Financial Derivatives
Lecture 5: Option trading strategies

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1 Option strategies

In this notebook, we will demonstrate how to use Python to construct payoff diagrams for option strategies. We need the numpy package for a few useful mathematical functions, the matplotlib package for plotting payoff diagrams, and the scipy package for statistical distributions.

[2]:

```
import numpy as np
import matplotlib.pyplot as plt
from scipy import stats
```

1.1 Specify option payoffs

In this section, we need to specify payoff functions for options using Python function (def).

[3]:

```
def call_payoff(S, K):
    payoff = np.maximum(S - K, 0)
    return payoff

def put_payoff(S, K):
    payoff = np.maximum(K - S, 0)
    return payoff

def digital_call_payoff(S, K):
    payoff = 1*(S>K)
    return payoff

def digital_put_payoff(S, K):
    payoff = 1*(S<K)
    return payoff
```

```
def risk_free_payoff(S, P):
    payoff = [P] * len(S)
    return payoff
```

1.2 Black-Scholes model

To estimate the profit and loss, we also have to specify the Black-Scholes option pricing model.

$$C_t = S\mathcal{N}(d_1) - K\exp^{-rt}\mathcal{N}(d_2)$$

$$P_t = K\exp^{-rt}\mathcal{N}(-d_2) - S\mathcal{N}(-d_1)$$

$$d_1 = \frac{\ln(\frac{S}{K}) + (r + \frac{1}{2}\sigma^2)t}{\sigma\sqrt{t}}$$

$$d_2 = d_1 - \sigma\sqrt{t}$$

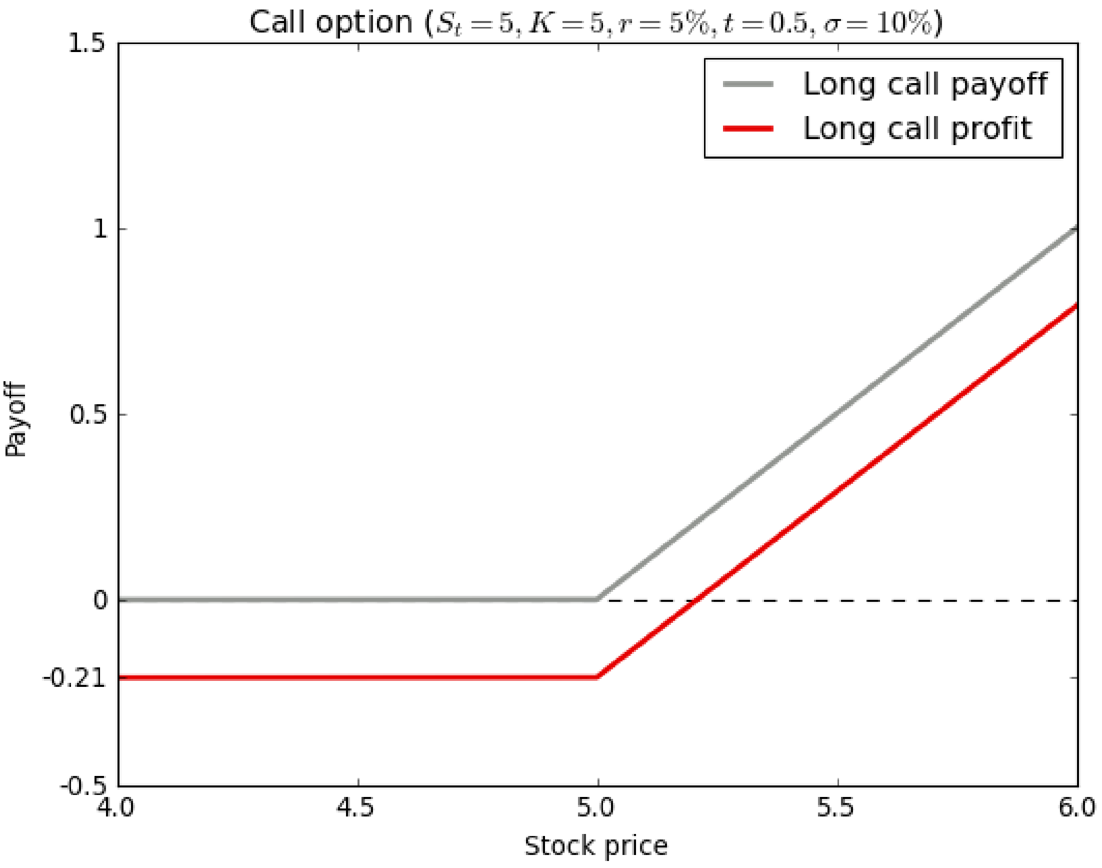
[4]:

```
def BS_call(S, K, r, t, Sigma):
    d1 = (np.log(S/K) + (r + 0.5 * Sigma**2)*t)/(Sigma * np.sqrt(t))
    d2 = d1 - Sigma * np.sqrt(t)
    Call = S * stats.norm.cdf(d1,0.0,1.0) - K * np.exp(-r*t) * stats.norm.cdf(d2,0.0,1.0)
    return Call

def BS_put(S, K, r, t, Sigma):
    d1 = (np.log(S/K) + (r + 0.5 * Sigma**2)*t)/(Sigma * np.sqrt(t))
    d2 = d1 - Sigma * np.sqrt(t)
    Put = K * np.exp(-r*t) * stats.norm.cdf(-d2,0.0,1.0) - S * stats.norm.cdf(-d1,0.0,1.0)
    return Put
```

