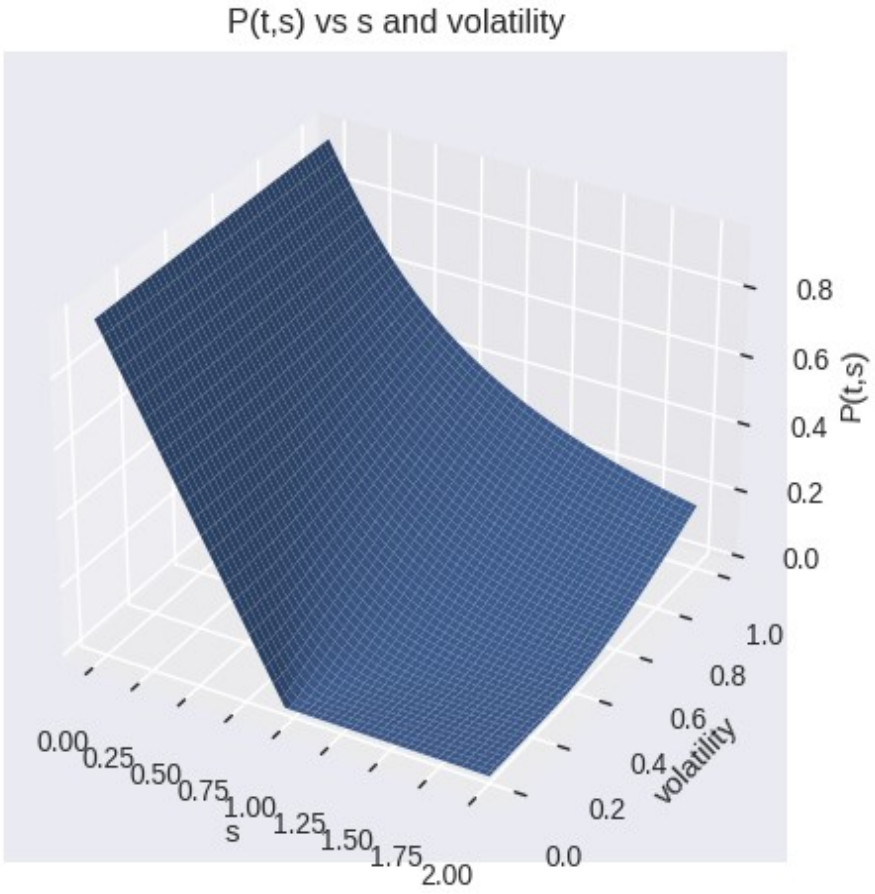
Surface plot of P(t,s) vs s and k



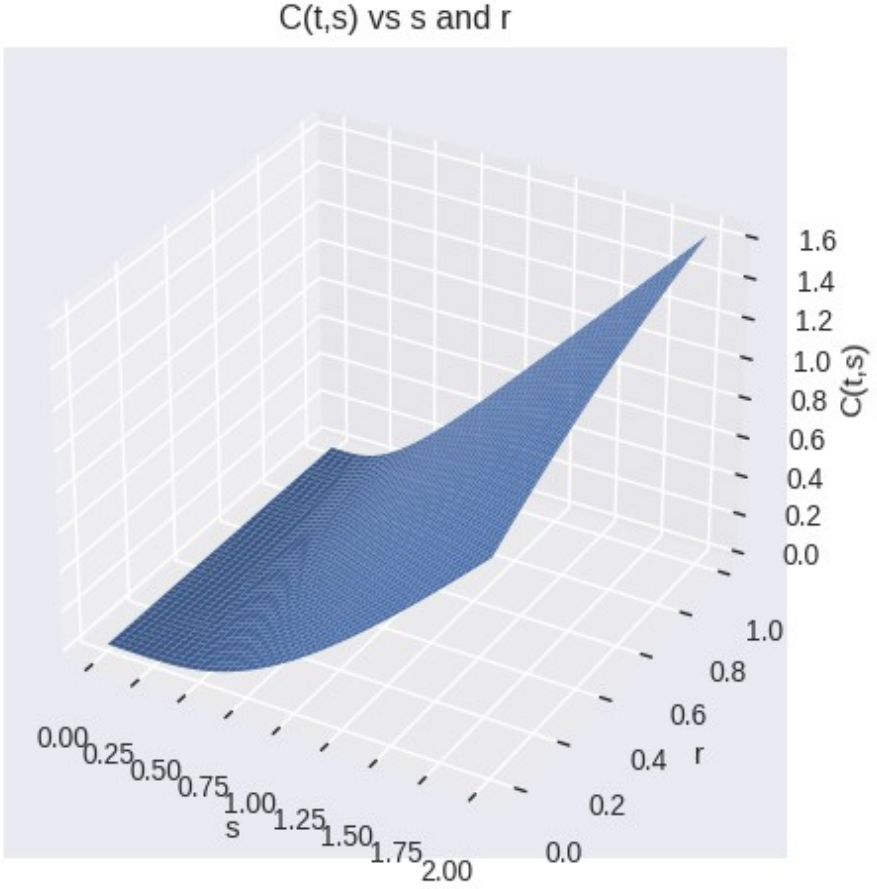
Surface plot of C(t,s) vs s and σ



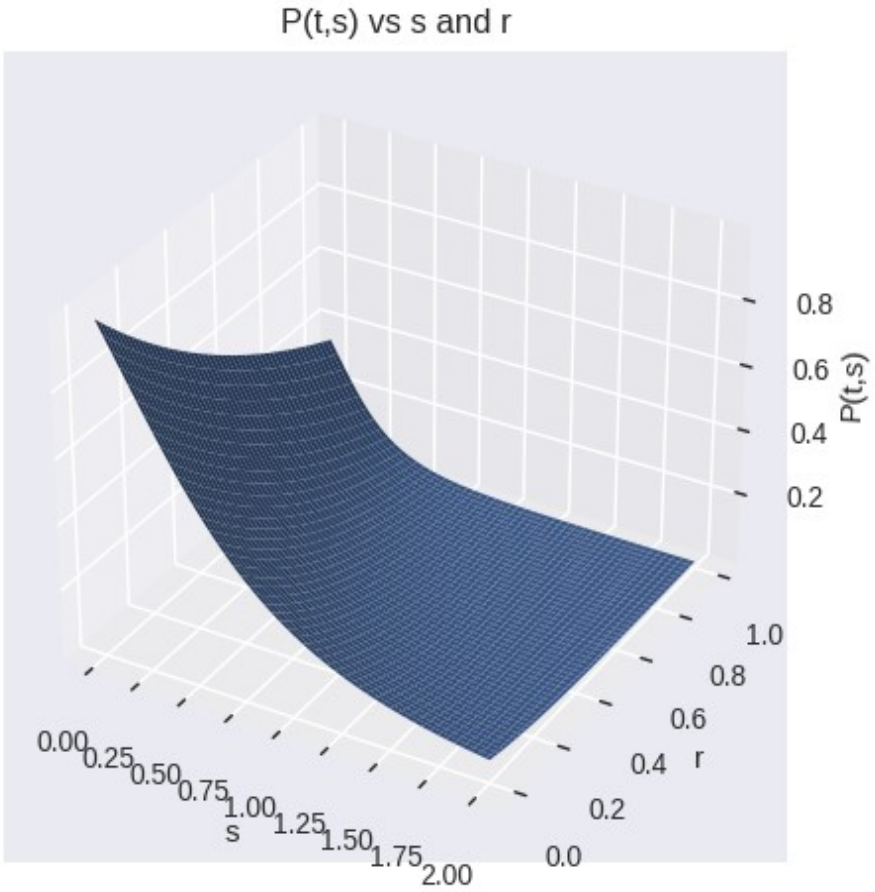
Surface plot of P(t,s) vs s and σ



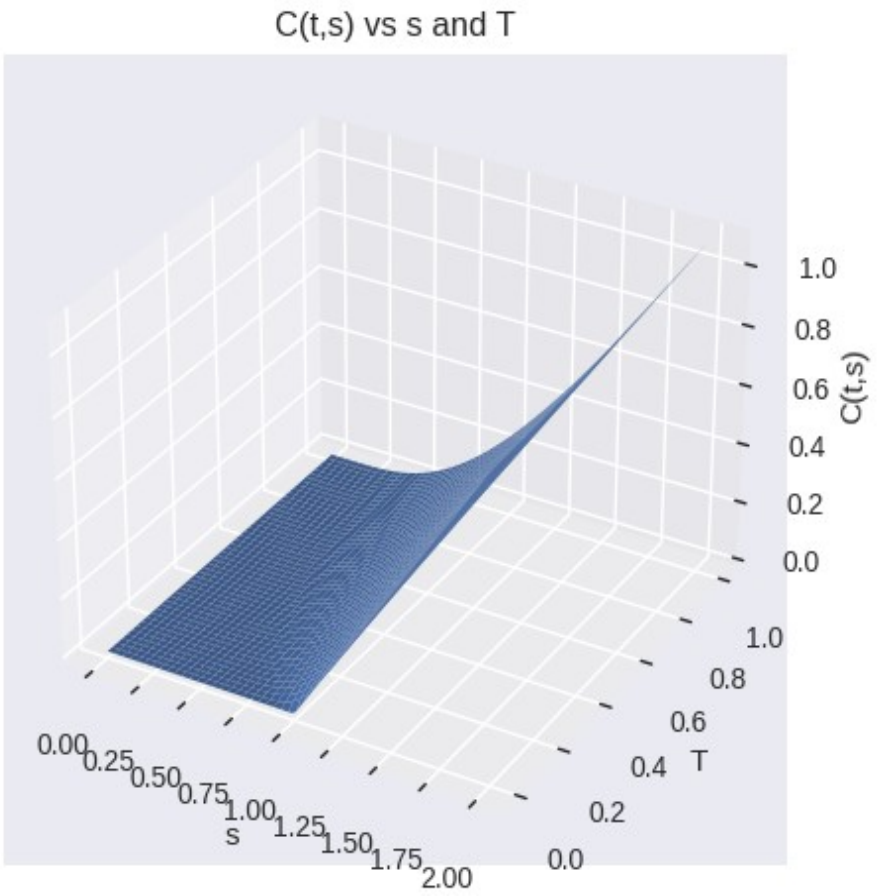
Surface plot of C(t,s) vs s and r



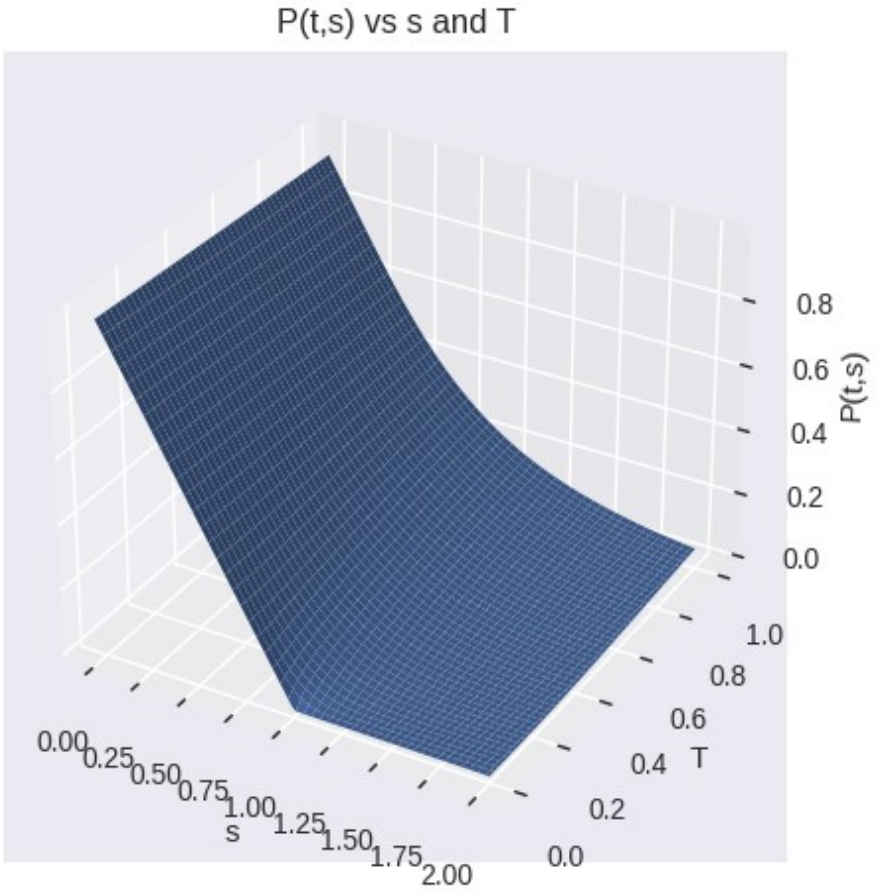
Surface plot of P(t,s) vs s and r



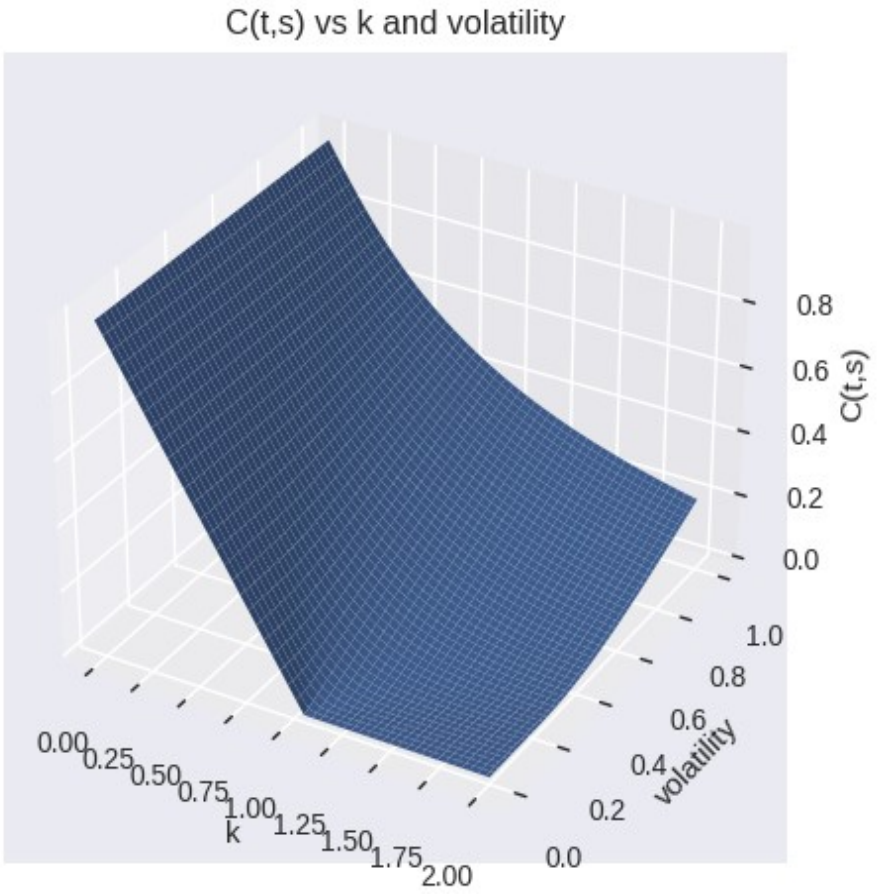
Surface plot of C(t,s) vs s and T



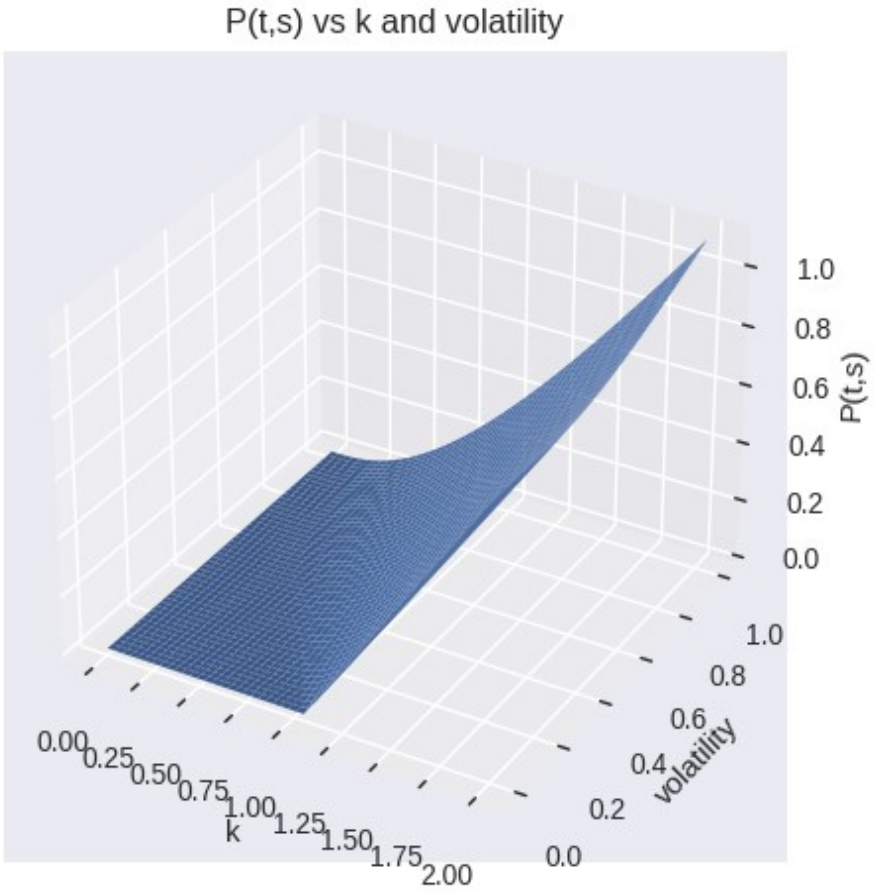
Surface plot of P(t,s) vs s and T



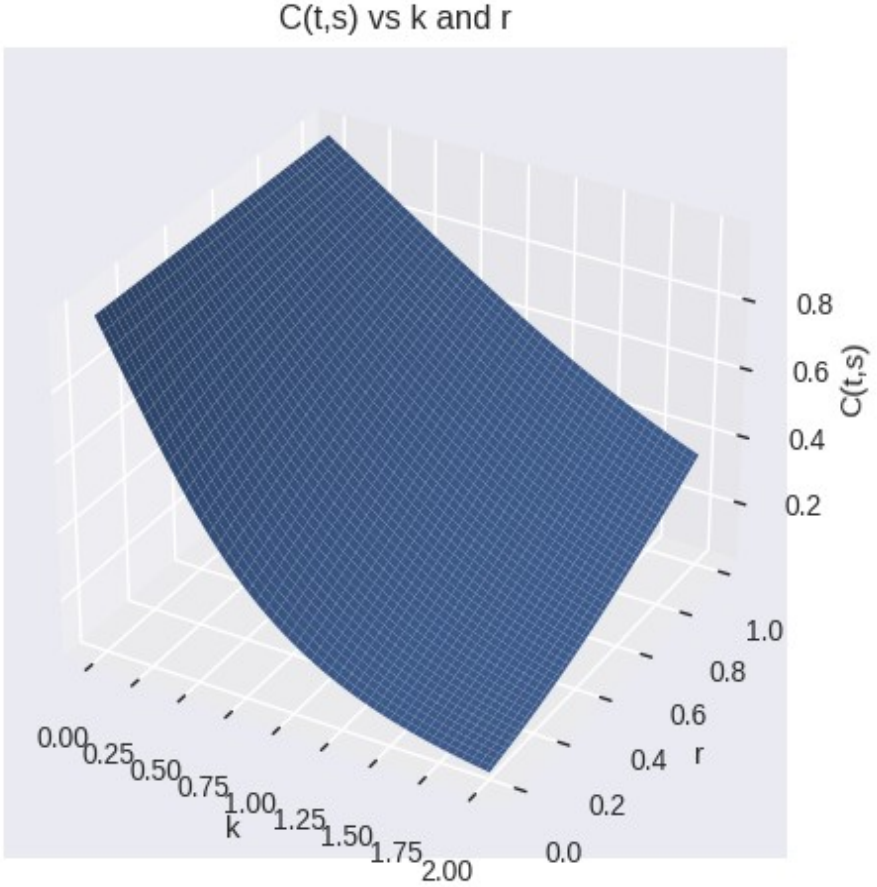
Surface plot of C(t,s) vs k and σ



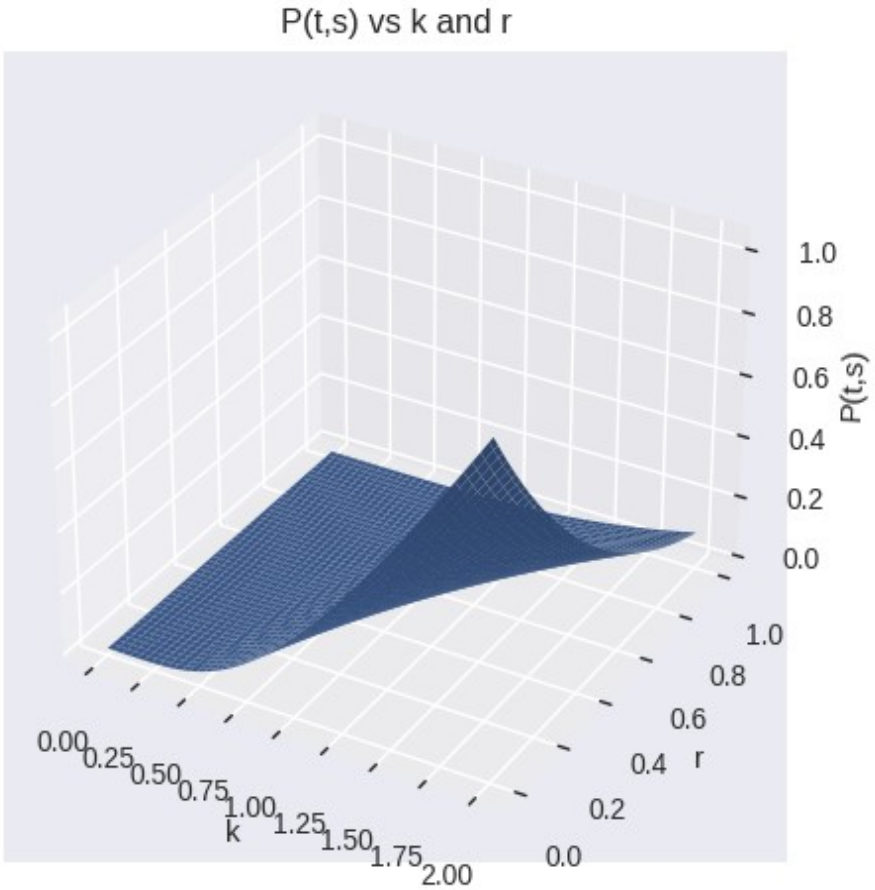
Surface plot of P(t,s) vs k and σ



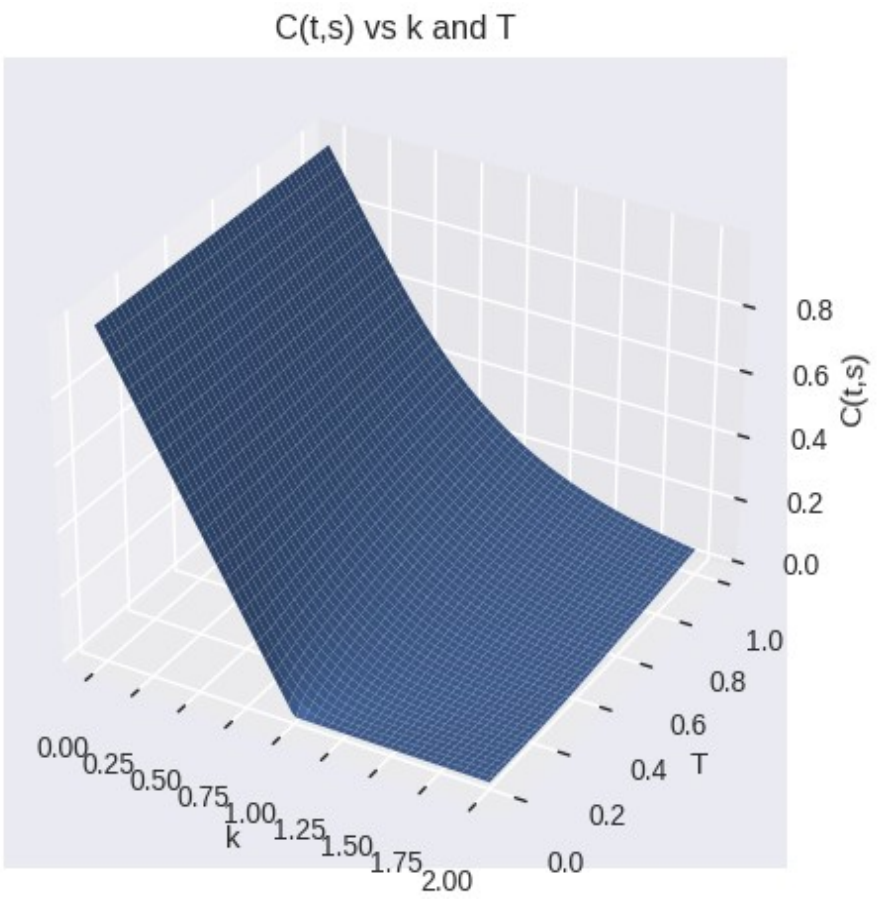
Surface plot of C(t,s) vs k and r



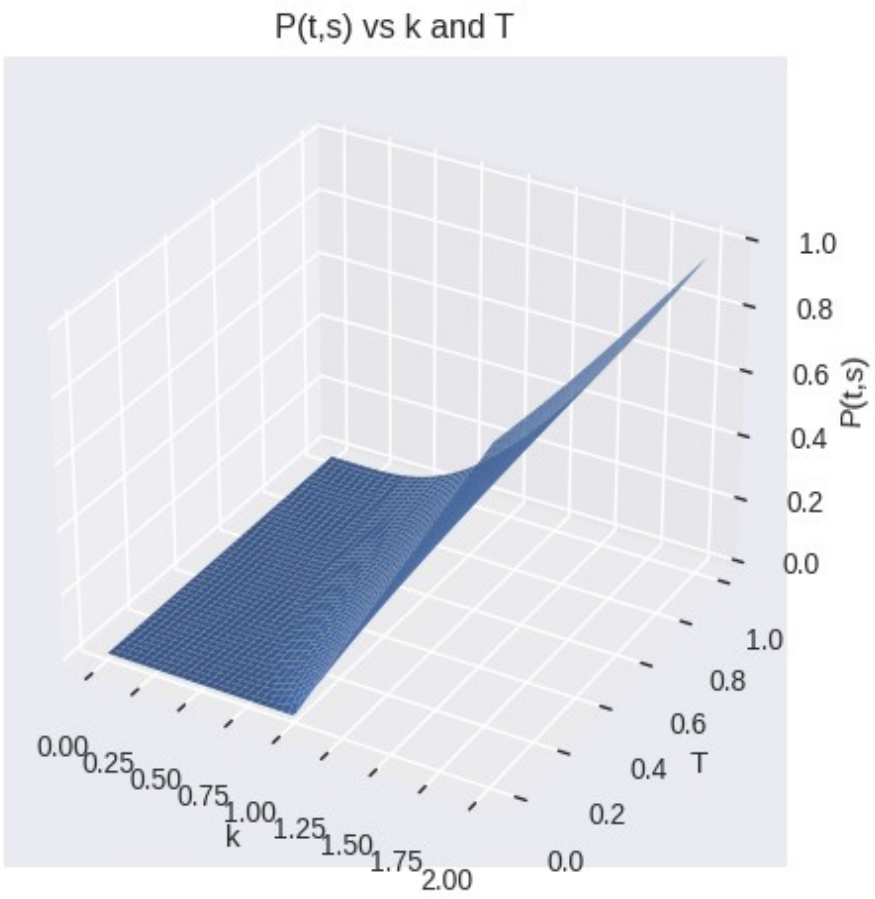
Surface plot of P(t,s) vs k and r



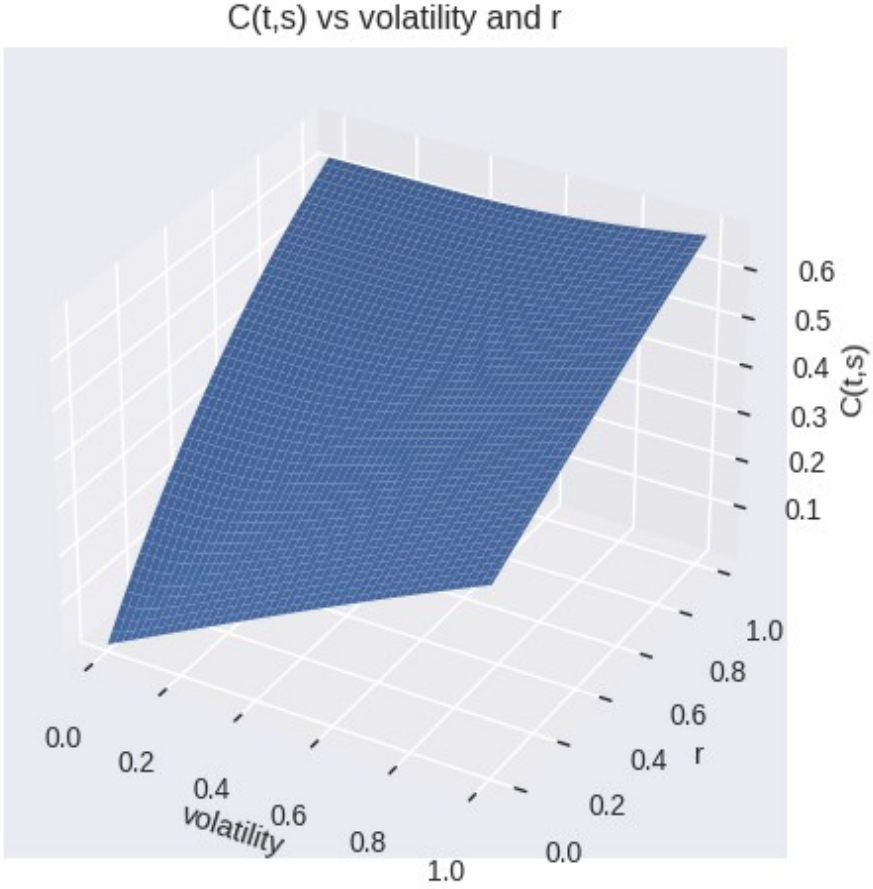
Surface plot of C(t,s) vs k and T



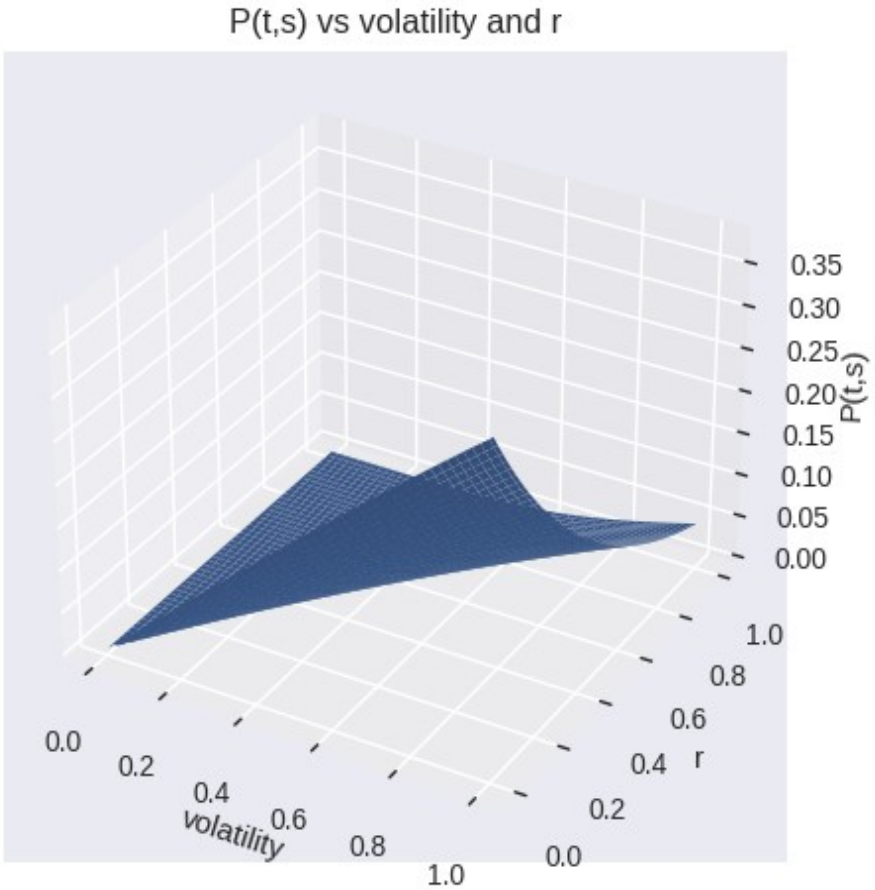
Surface plot of P(t,s) vs k and T



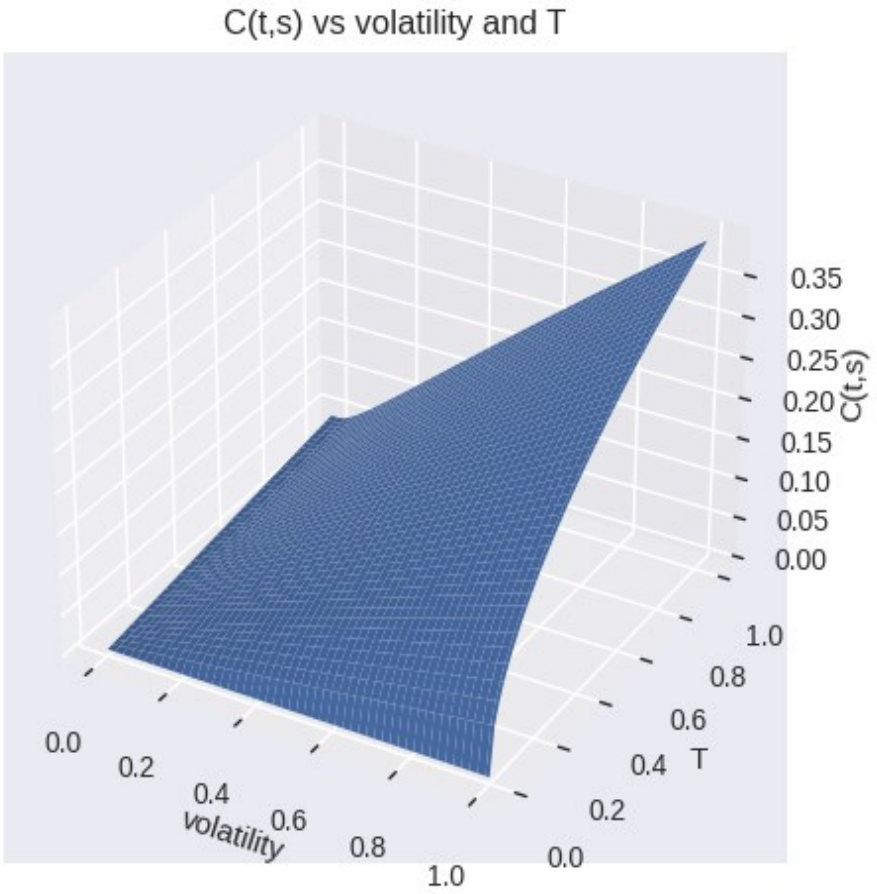
Surface plot of C(t,s) vs σ and r



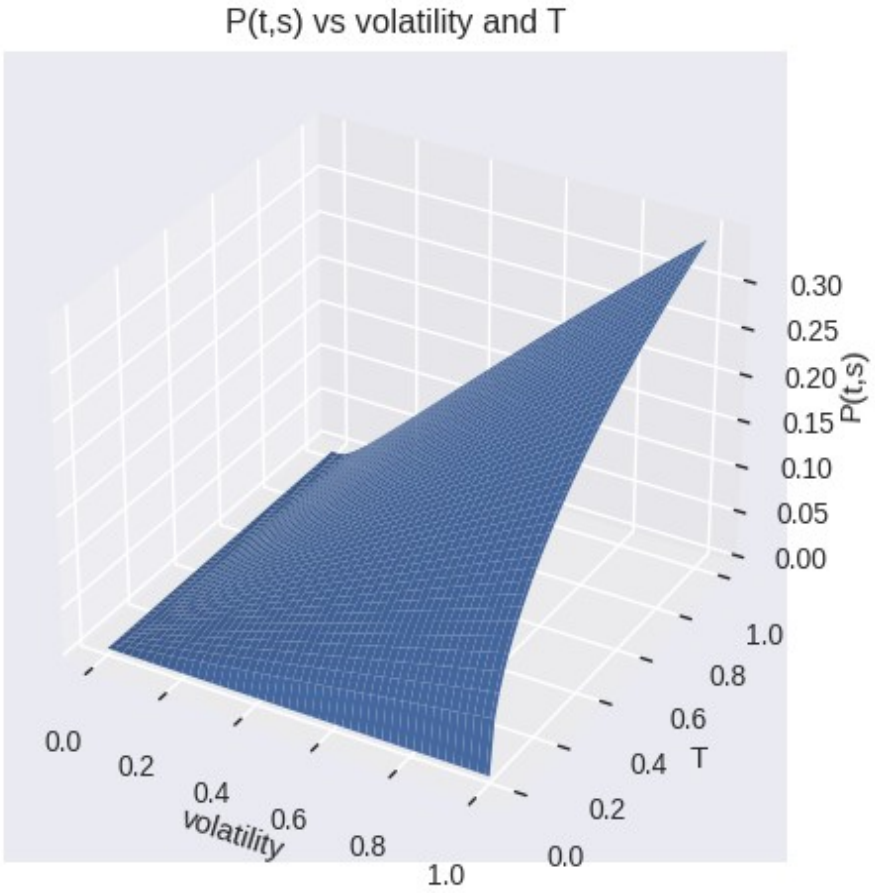
Surface plot of P(t,s) vs σ and r



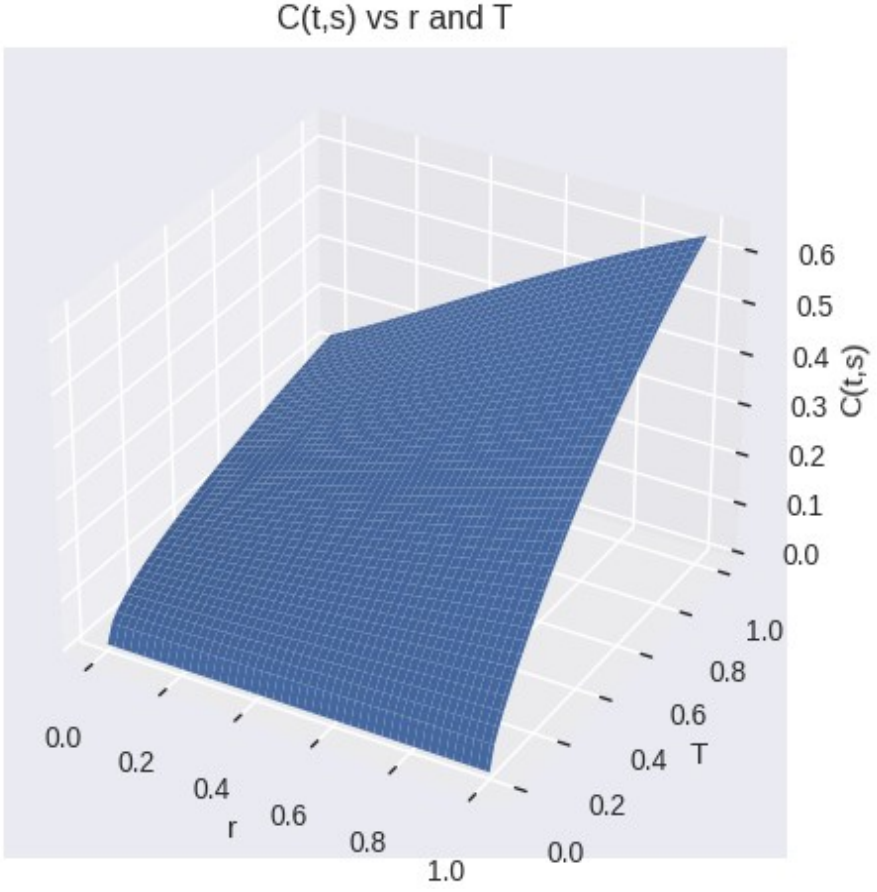
Surface plot of C(t,s) vs σ and T



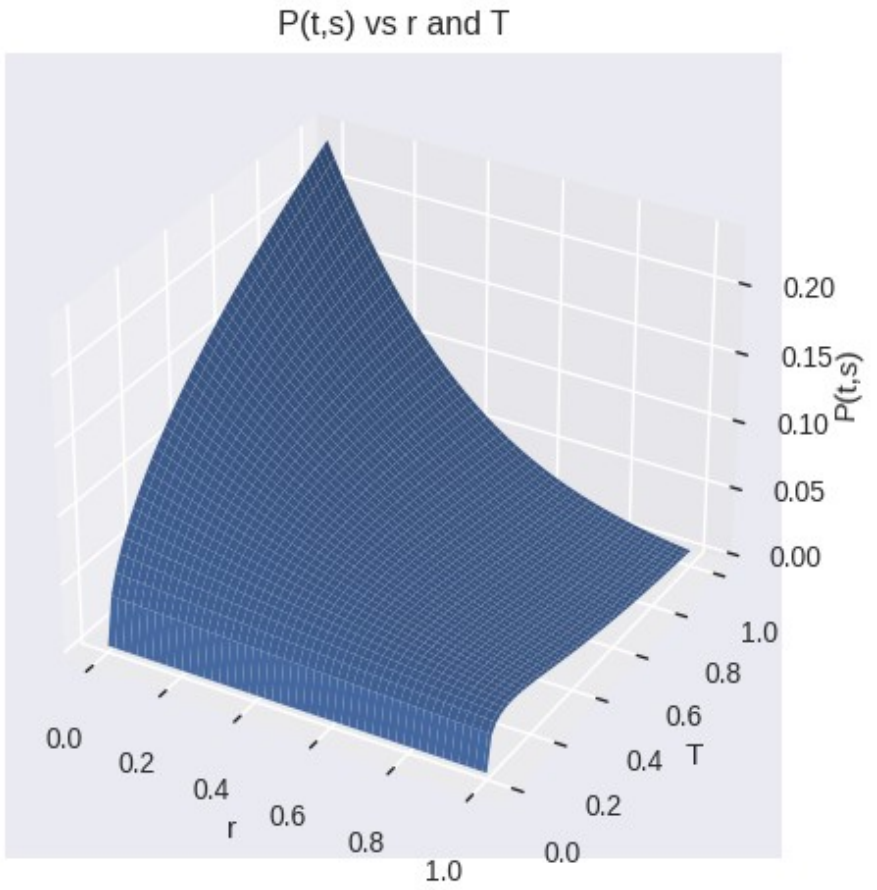
Surface plot of P(t,s) vs σ and T



Surface plot of C(t,s) vs r and T



Surface plot of P(t,s) vs r and T



Tabulation of values

Table of prices with respect to different values of k:

	k	C(t,s)	P(t,s)
0	0.001000	0.399049	3.794708e-18
1	0.040988	0.361012	8.680143e-07
2	0.200940	0.217333	8.472773e-03
3	0.400880	0.101747	8.307551e-02
4	0.600820	0.047643	2.191607e-01
5	0.800760	0.023254	3.849602e-01
6	1.000700	0.011897	5.637925e-01
7	1.400580	0.003539	9.358119e-01
8	1.600520	0.002039	1.124500e+00
9	1.800460	0.001211	1.313861e+00

Table of prices with respect to different values of volatility:

	volatility	C(t,s)	P(t,s)
0	0.001000	0.048771	0.000000
1	0.020984	0.048829	0.000059
2	0.100920	0.068365	0.019595
3	0.200840	0.104821	0.056050
4	0.300760	0.142601	0.093830
5	0.400680	0.180487	0.131716
6	0.500600	0.218151	0.169381
7	0.700440	0.292187	0.243417
8	0.800360	0.328339	0.279568
9	0.900280	0.363793	0.315022

Table of prices with respect to different values of r:

	r	C(t,s)	P(t,s)
0	0.001000	0.236205	0.235206
1	0.020984	0.243896	0.223130
2	0.100920	0.275572	0.179578
3	0.200840	0.316844	0.134887
4	0.300760	0.359345	0.099600
5	0.400680	0.402378	0.072242
6	0.500600	0.445268	0.051435
7	0.700440	0.528229	0.024596
8	0.800360	0.567334	0.016501
9	0.900280	0.604385	0.010840

Question - 5 Incorporating Dividends

In order to incorporate dividends in the analysis, I considered the stock to be such that it pays dividends at a rate of $\boldsymbol{a}$ *continuously. According to the classical BSM setup the formulae for call and put option in this case would be:-*

$$C(t,s) = se^{-a\tau}N(d_1) - ke^{-r\tau}N(d_2)$$

$$d_1 = \frac{1}{\sigma\sqrt{(\tau)}}\left(\log\left(\frac{s}{k}\right) + (r - a + \sigma^2/2)\,\tau\right)$$

$$d2 = d1 - \sigma\sqrt{(\tau)}$$

$$\tau = T - t$$

Now from the above relations we can calculate the price of a European Call option in the classical BSM framework. For put option we use the put-call parity:-

$$C(t,s) - P(t,s) = se^{-a\tau} - Ke^{-r\tau}$$

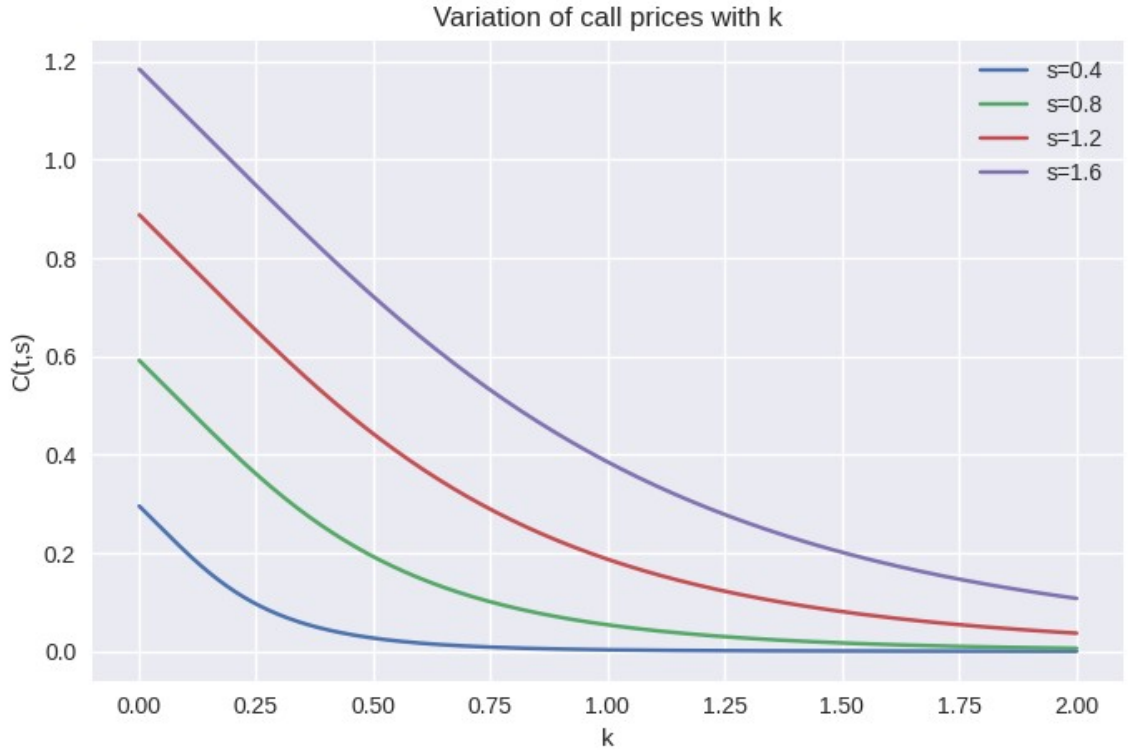
I implemented the below formuales in my program and calculated the price of a European call and put option in the classical BSM framework. The paramters chosen were as follows:-