1.3 Payoff and profit diagram for call option

[9]:

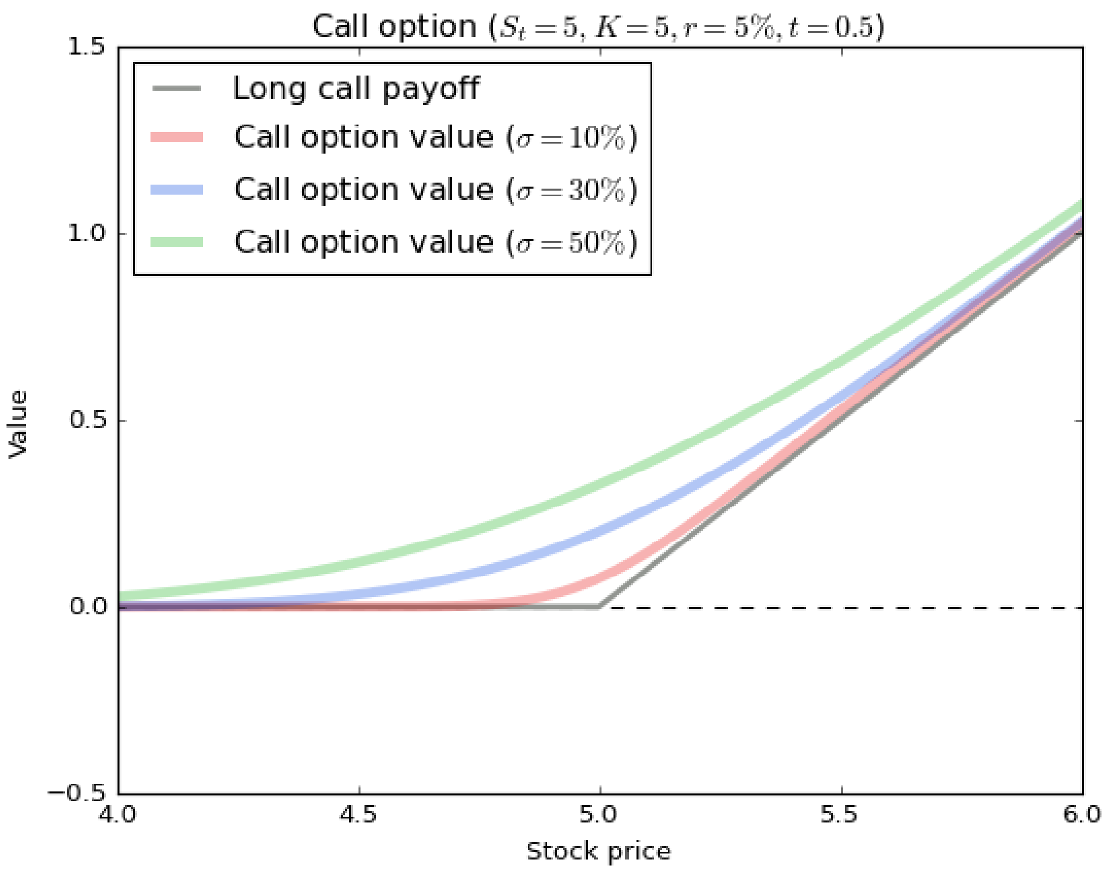
```
plt.style.use('classic')

S_t = 5
K = 5
r = 0.05
t = 0.5
Sigma = 0.1
Call_price = BS_call(S_t, K, r, t, Sigma)

S = np.linspace(0.0001, S_t*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Call option ($S_t = 5, K = 5, r = 5\%, t = 0.5, \sigma = 10\%$)')
plt.ylabel('Payoff')
plt.xlabel('Stock price')

plt.plot(S, call_payoff(S, K), color='xkcd:gray', linewidth=2.5)