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

Now, I repeated question 4 of the previous problem and did sensitivity analysis of C(t,s) and P(t,s). In this case I also did sensitivity analysis with respect to the parameter $\boldsymbol{a}$*. I took the value of* $\boldsymbol{a}$ *to be* $\boldsymbol{a = 0.3}$

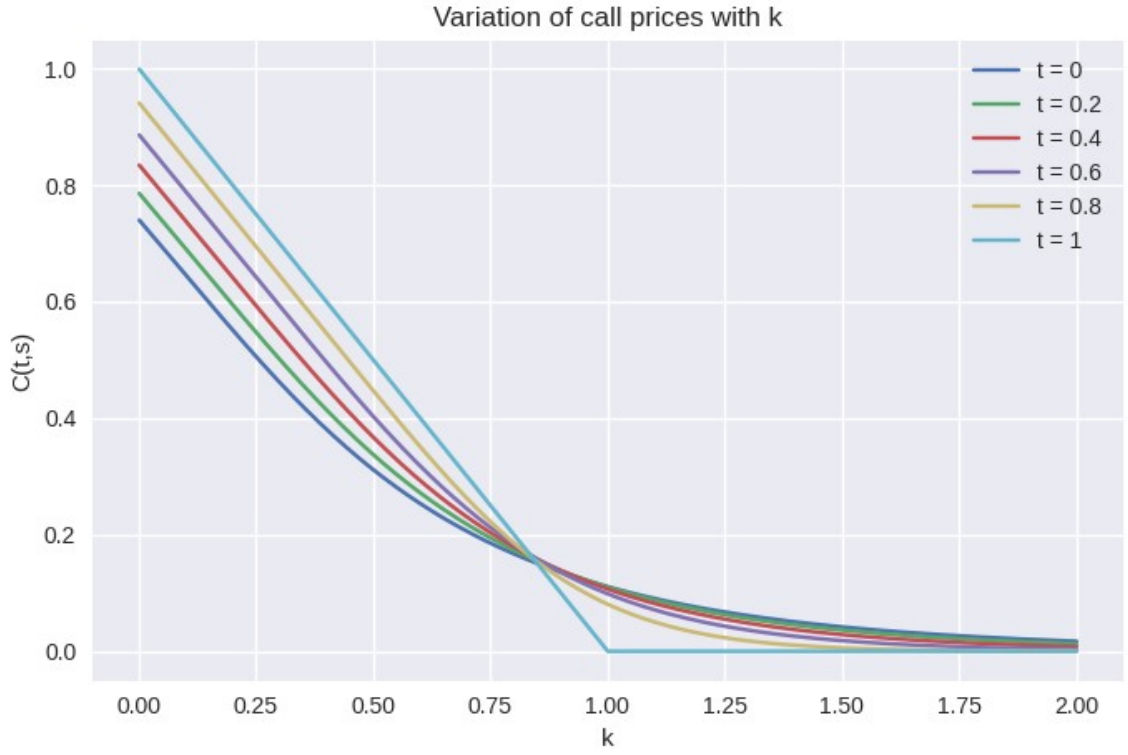
Sensitivity Analysis

Plot of C(t,s) with k for different values of s

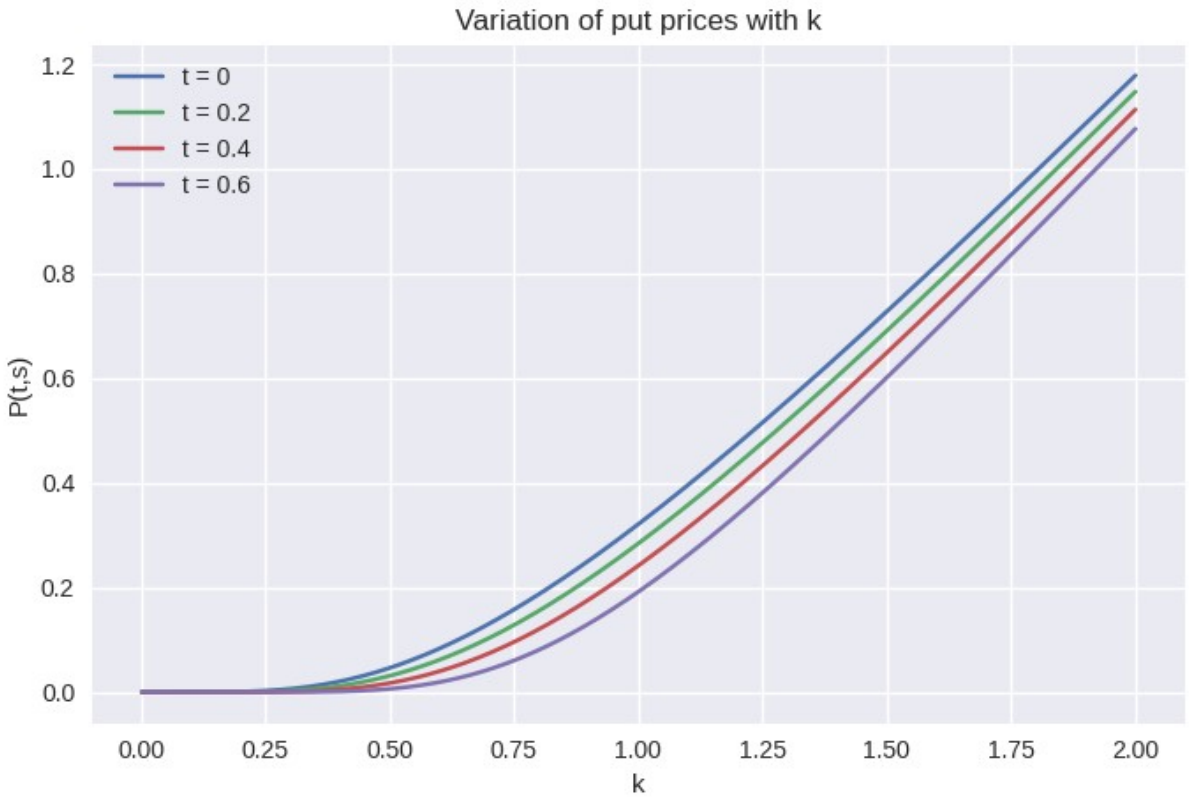


Plot of P(t,s) with k for different values of s

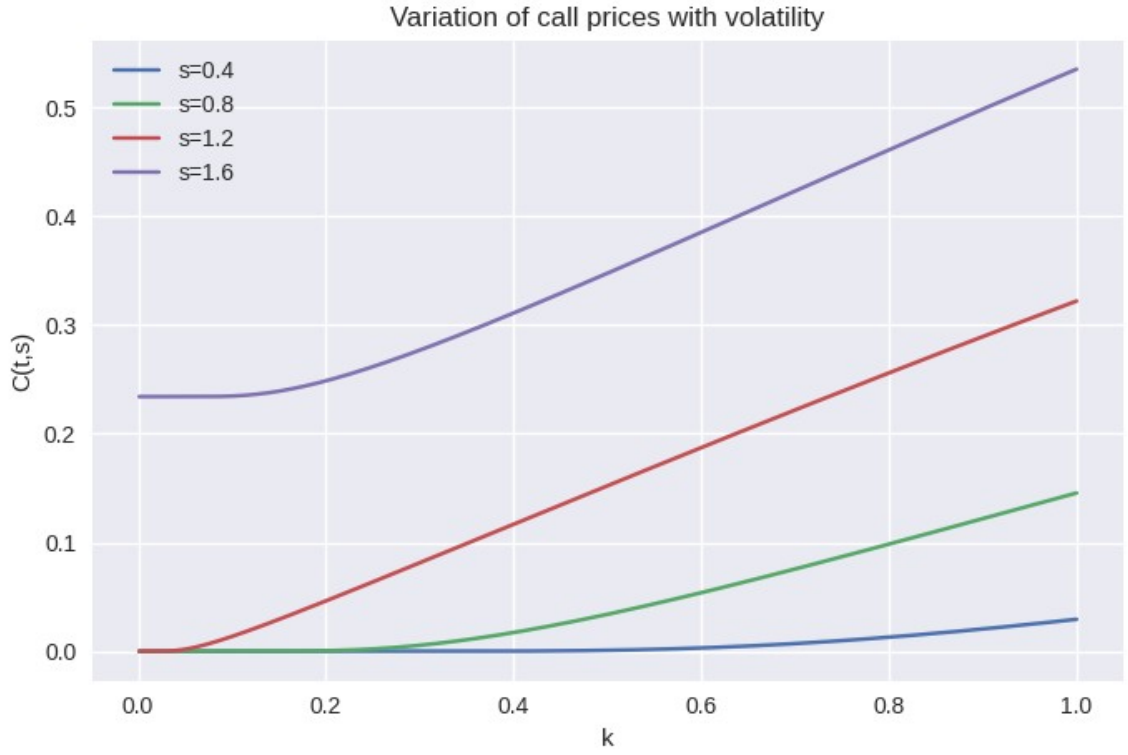
Plot of C(t,s) with k for different values of t



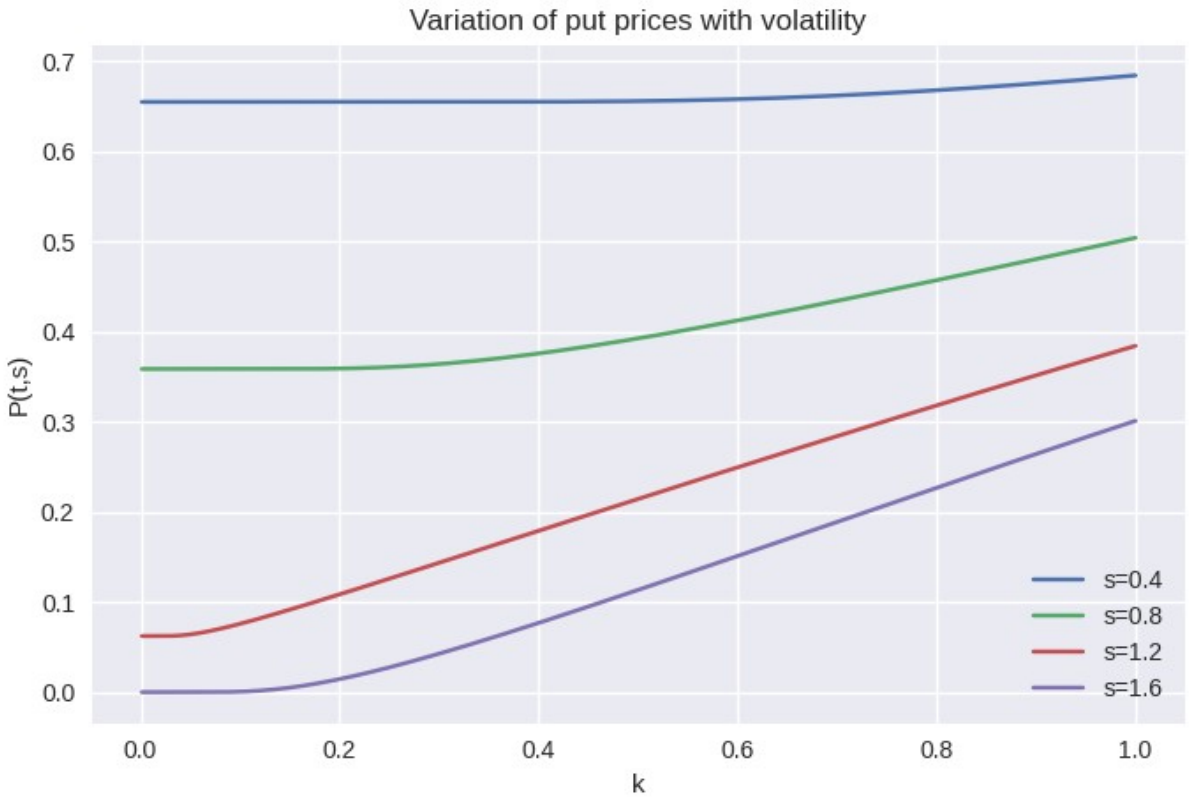
Plot of P(t,s) with k for different values of t



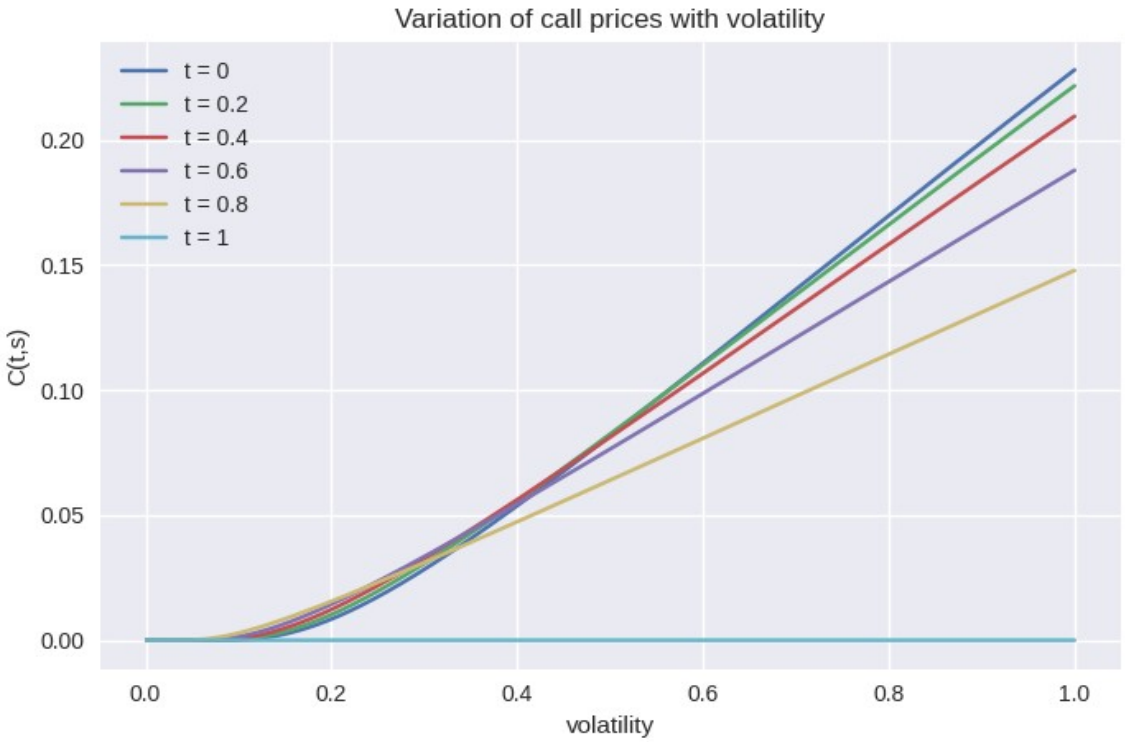
Plot of C(t,s) with σ for different values of s



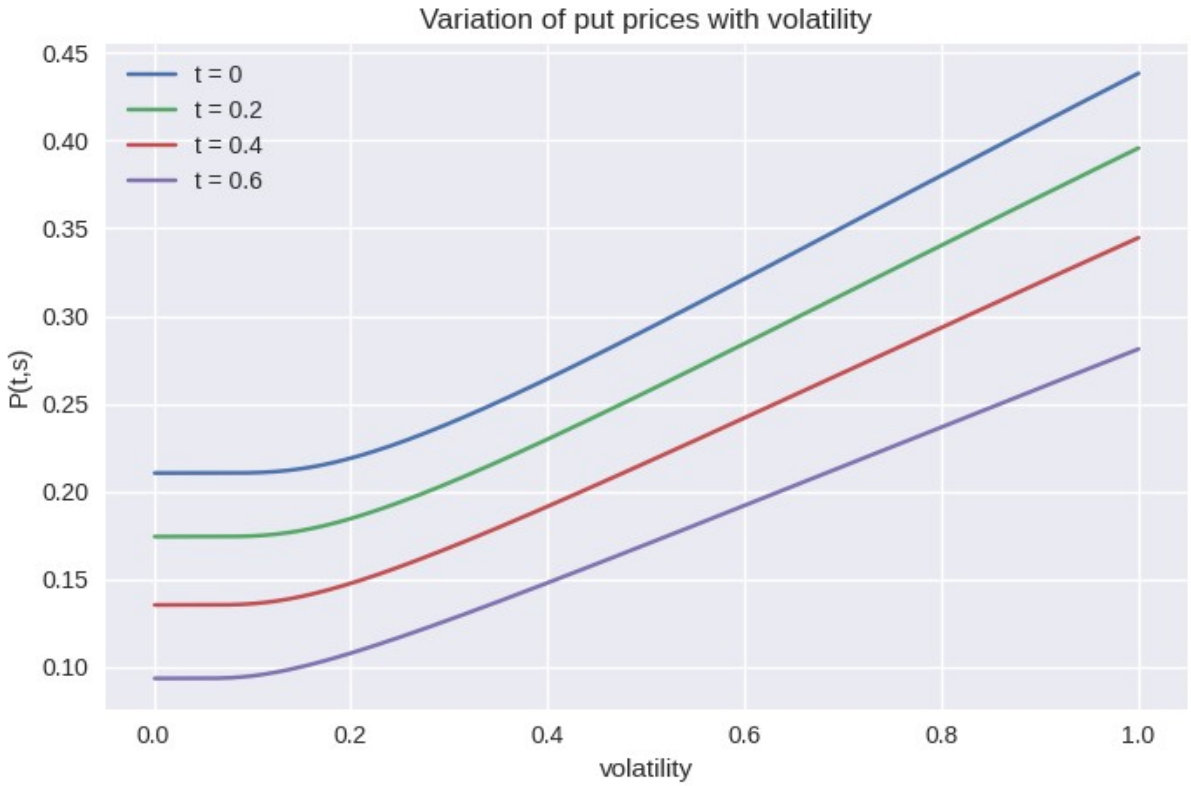
Plot of P(t,s) with σ for different values of s



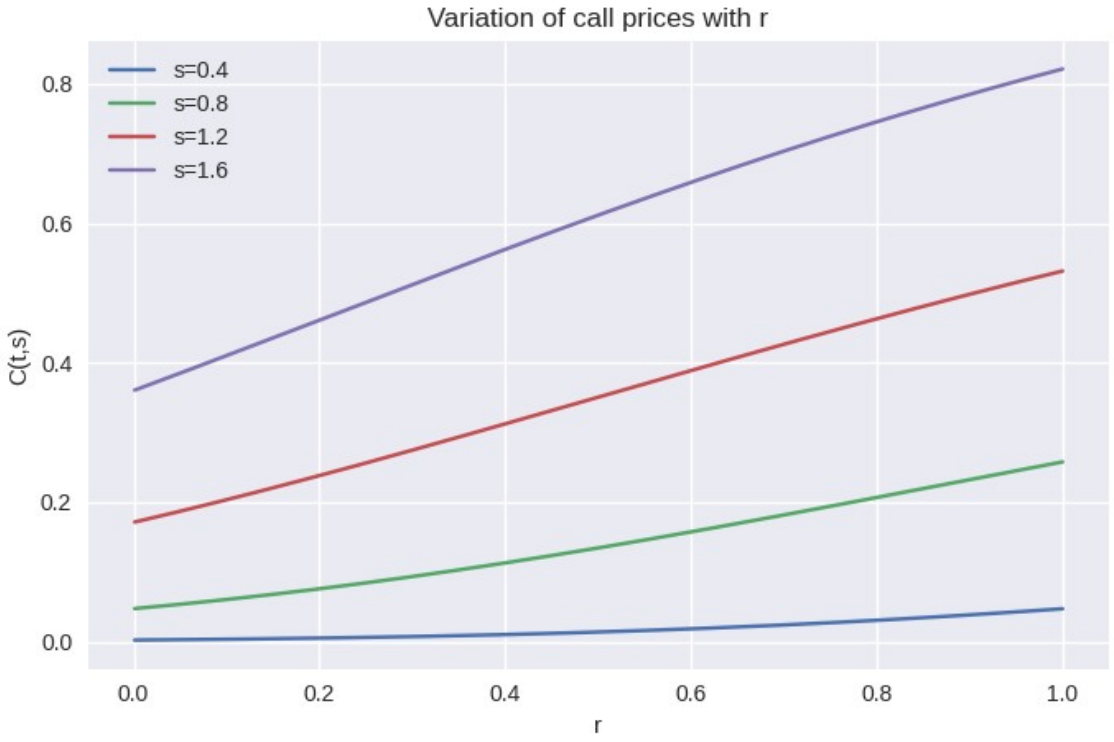
Plot of C(t,s) with σ for different values of t



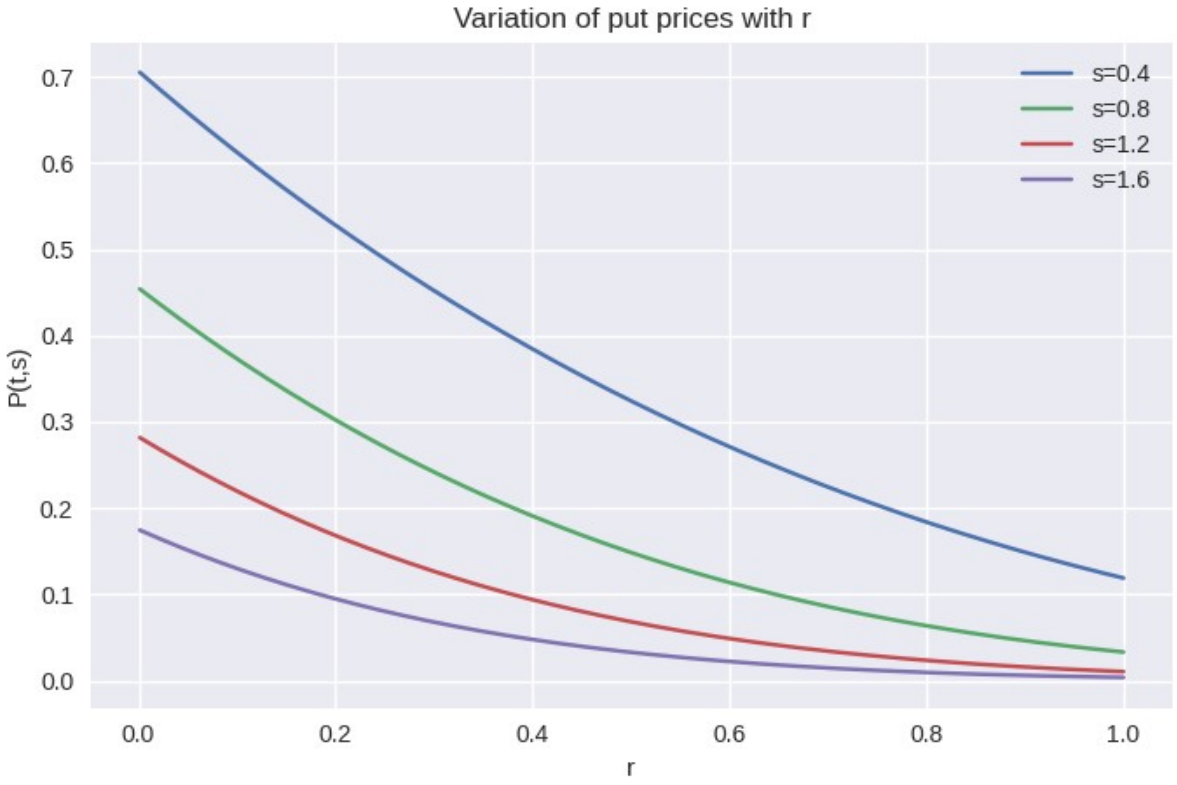
Plot of P(t,s) with σ for different values of t



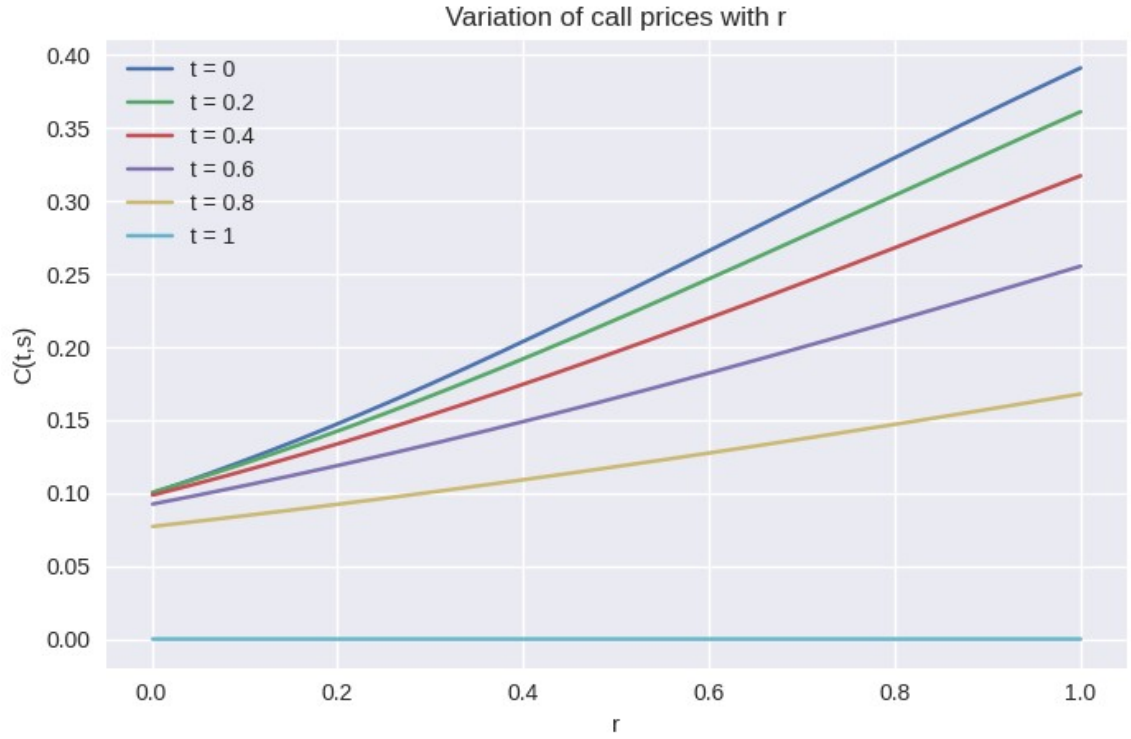
Plot of C(t,s) with r for different values of s



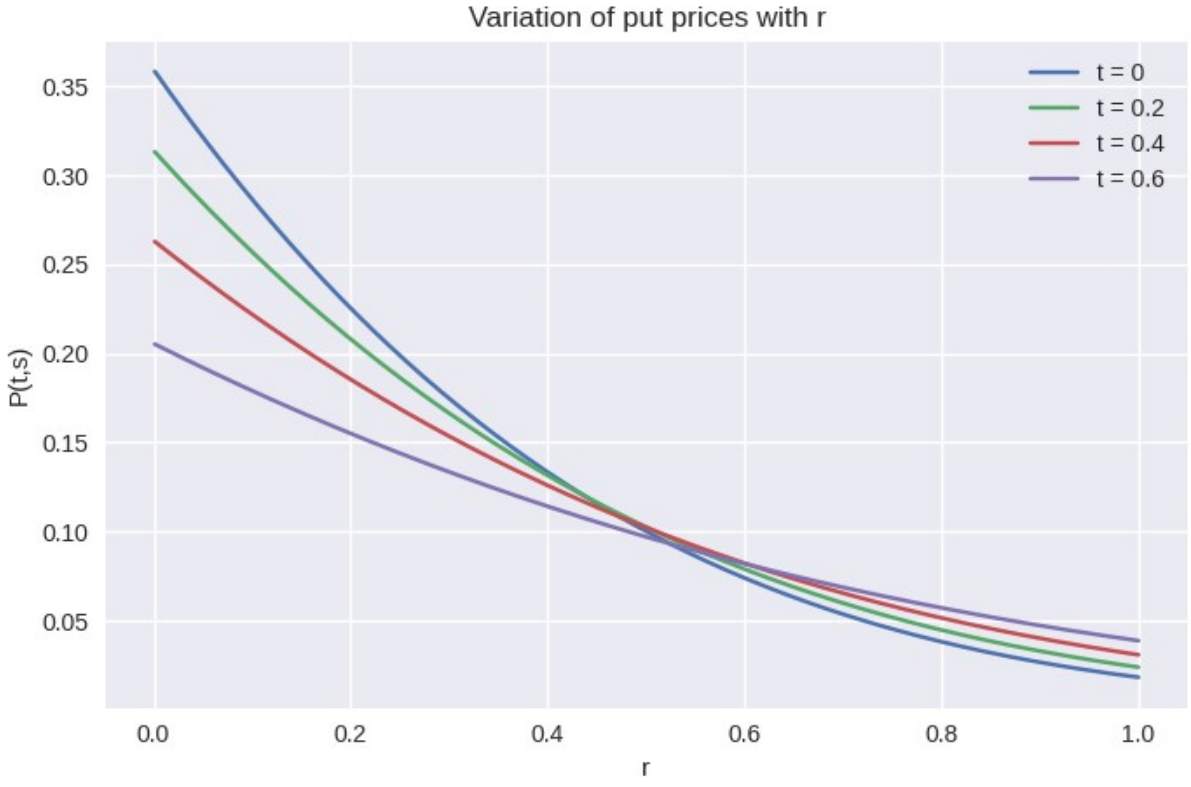
Plot of P(t,s) with r for different values of s



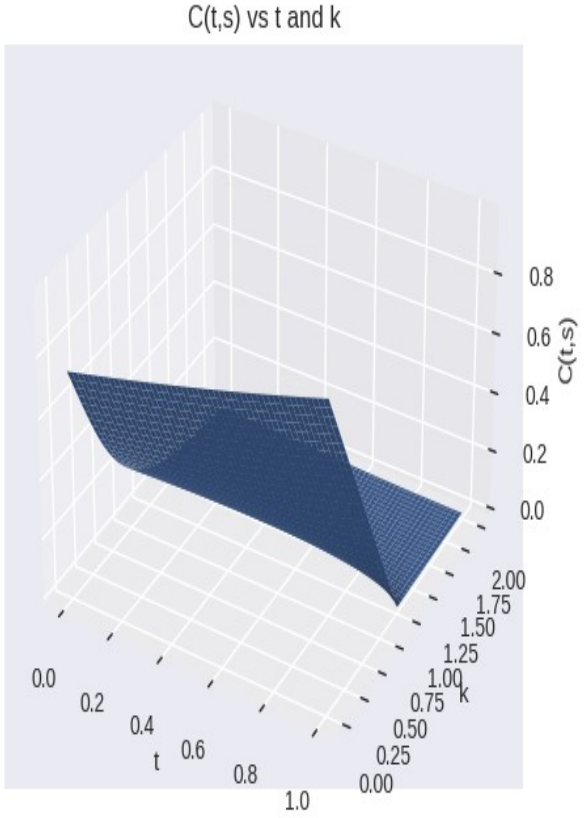
Plot of C(t,s) with r for different values of t



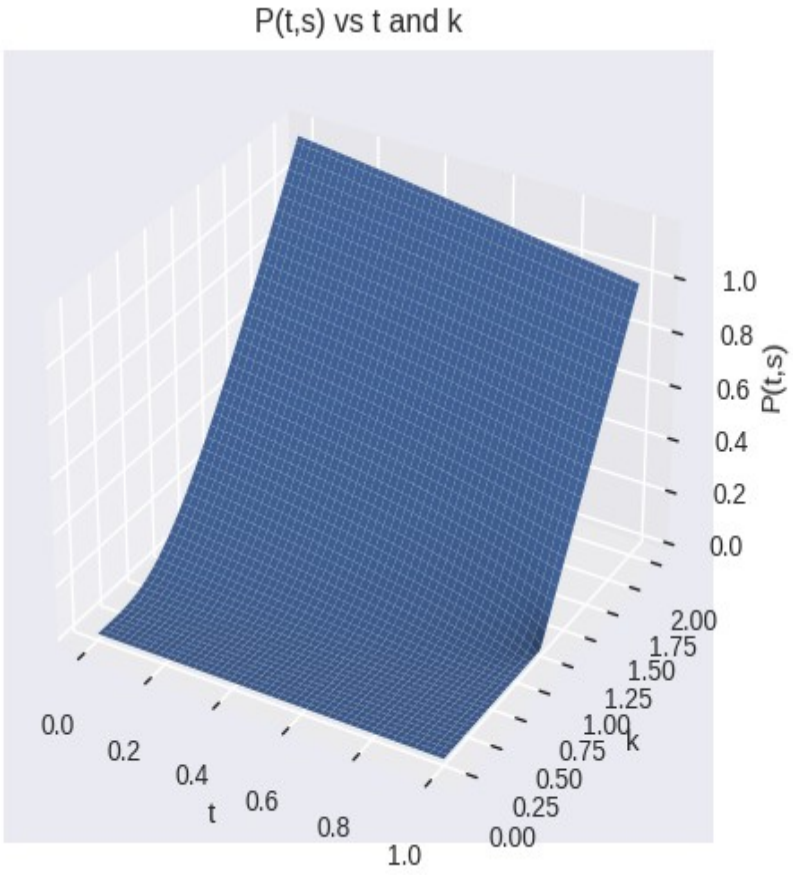
Plot of P(t,s) with r for different values of t