plt.plot(S, call_payoff(S, K) - Call_price, color='xkcd:red', linewidth=2.5)
plt.yticks([-0.5, -Call_price, 0, 0.5, 1, 1.5], ['-0.5',␣
  ↪str(-round(Call_price,2)), '0', '0.5', '1', '1.5'])
plt.xlim(4,6)
plt.ylim(-0.5,1.5)
plt.legend(['Long call payoff', 'Long call profit'], loc='best')
#plt.savefig('call_payoff.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.4 Volatility and option value

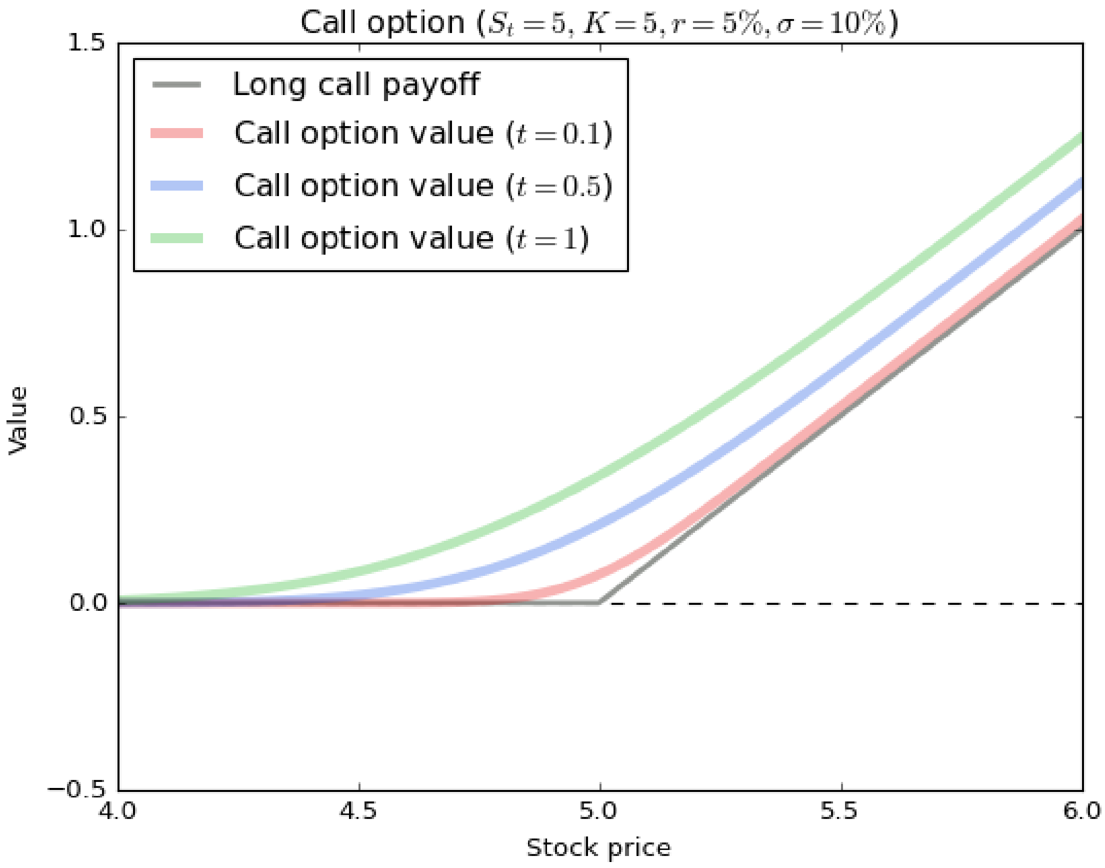
[5]:

```
plt.style.use('classic')

S_t = 5
K = 5
r = 0.05
t = 0.5
Sigma = 0.1
Call_price = BS_call(S_t, K, r, t, Sigma)

S = np.linspace(0.0001, S_t*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Call option ($S_t = 5, K = 5, r = 5\%, t = 0.5$)')
plt.ylabel('Value')
plt.xlabel('Stock price')

plt.plot(S, call_payoff(S, K), color='xkcd:gray', linewidth=2.5)
plt.plot(S, BS_call(S, K, r, 0.1, Sigma), color='xkcd:red', linewidth=4.5,␣
 ↪alpha=0.3)
plt.plot(S, BS_call(S, K, r, 0.1, 0.3), color='xkcd:blue', linewidth=4.5,␣
 ↪alpha=0.3)
plt.plot(S, BS_call(S, K, r, 0.1, 0.5), color='xkcd:green', linewidth=4.5,␣
 ↪alpha=0.3)

plt.xlim(4,6)
plt.ylim(-0.5,1.5)
plt.legend(['Long call payoff', 'Call option value ($\sigma=10\%$)', 'Call␣
 ↪option value ($\sigma=30\%$)',
            'Call option value ($\sigma=50\%$)'], loc='best')
#plt.savefig('call_vola.png', bbox_inches="tight", dpi=600)
plt.show()
```



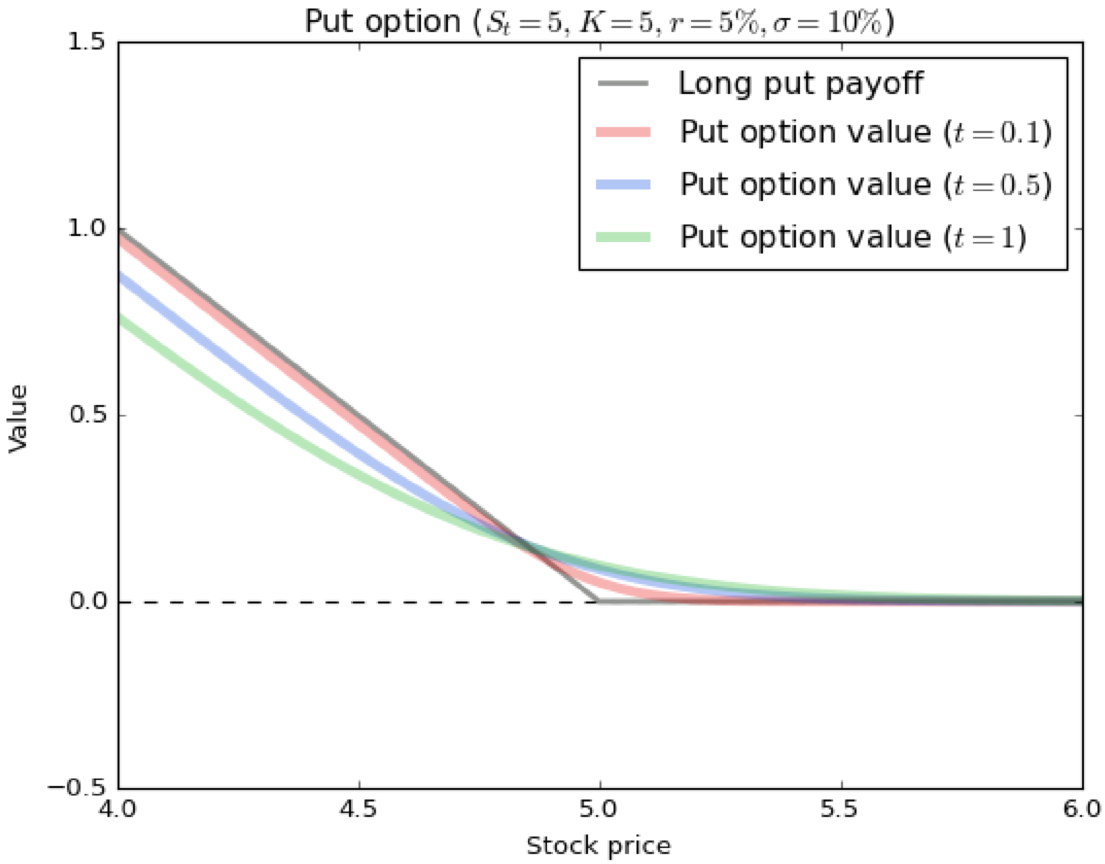
1.5 Time to maturity and option value

[6]:
```
plt.style.use('classic')

S_t = 5
K = 5
r = 0.05
t = 0.5
Sigma = 0.1
Call_price = BS_call(S_t, K, r, t, Sigma)

S = np.linspace(0.0001, S_t*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Call option ($S_t = 5, K = 5, r = 5\%, \sigma = 10\%$)')
plt.ylabel('Value')
plt.xlabel('Stock price')
plt.plot(S, call_payoff(S, K), color='xkcd:gray', linewidth=2.5)
plt.plot(S, BS_call(S, K, r, 0.1, Sigma), color='xkcd:red', linewidth=4.5,␣
 ↪alpha=0.3)
plt.plot(S, BS_call(S, K, r, 0.5, Sigma), color='xkcd:blue', linewidth=4.5,␣
 ↪alpha=0.3)
plt.plot(S, BS_call(S, K, r, 1, Sigma), color='xkcd:green', linewidth=4.5,␣
 ↪alpha=0.3)