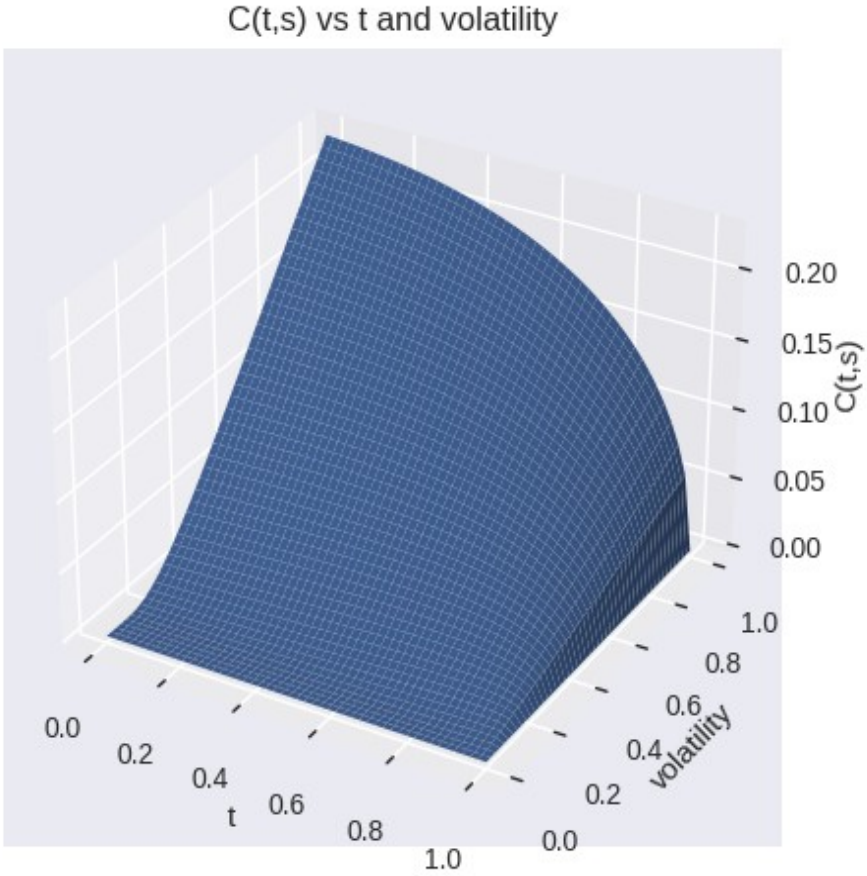
Surface plot of C(t,s) vs t and k



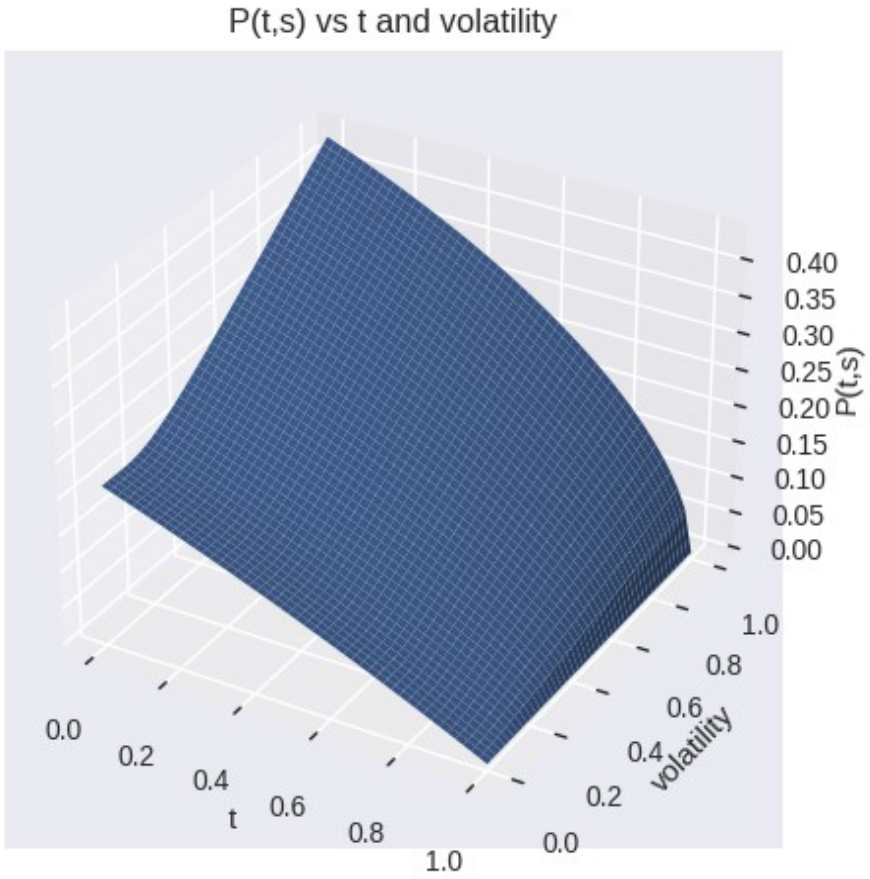
Surface plot of P(t,s) vs t and k



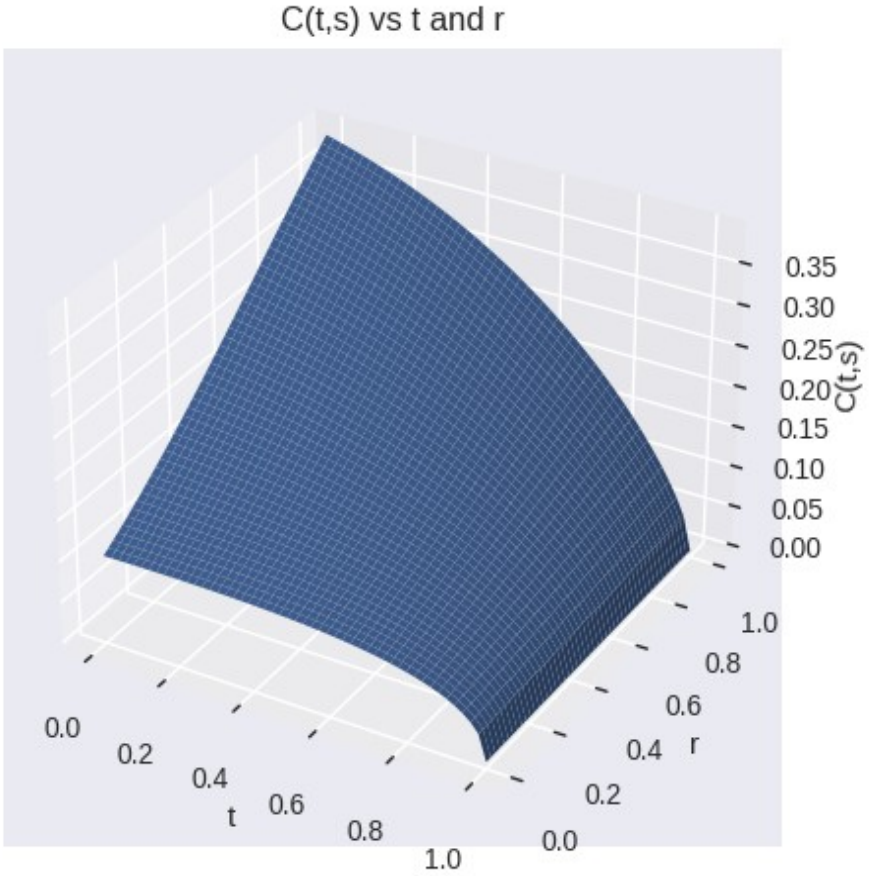
Surface plot of C(t,s) vs t and σ



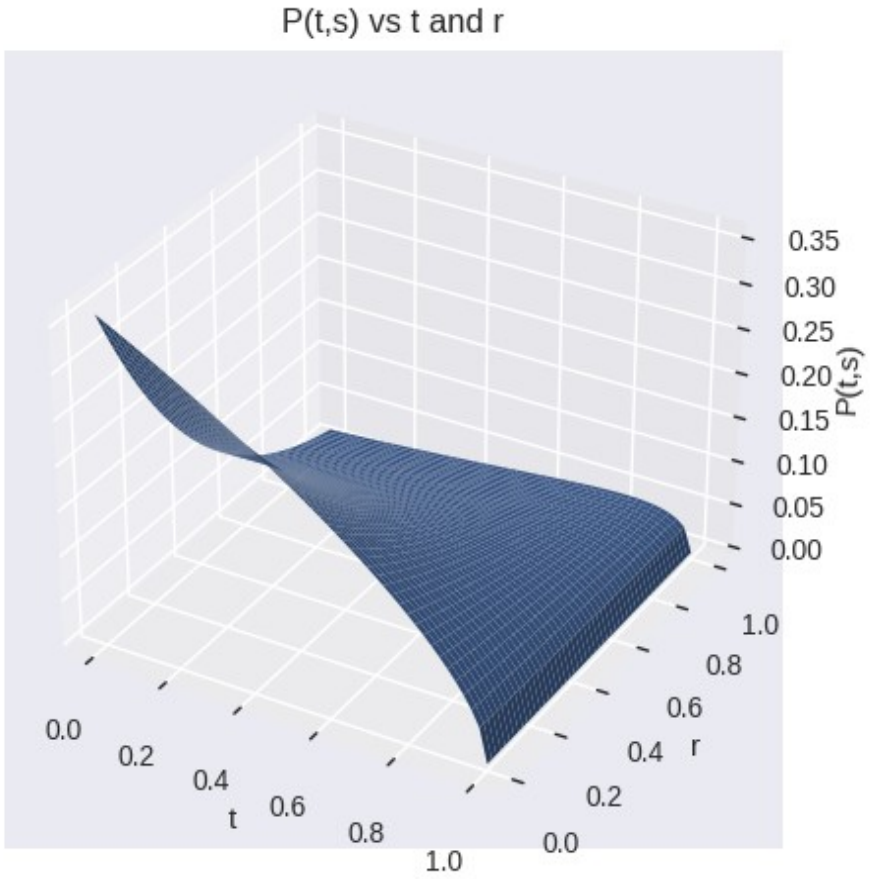
Surface plot of P(t,s) vs t and σ



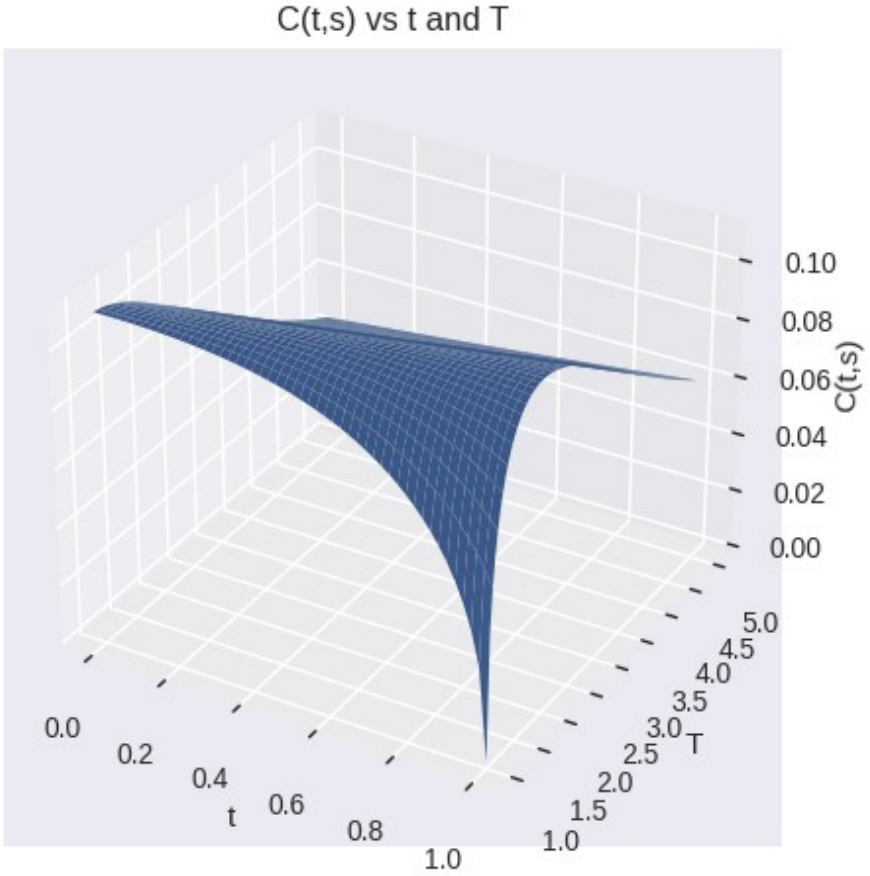
Surface plot of C(t,s) vs t and r



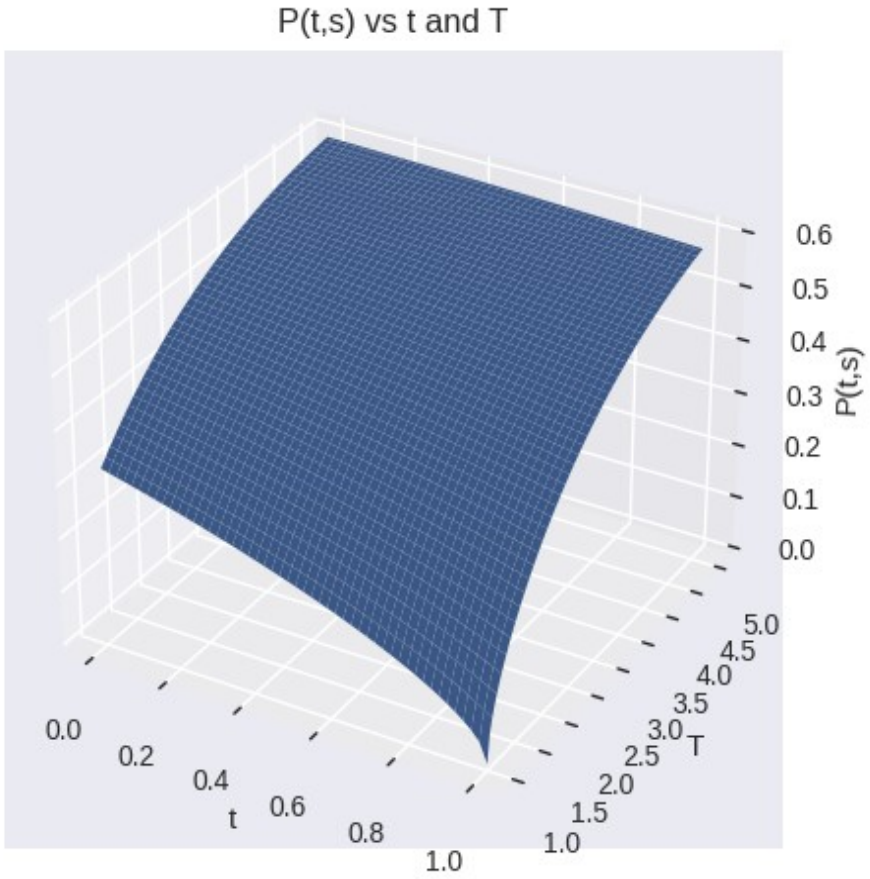
Surface plot of P(t,s) vs t and r



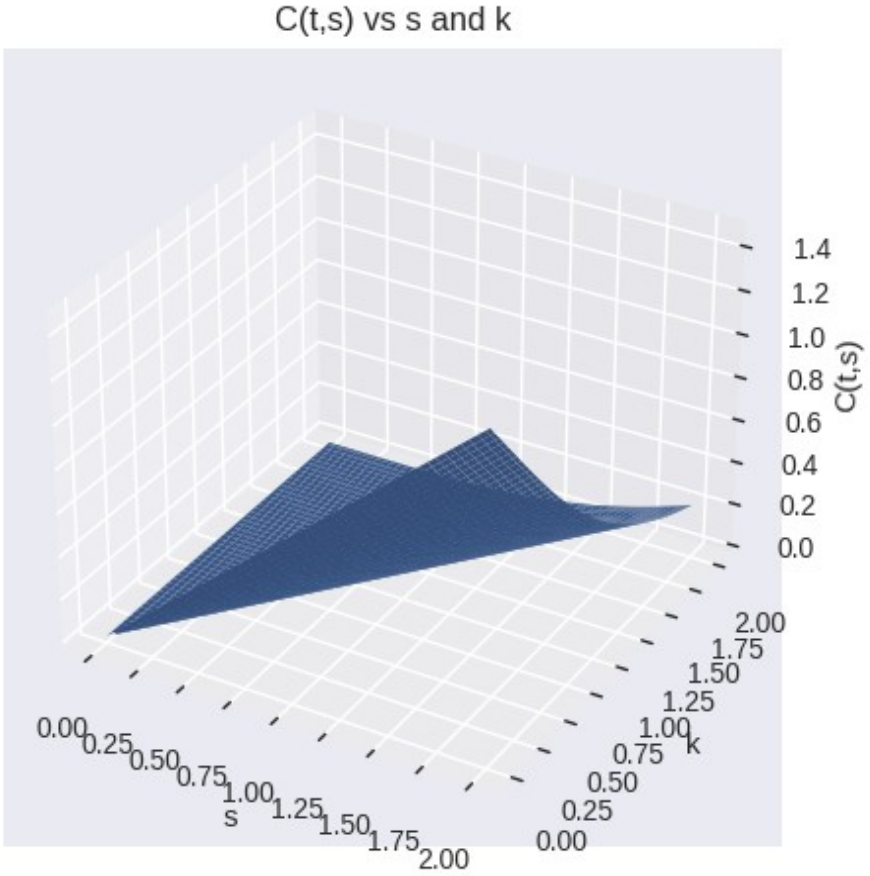
Surface plot of C(t,s) vs t and T



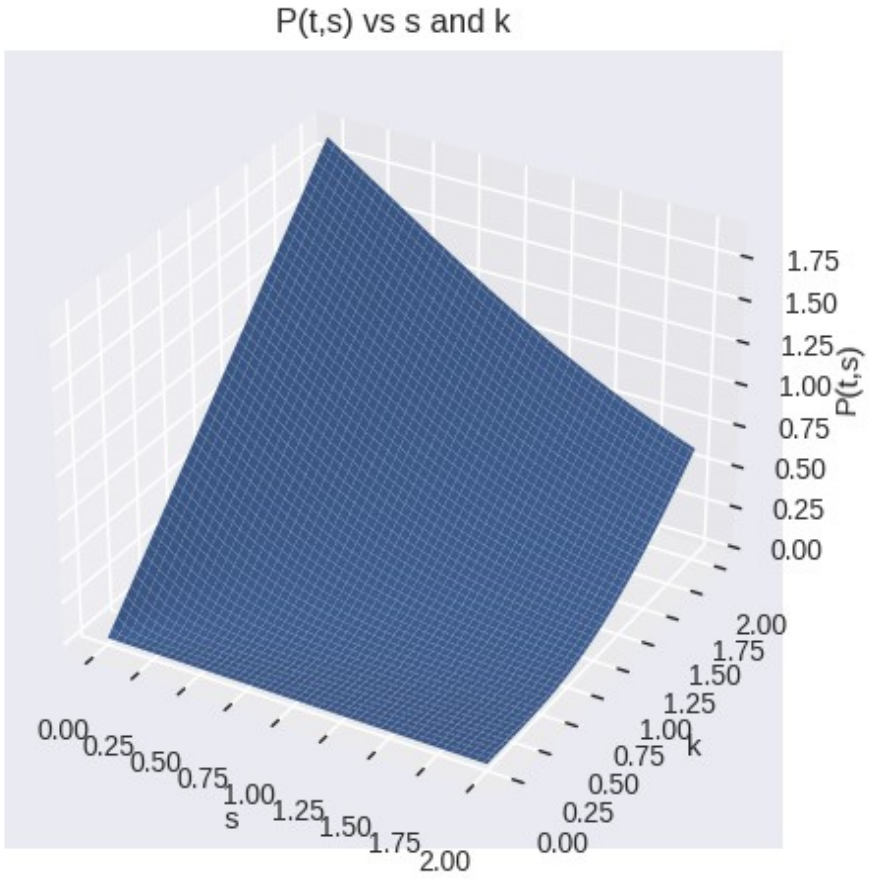
Surface plot of P(t,s) vs t and T



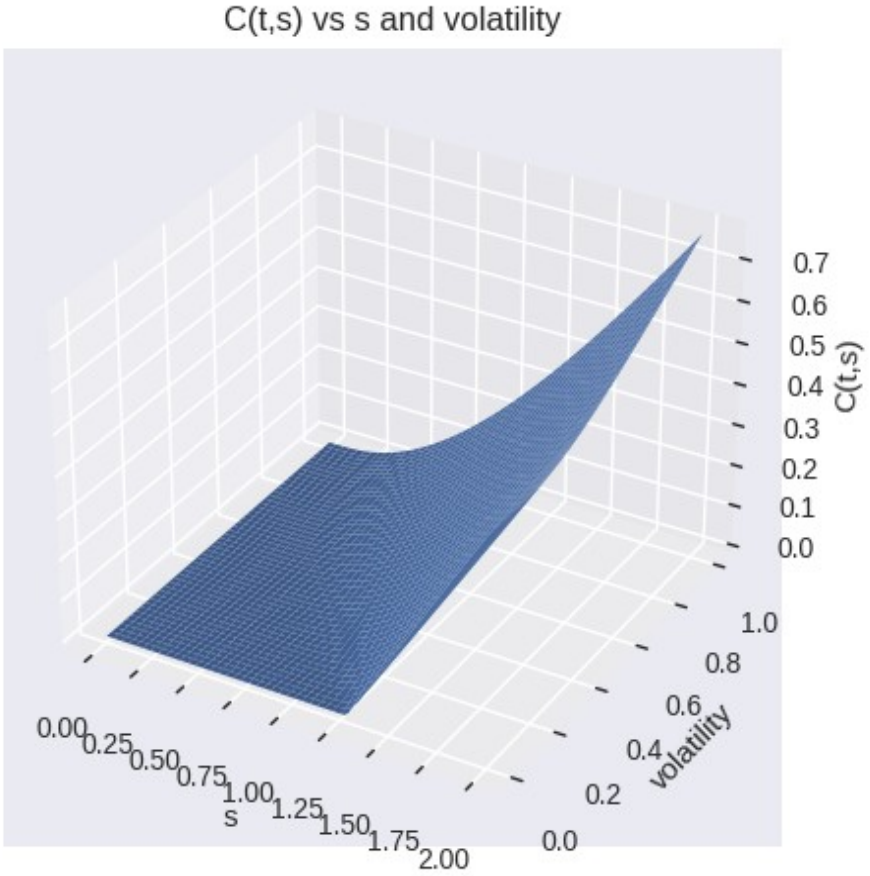
Surface plot of C(t,s) vs s and k



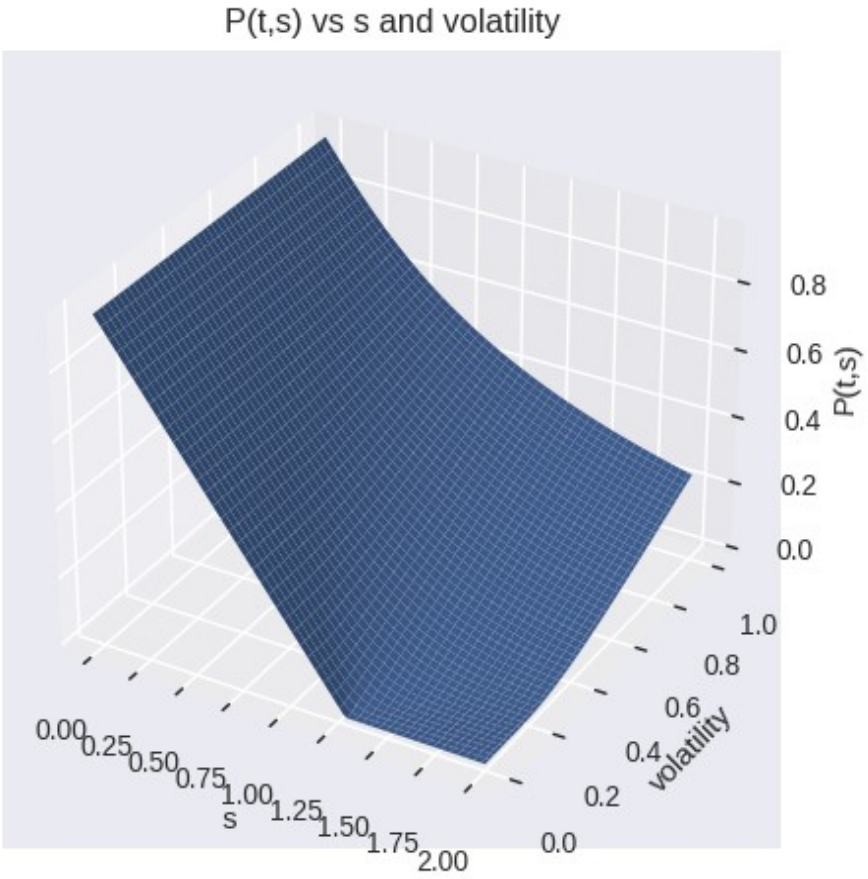
Surface plot of P(t,s) vs s and k



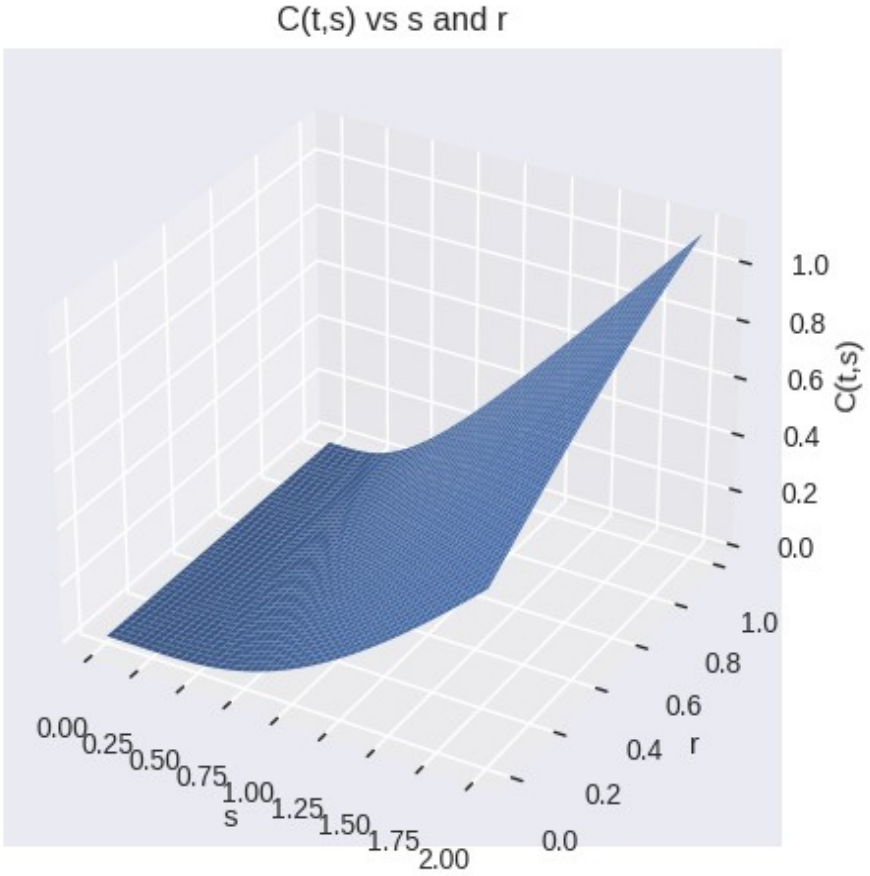
Surface plot of C(t,s) vs s and σ



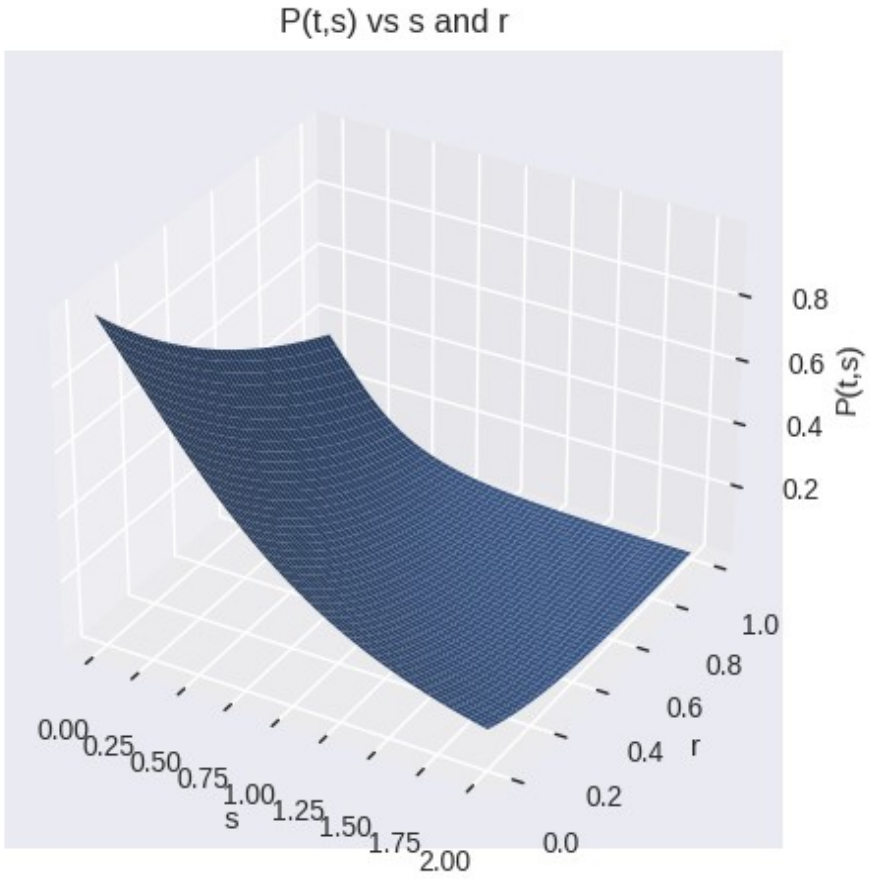
Surface plot of P(t,s) vs s and σ



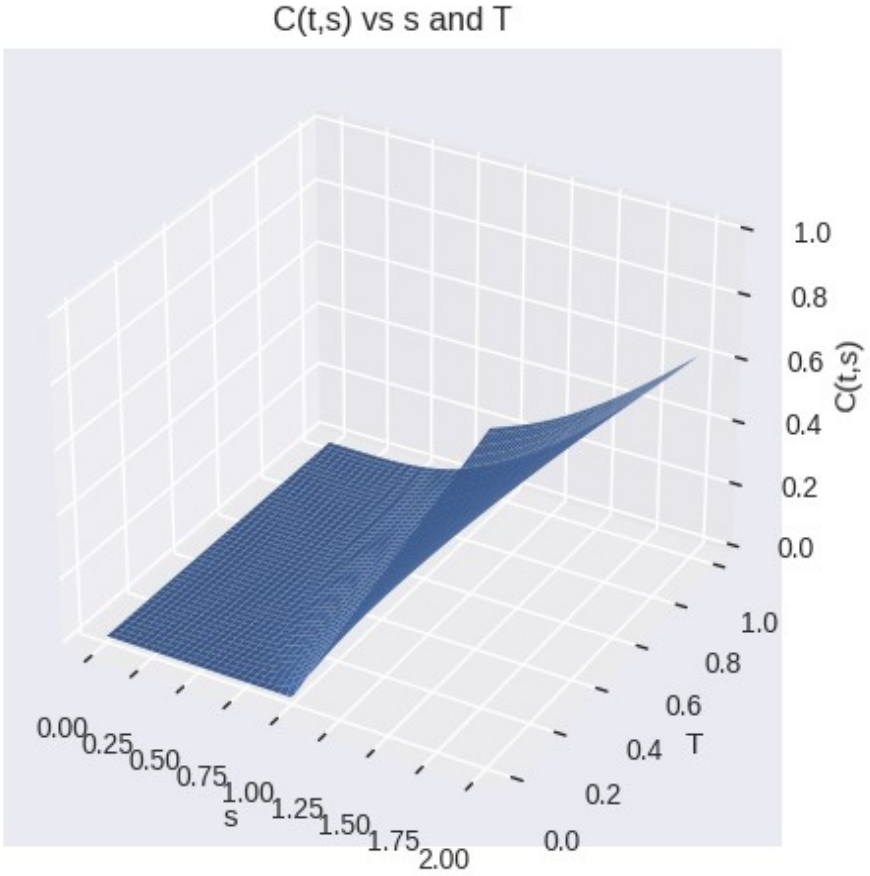
Surface plot of C(t,s) vs s and r



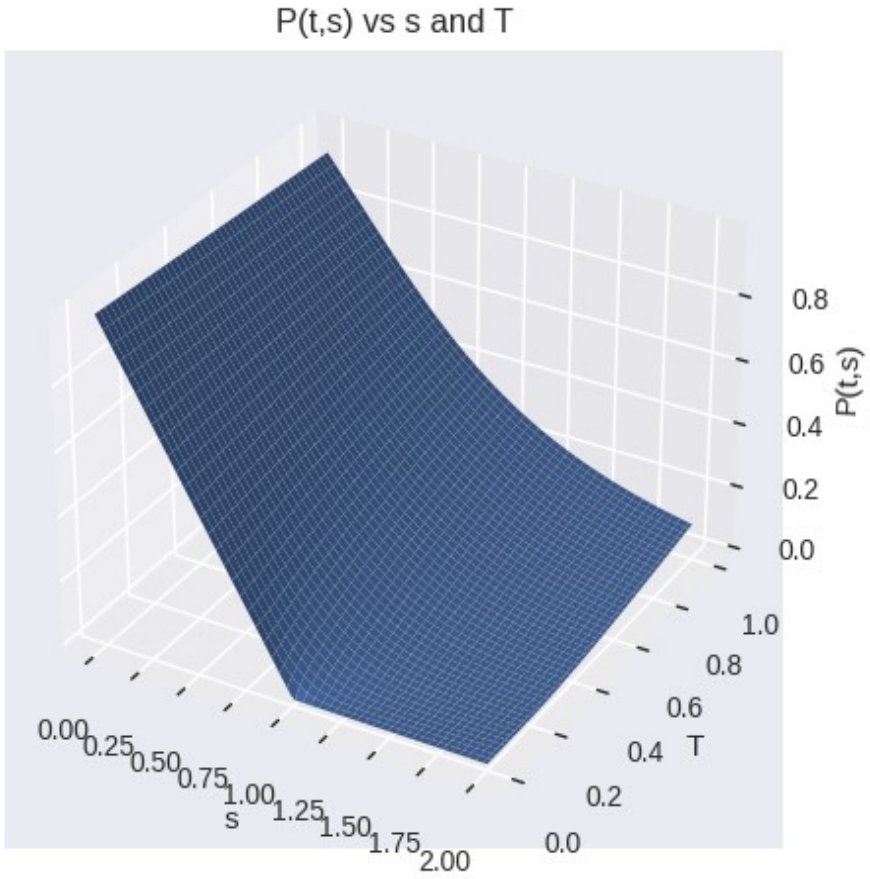
Surface plot of P(t,s) vs s and r



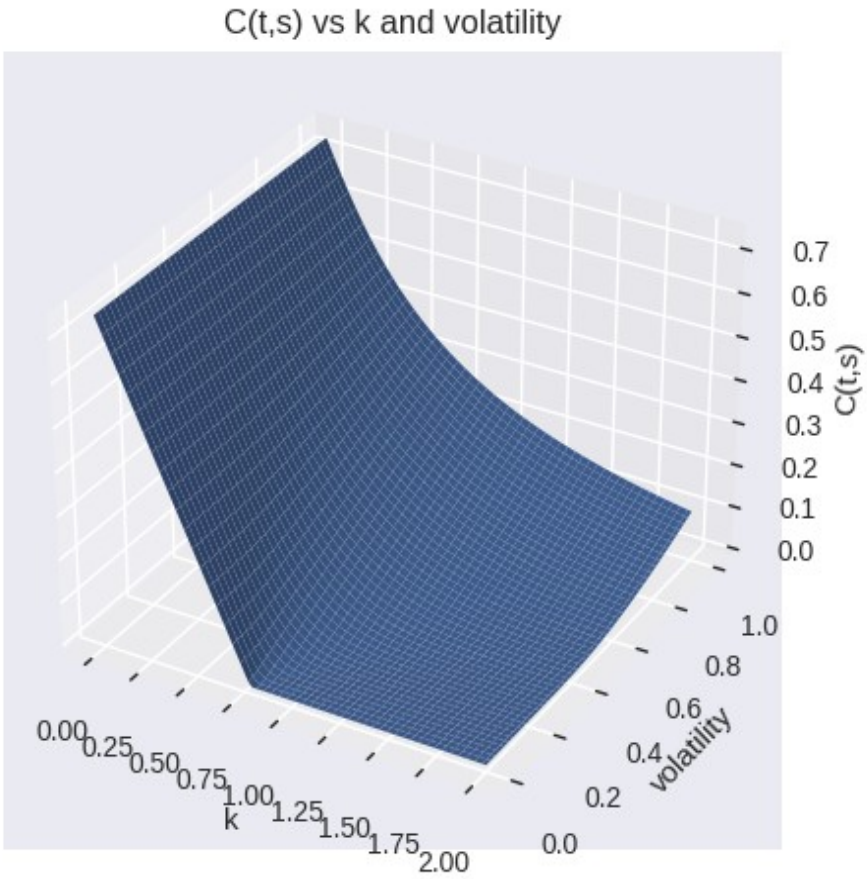
Surface plot of C(t,s) vs s and T



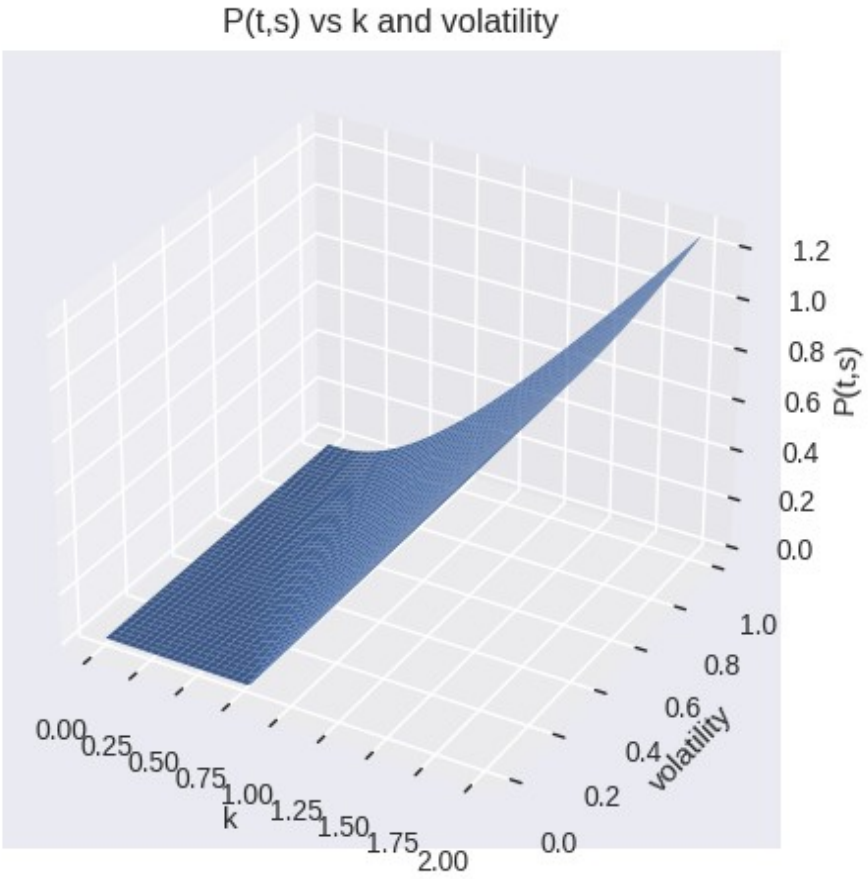
Surface plot of P(t,s) vs s and T



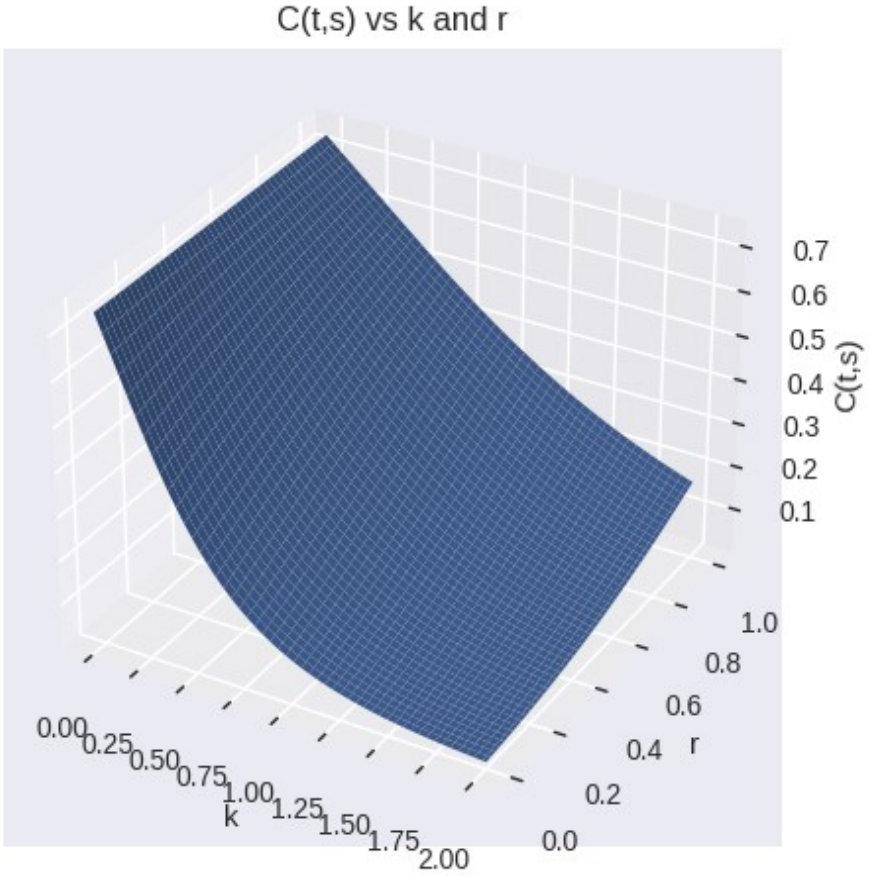
Surface plot of C(t,s) vs k and σ



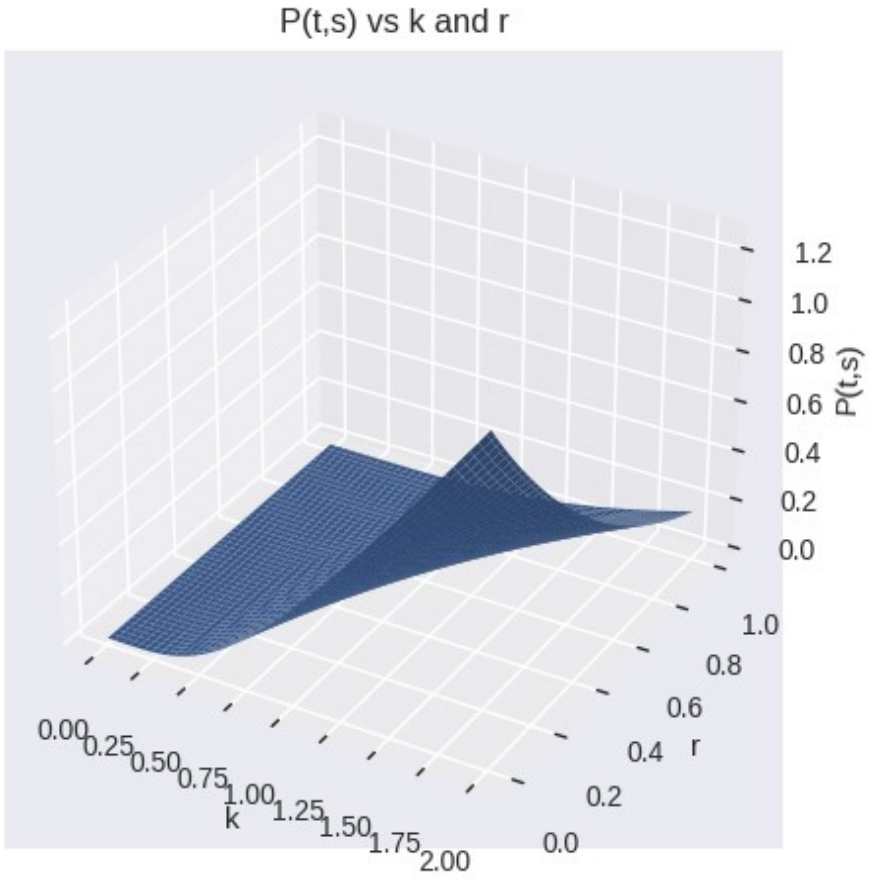
Surface plot of P(t,s) vs k and σ



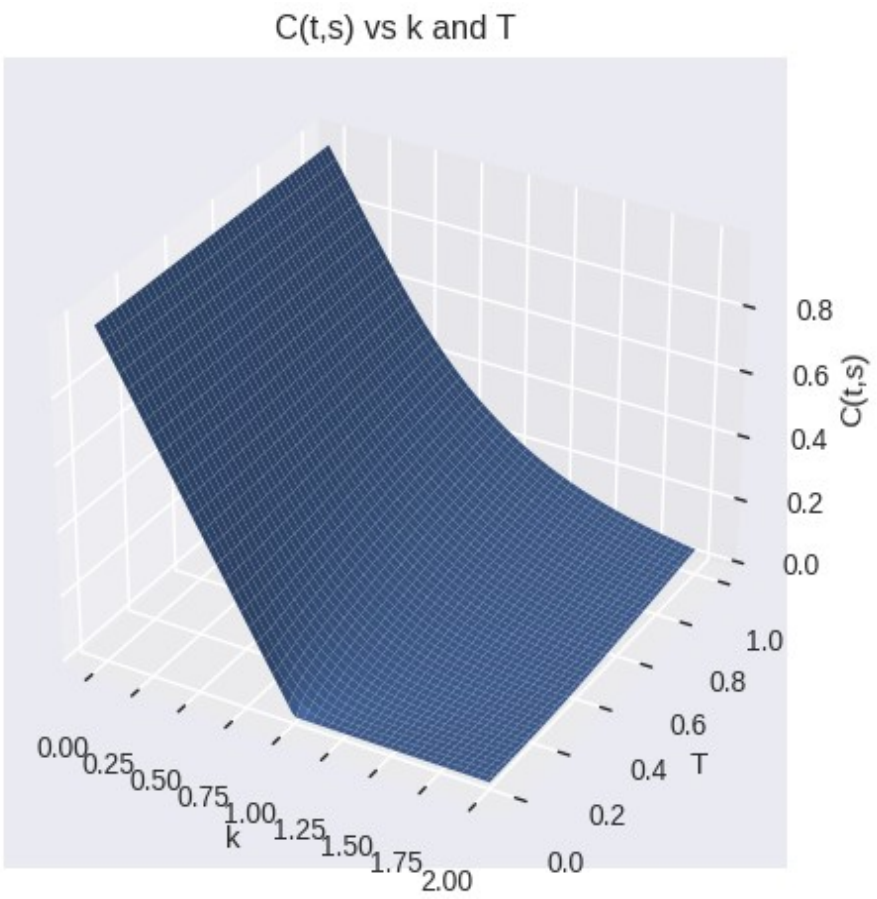
Surface plot of C(t,s) vs k and r



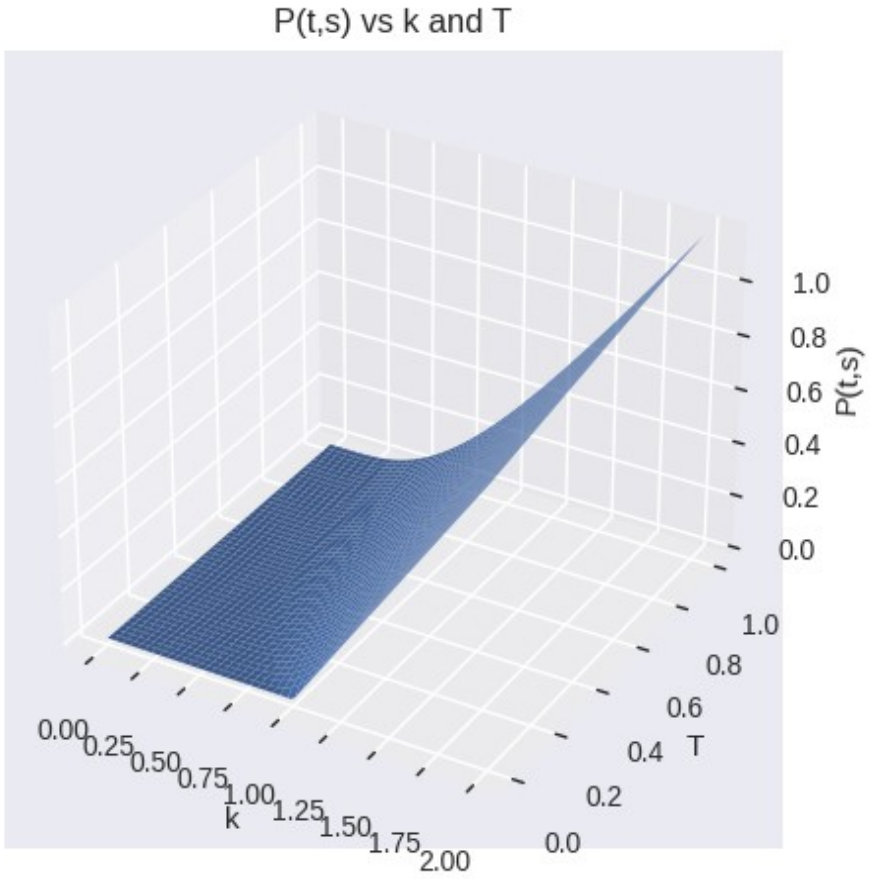
Surface plot of P(t,s) vs k and r



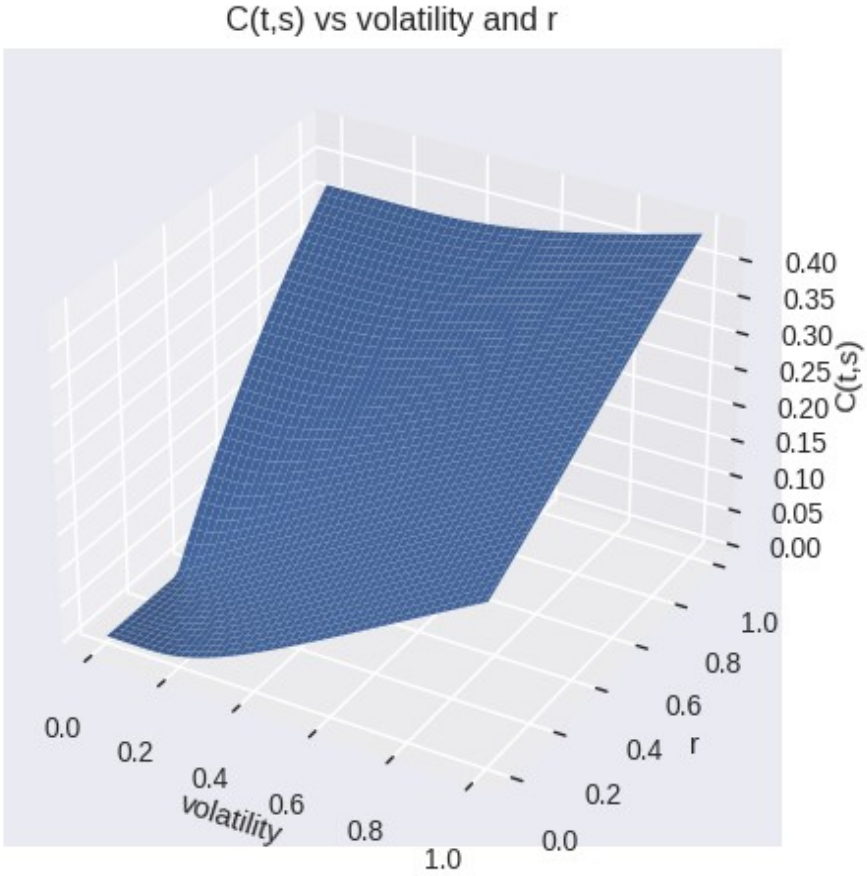
Surface plot of C(t,s) vs k and T



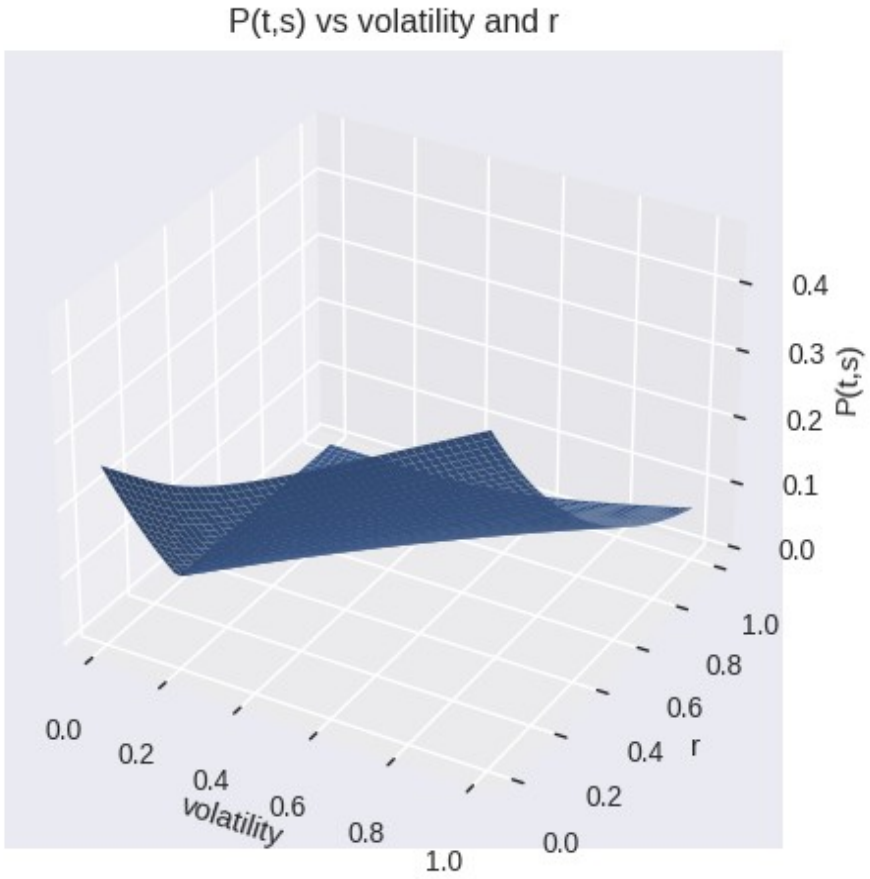
Surface plot of P(t,s) vs k and T



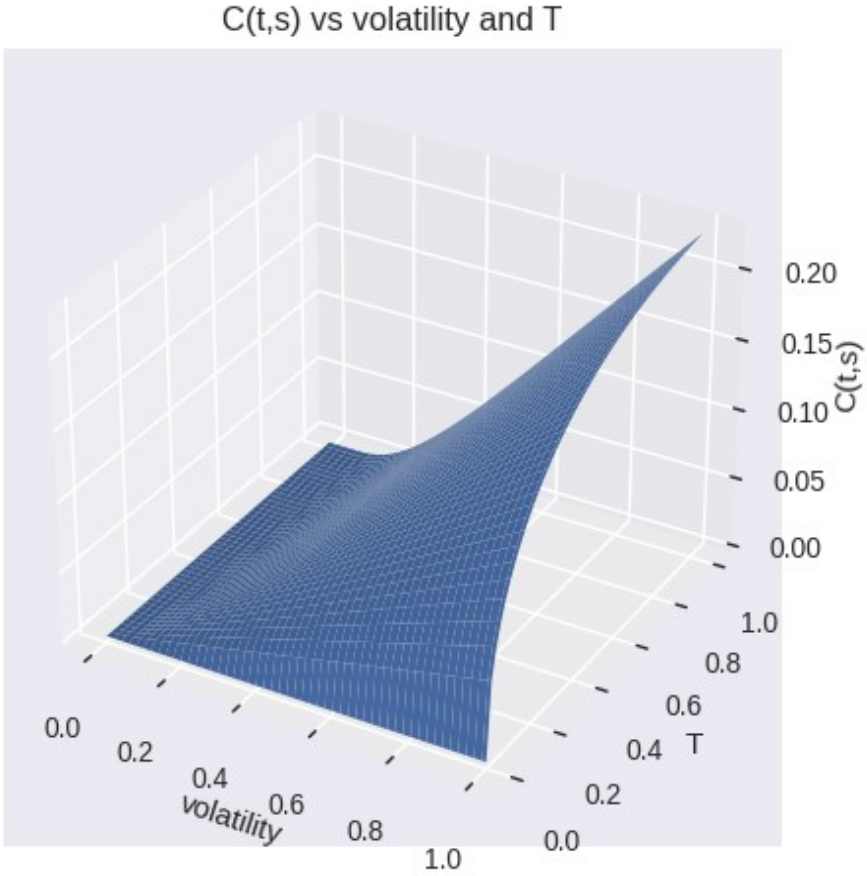
Surface plot of C(t,s) vs σ and r



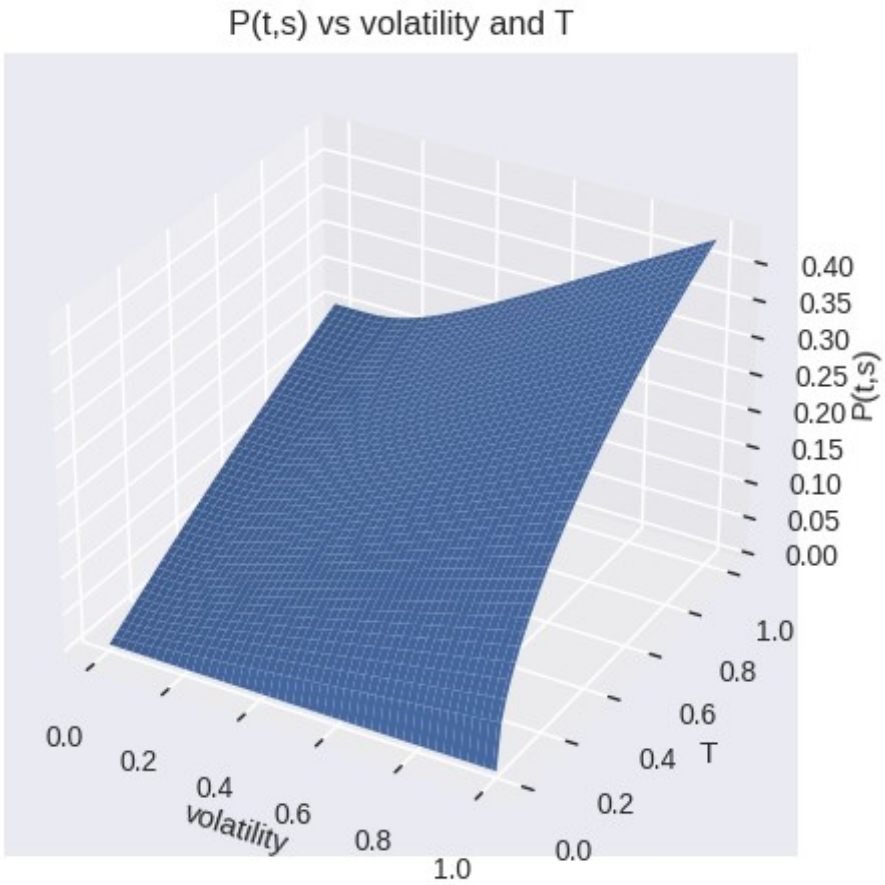
Surface plot of P(t,s) vs σ and r



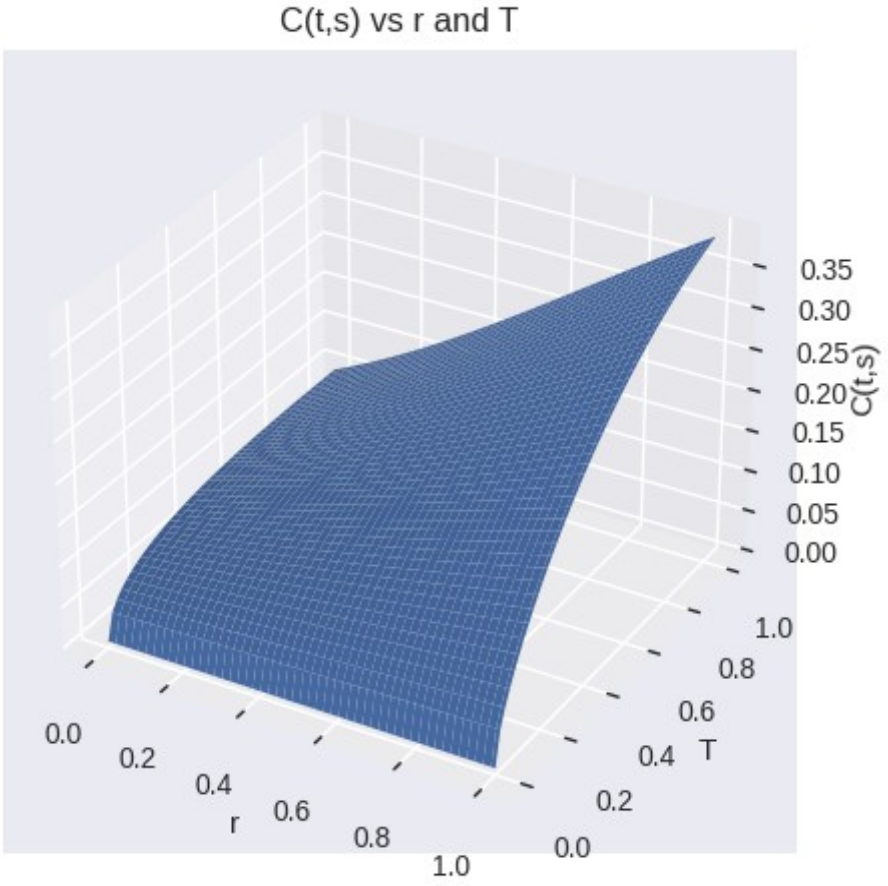
Surface plot of C(t,s) vs σ and T



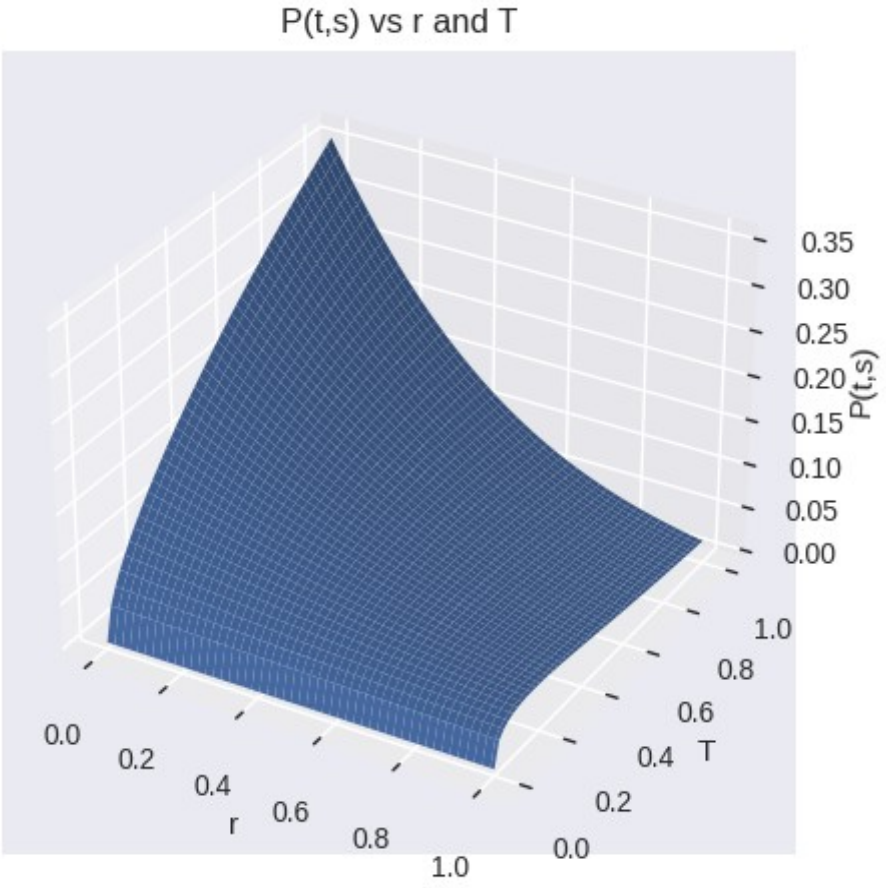
Surface plot of P(t,s) vs σ and T



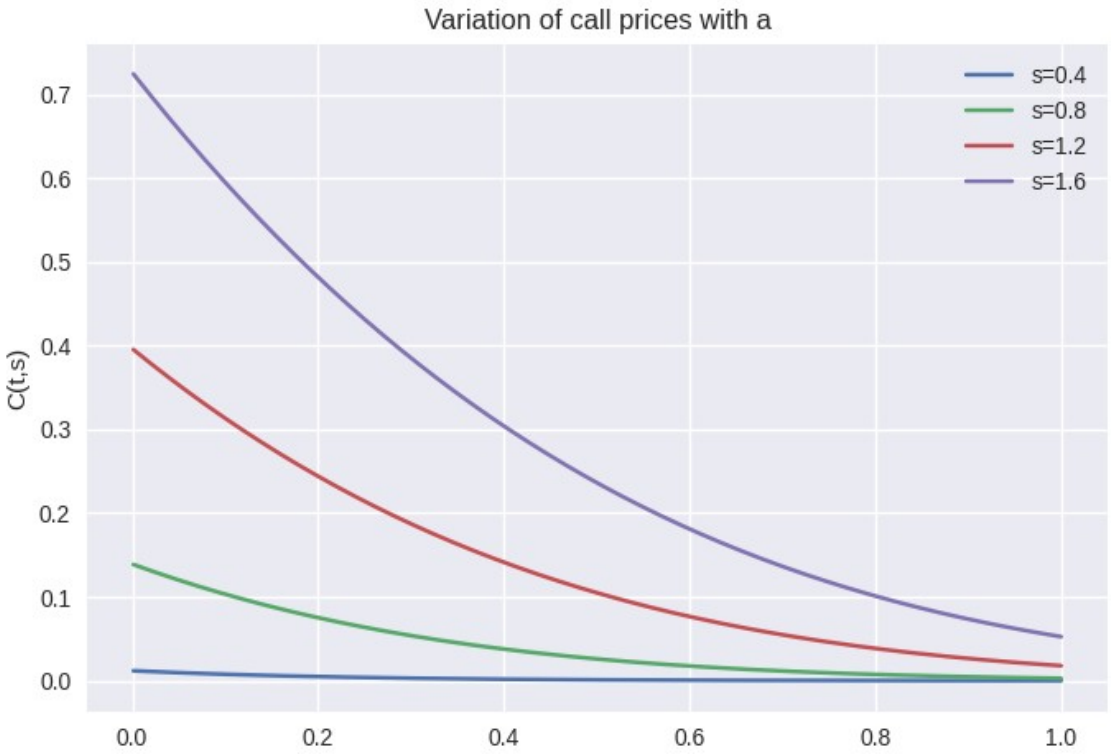
Surface plot of C(t,s) vs r and T



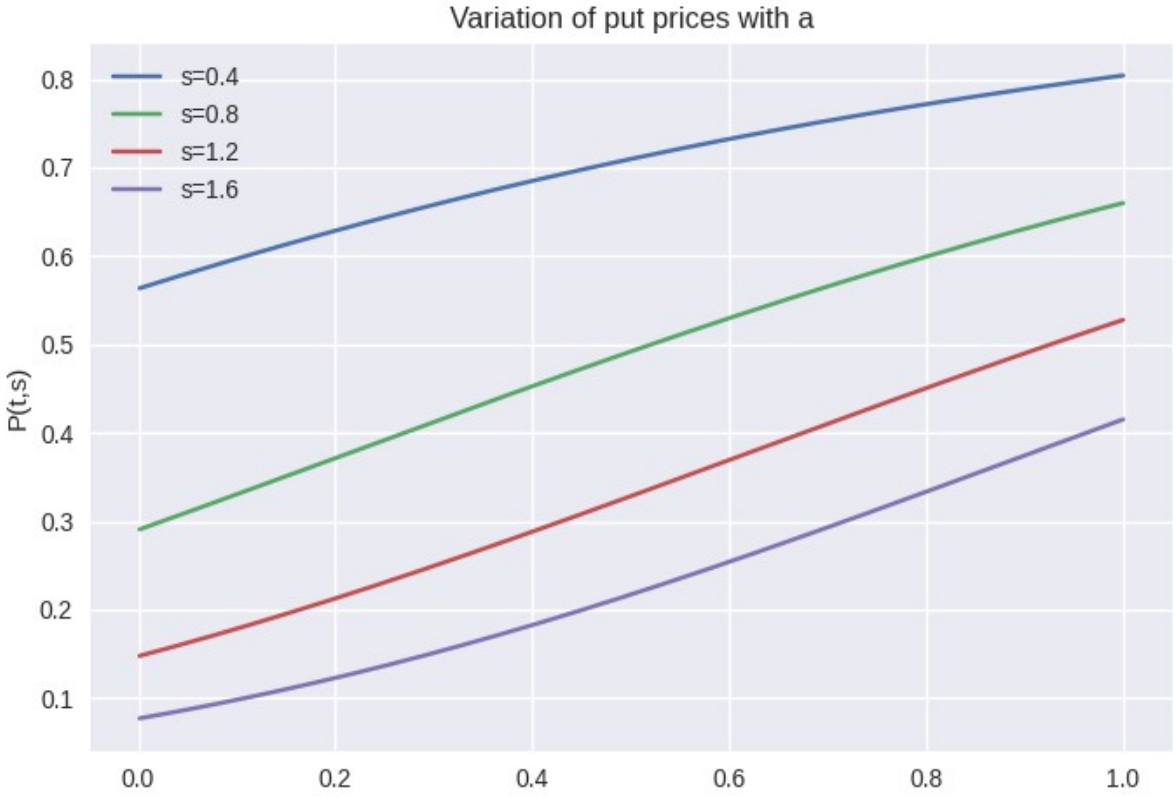
Surface plot of P(t,s) vs r and T



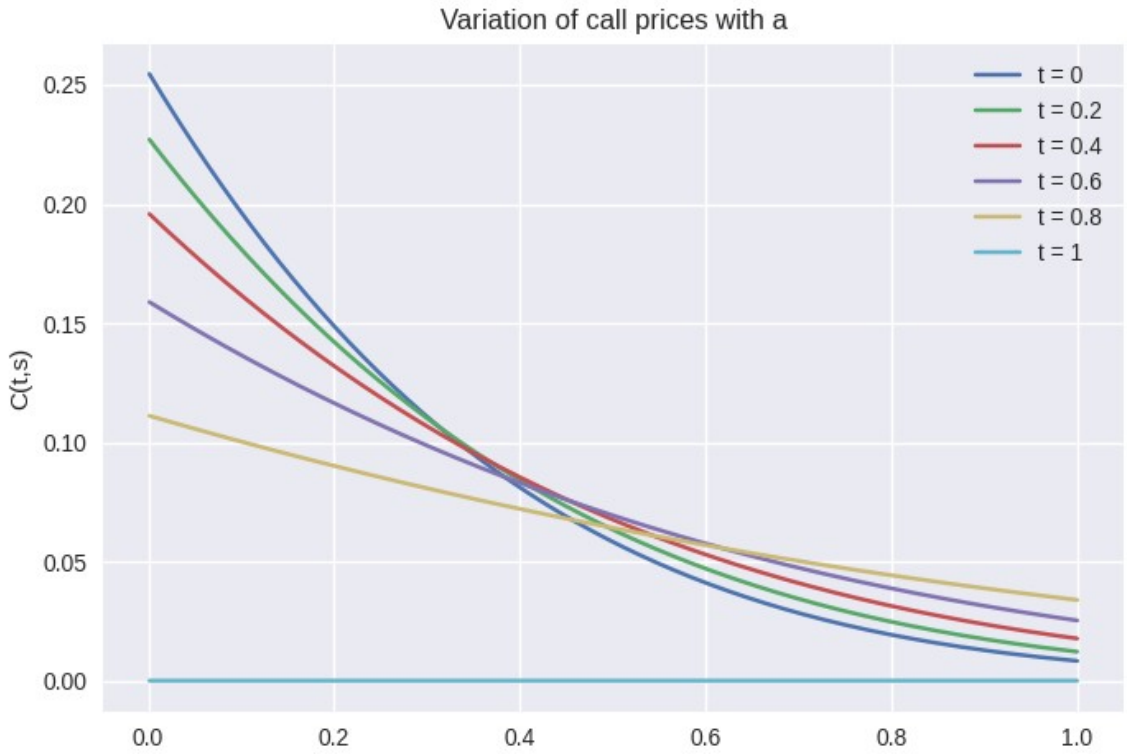
Plot of C(t,s) with a for different values of s



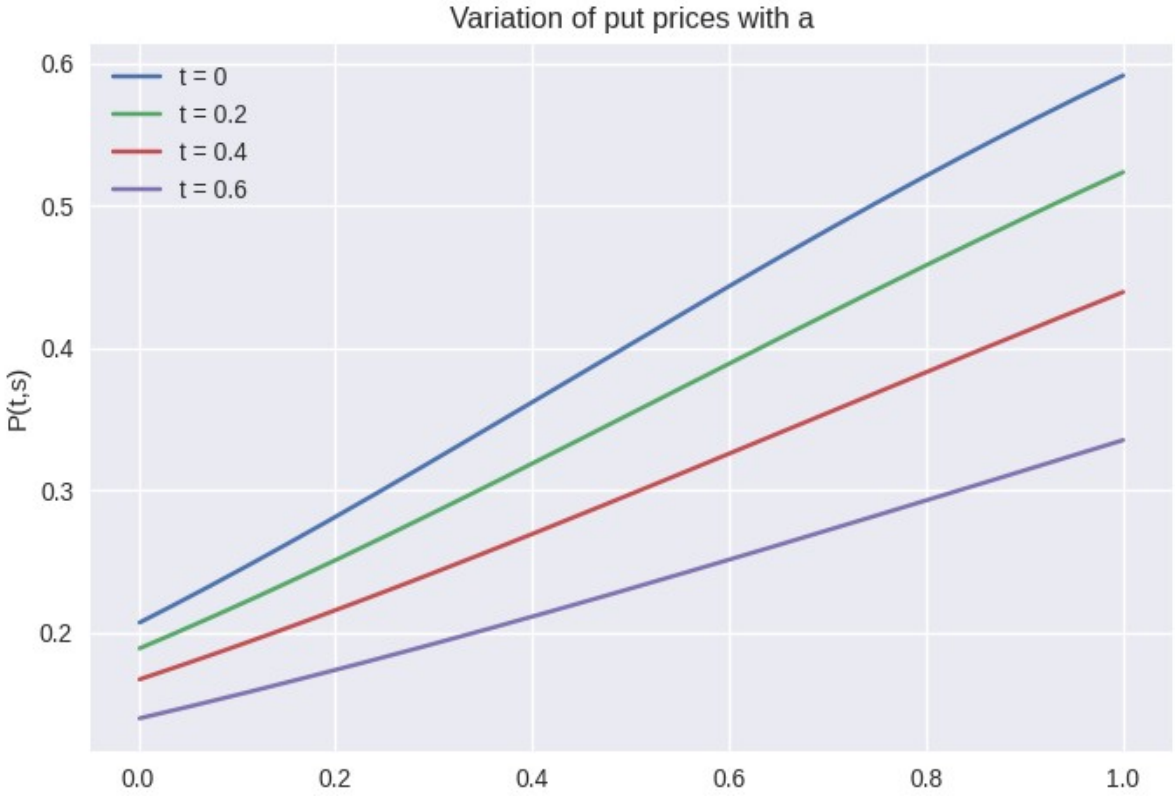
Plot of P(t,s) with a for different values of s



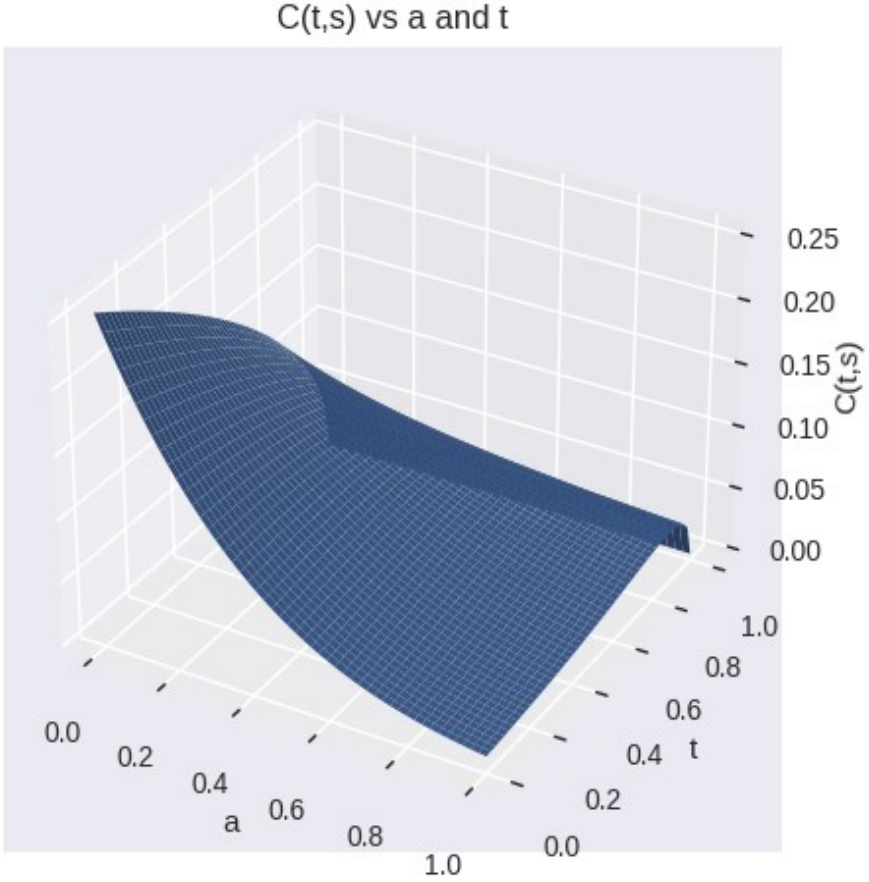
Plot of C(t,s) with a for different values of t



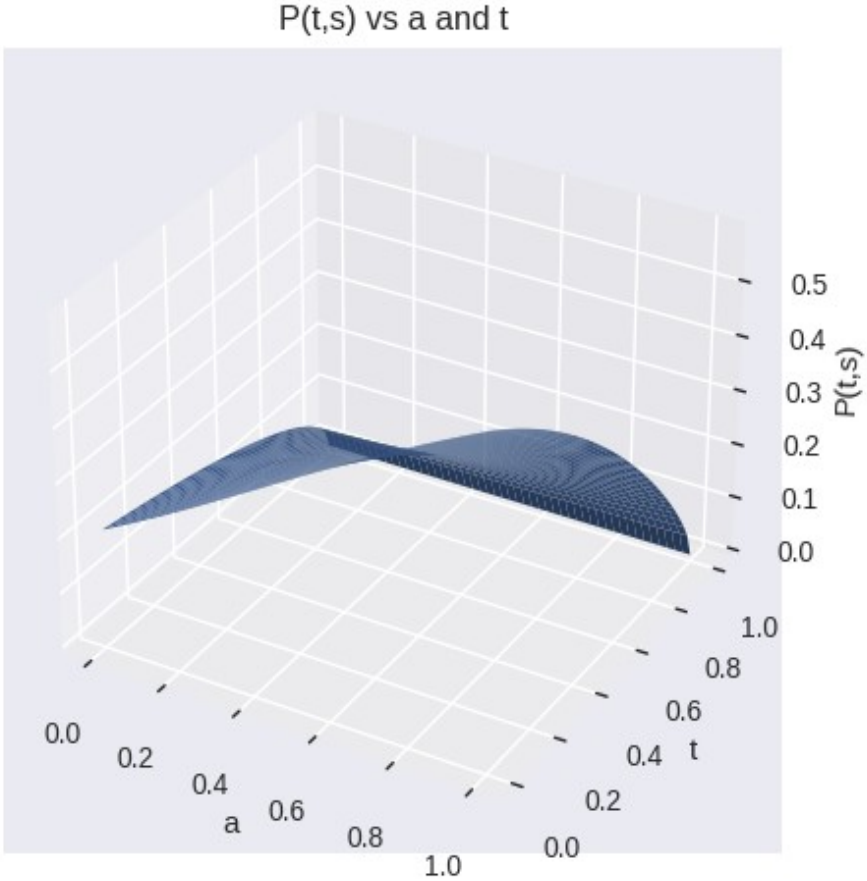
Plot of P(t,s) with a for different values of t



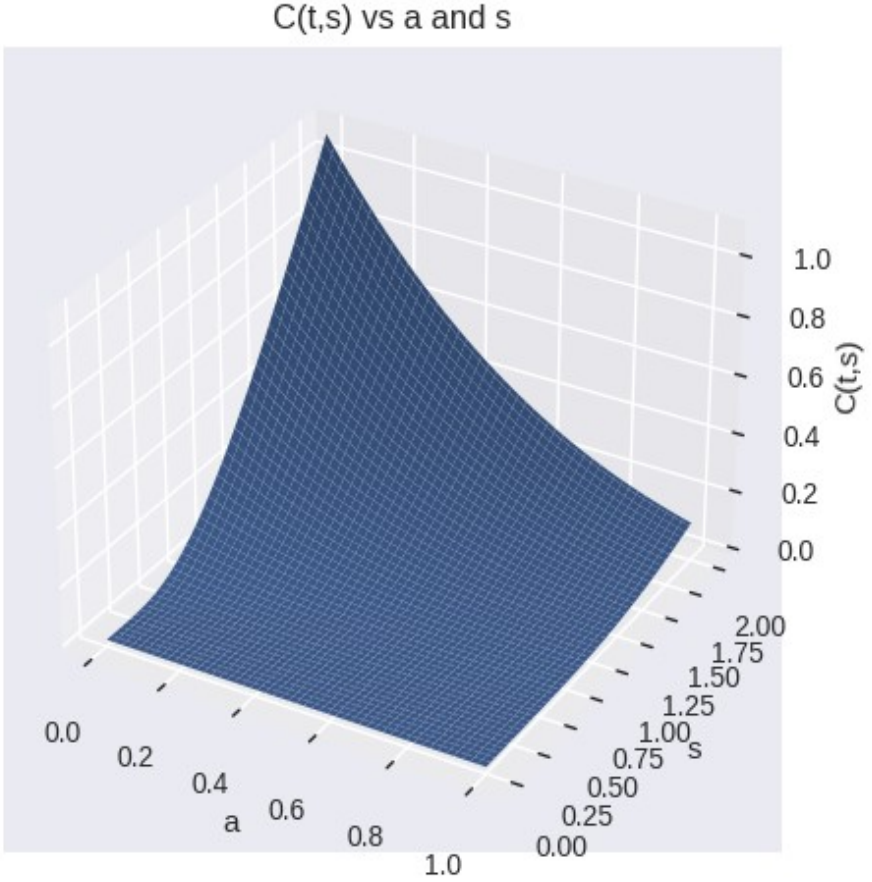
Surface plot of C(t,s) vs a and t



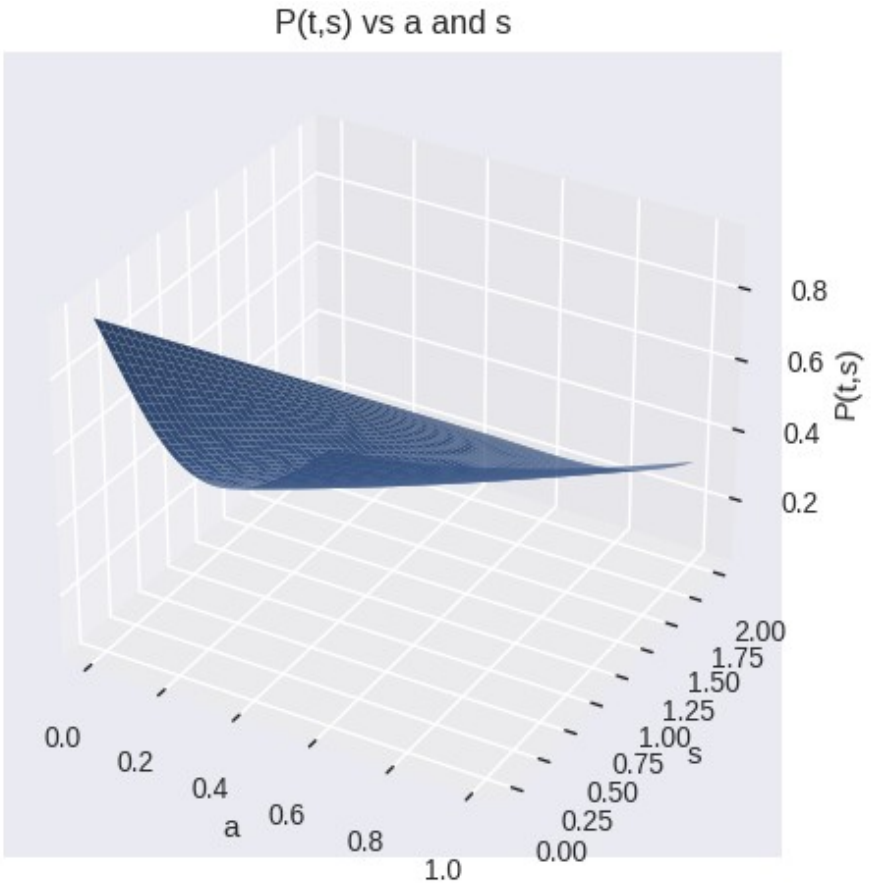
Surface plot of P(t,s) vs a and t



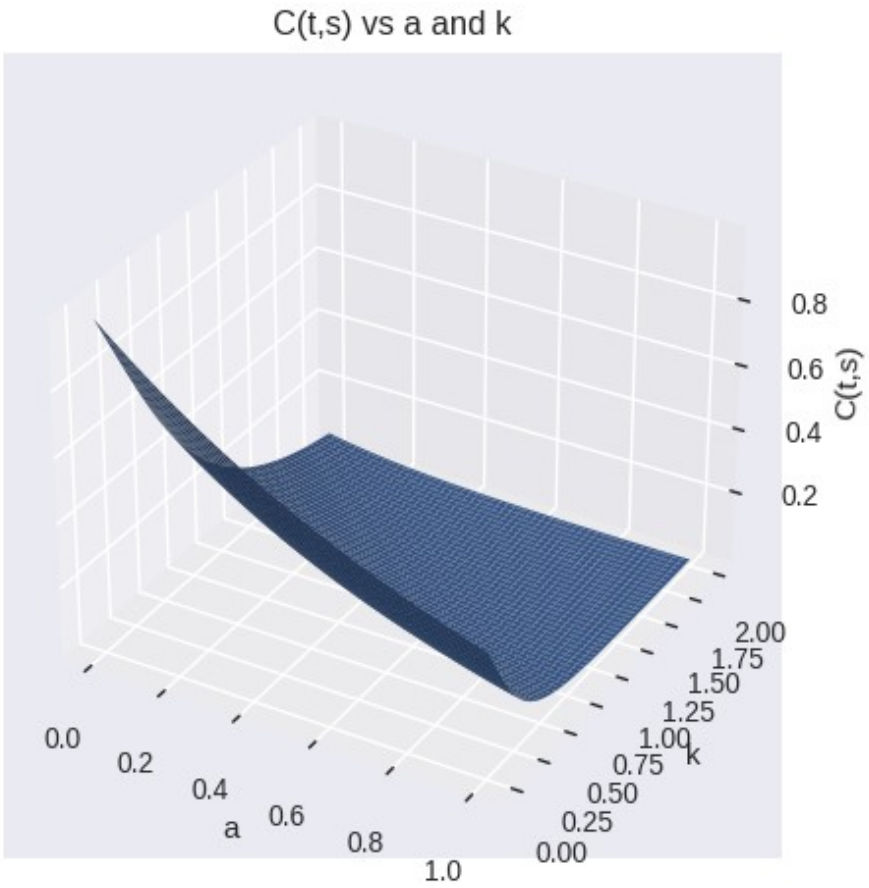
Surface plot of C(t,s) vs a and s



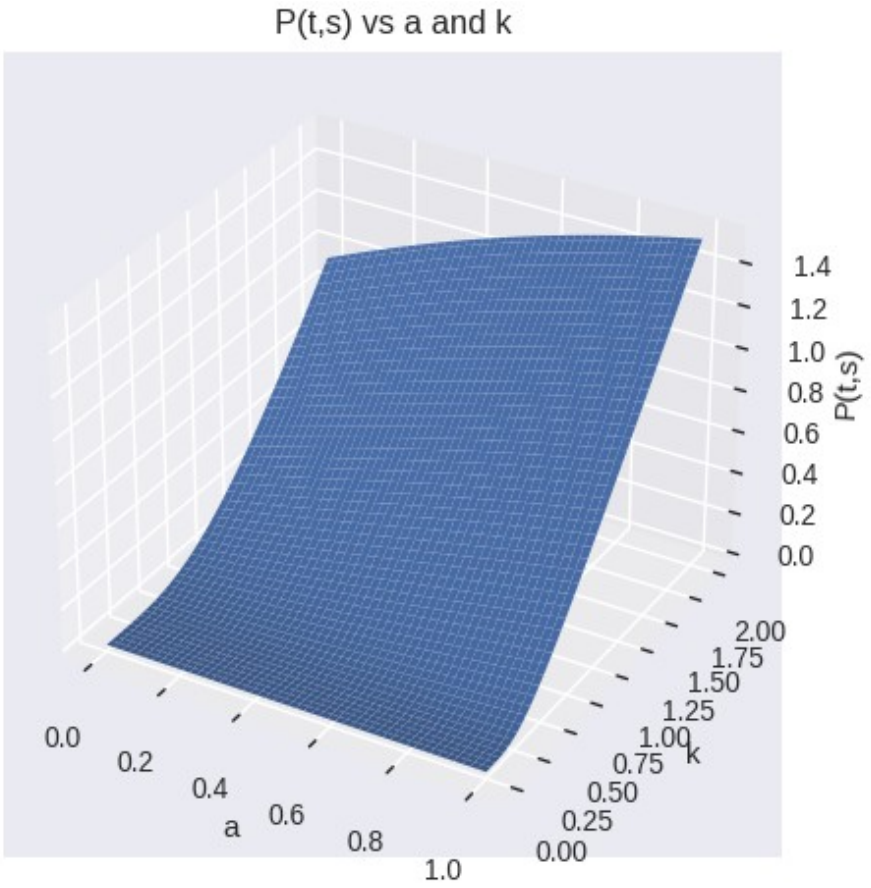
Surface plot of P(t,s) vs a and s



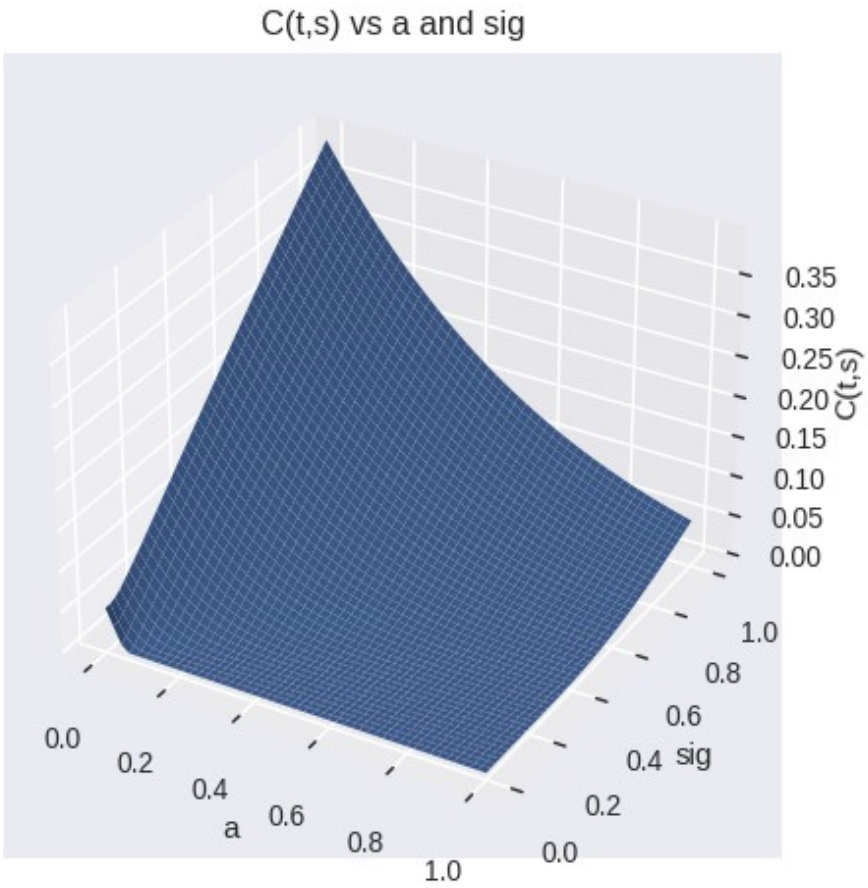
Surface plot of C(t,s) vs a and k



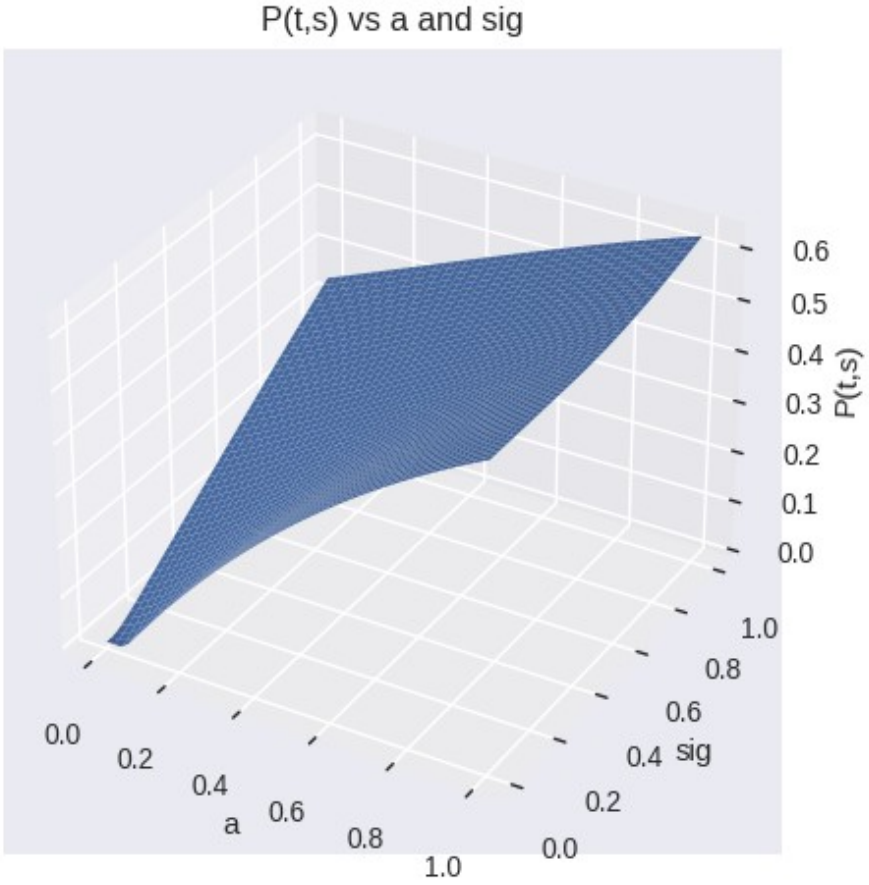
Surface plot of P(t,s) vs a and k



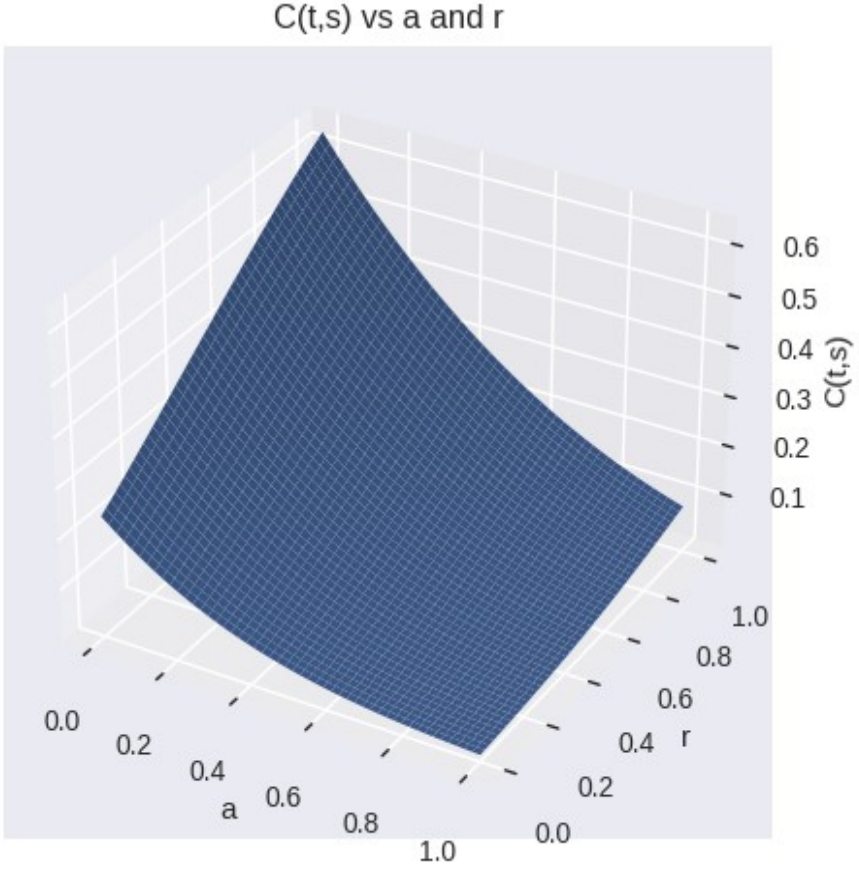
Surface plot of C(t,s) vs a and σ



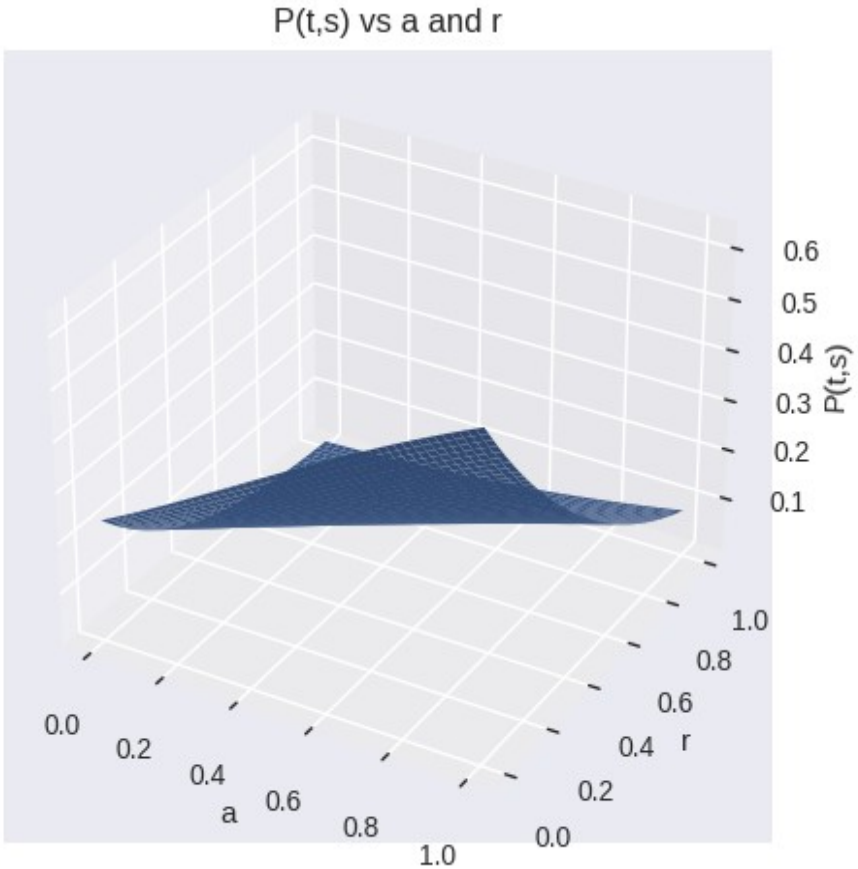
Surface plot of P(t,s) vs a and σ



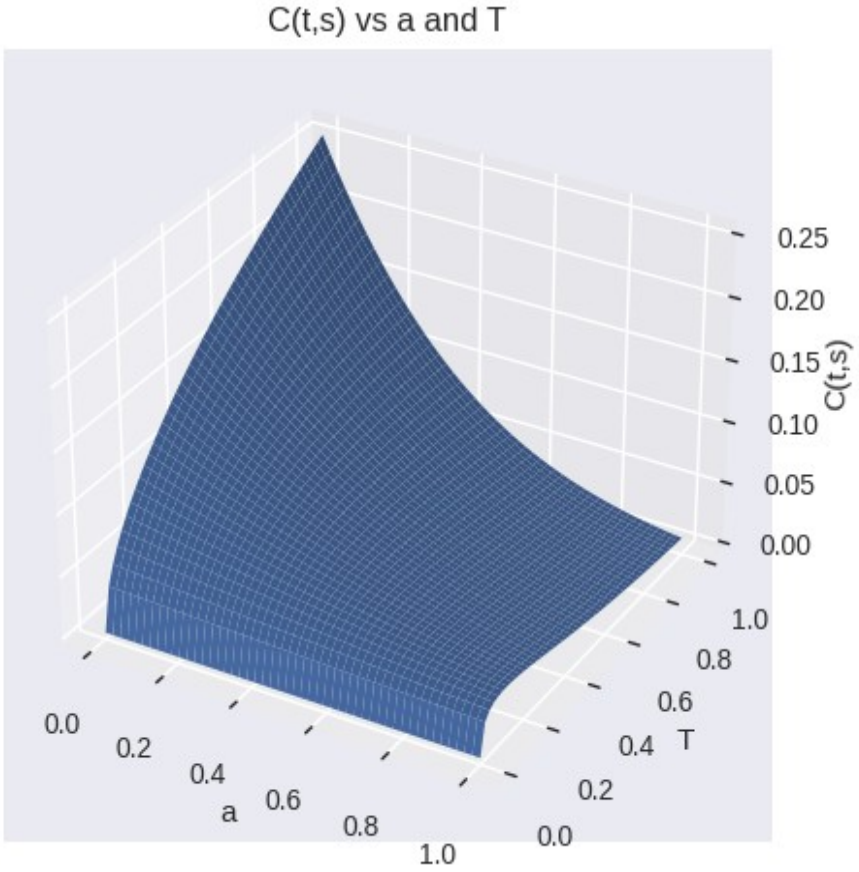
Surface plot of C(t,s) vs a and r



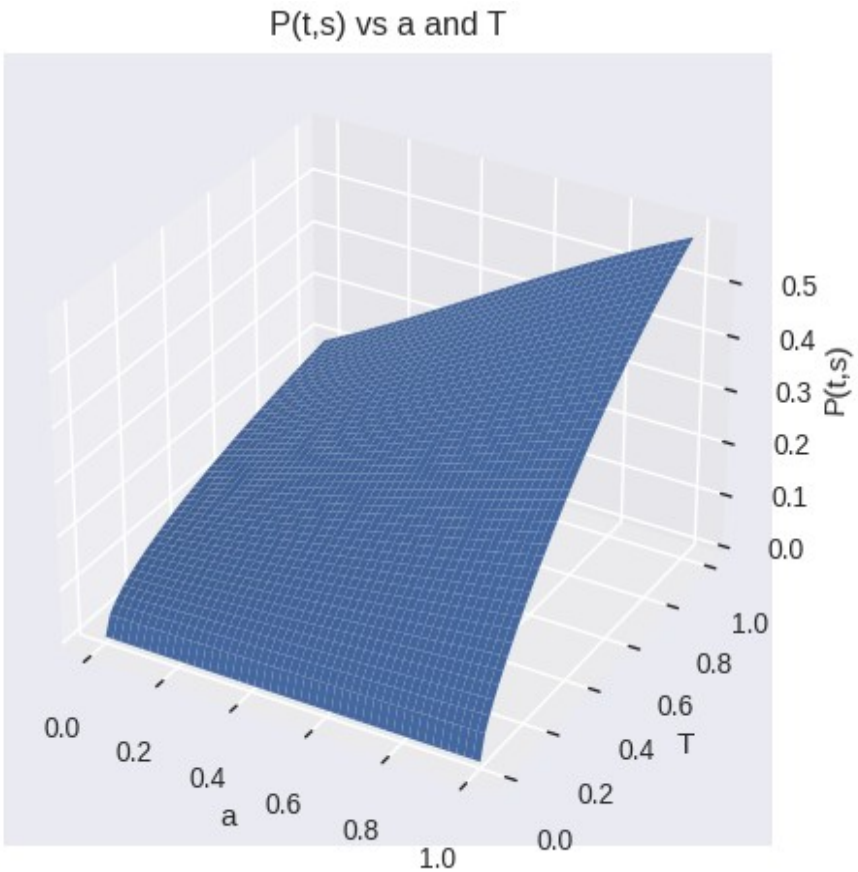
Surface plot of P(t,s) vs a and r



Surface plot of C(t,s) vs a and T



Surface plot of P(t,s) vs a and T



Tabulation of values

Table of prices with respect to different values of k:

	k	C(t,s)	P(t,s)
0	0.001000	0.739867	-5.171644e-17
1	0.040988	0.701829	8.550724e-09
2	0.200940	0.550579	9.009607e-04
3	0.400880	0.380451	2.096211e-02
4	0.600820	0.253118	8.381740e-02
5	0.800760	0.166905	1.877935e-01
6	1.000700	0.110608	3.216850e-01
7	1.400580	0.050320	6.417742e-01
8	1.600520	0.034644	8.162871e-01
9	1.800460	0.024179	9.960116e-01

Table of prices with respect to different values of volatility:

	volatility	C(t,s)	P(t,s)
0	0.001000	0.000000e+00	0.210411
1	0.020984	7.309929e-36	0.210411
2	0.100920	1.819762e-04	0.210593
3	0.200840	8.592727e-03	0.219004
4	0.300760	2.852118e-02	0.238932
5	0.400680	5.396452e-02	0.264376
6	0.500600	8.188293e-02	0.292294
7	0.700440	1.403815e-01	0.350793
8	0.800360	1.698758e-01	0.380287
9	0.900280	1.991463e-01	0.409558

Table of prices with respect to different values of r:

	r	C(t,s)	P(t,s)
0	0.001000	0.100049	0.358231
1	0.020984	0.104342	0.342758
2	0.100920	0.122573	0.285760
3	0.200840	0.147623	0.224848
4	0.300760	0.174917	0.174354
5	0.400680	0.204077	0.133123
6	0.500600	0.234649	0.099998
7	0.700440	0.298012	0.053561
8	0.800360	0.329787	0.038136
9	0.900280	0.360998	0.026636

Table of prices with respect to different values of a:

	a	C(t,s)	P(t,s)
0	0.001000	0.254583	0.206812
1	0.020984	0.241885	0.213879
2	0.100920	0.195905	0.243129
3	0.200840	0.148373	0.281559
4	0.300760	0.110510	0.321484
5	0.400680	0.080883	0.362248
6	0.500600	0.058129	0.403192
7	0.700440	0.028351	0.483213
8	0.800360	0.019216	0.521278
9	0.900280	0.012758	0.557532