plt.xlim(4,6)
plt.ylim(-0.5,1.5)
plt.legend(['Long call payoff', 'Call option value ($t=0.1$)', 'Call option␣
 ↪value ($t=0.5$)',
            'Call option value ($t=1$)'], loc='best')
#plt.savefig('call_ttm.png', bbox_inches="tight", dpi=600)
plt.show()
```



[7]:

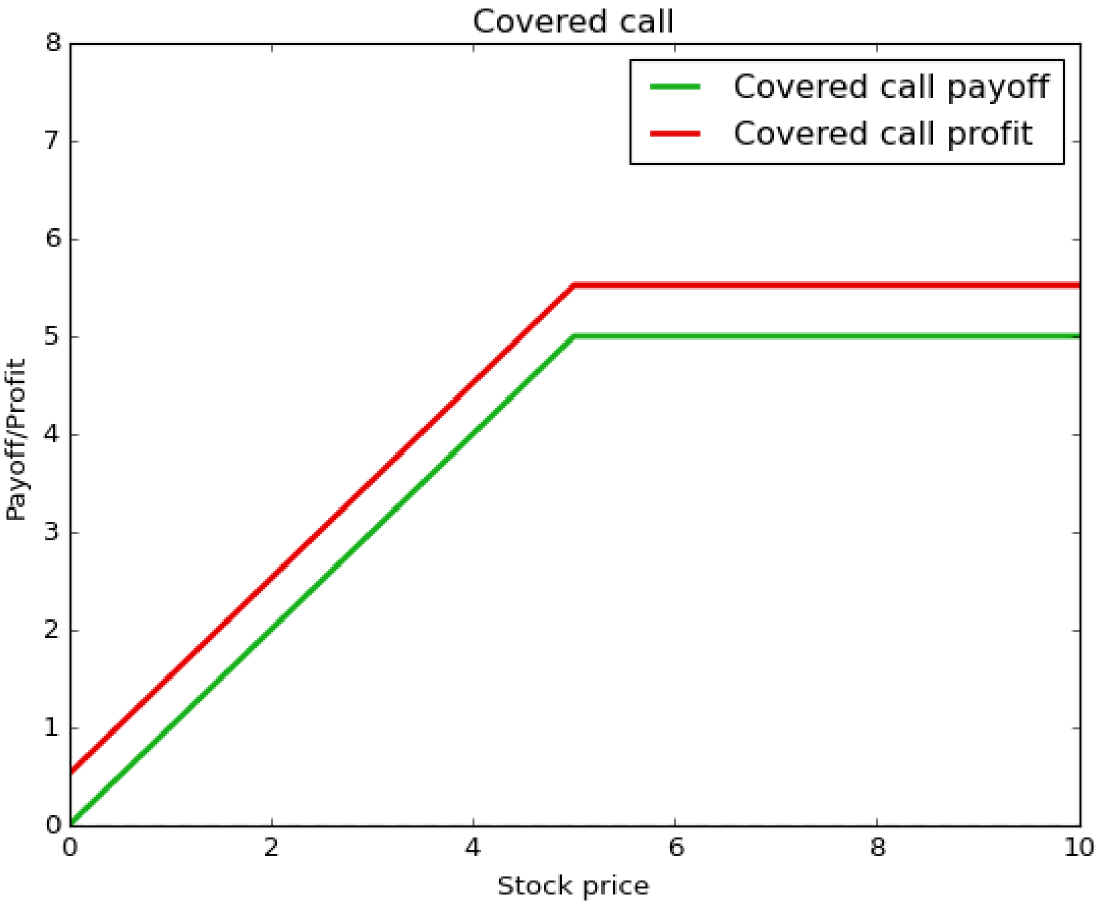
```
plt.style.use('classic')

S_t = 5
K = 5
r = 0.05
t = 0.5
Sigma = 0.1
S = np.linspace(0.0001, S_t*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Put option ($S_t = 5, K = 5, r = 5\%, \sigma = 10\%$)')
plt.ylabel('Value')
plt.xlabel('Stock price')

plt.plot(S, put_payoff(S, K), color='xkcd:gray', linewidth=2.5)
plt.plot(S, BS_put(S, K, r, 0.1, Sigma), color='xkcd:red', linewidth=4.5, alpha=0.3)
plt.plot(S, BS_put(S, K, r, 0.5, Sigma), color='xkcd:blue', linewidth=4.5, alpha=0.3)
plt.plot(S, BS_put(S, K, r, 1, Sigma), color='xkcd:green', linewidth=4.5, alpha=0.3)

plt.xlim(4,6)
plt.ylim(-0.5,1.5)
plt.legend(['Long put payoff', 'Put option value ($t=0.1$)', 'Put option value ($t=0.5$)',
            'Put option value ($t=1$)'], loc='best')
#plt.savefig('put_ttm.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.6 Covered calls

[8]:
```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Covered call')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = S - call_payoff(S, 5)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
```

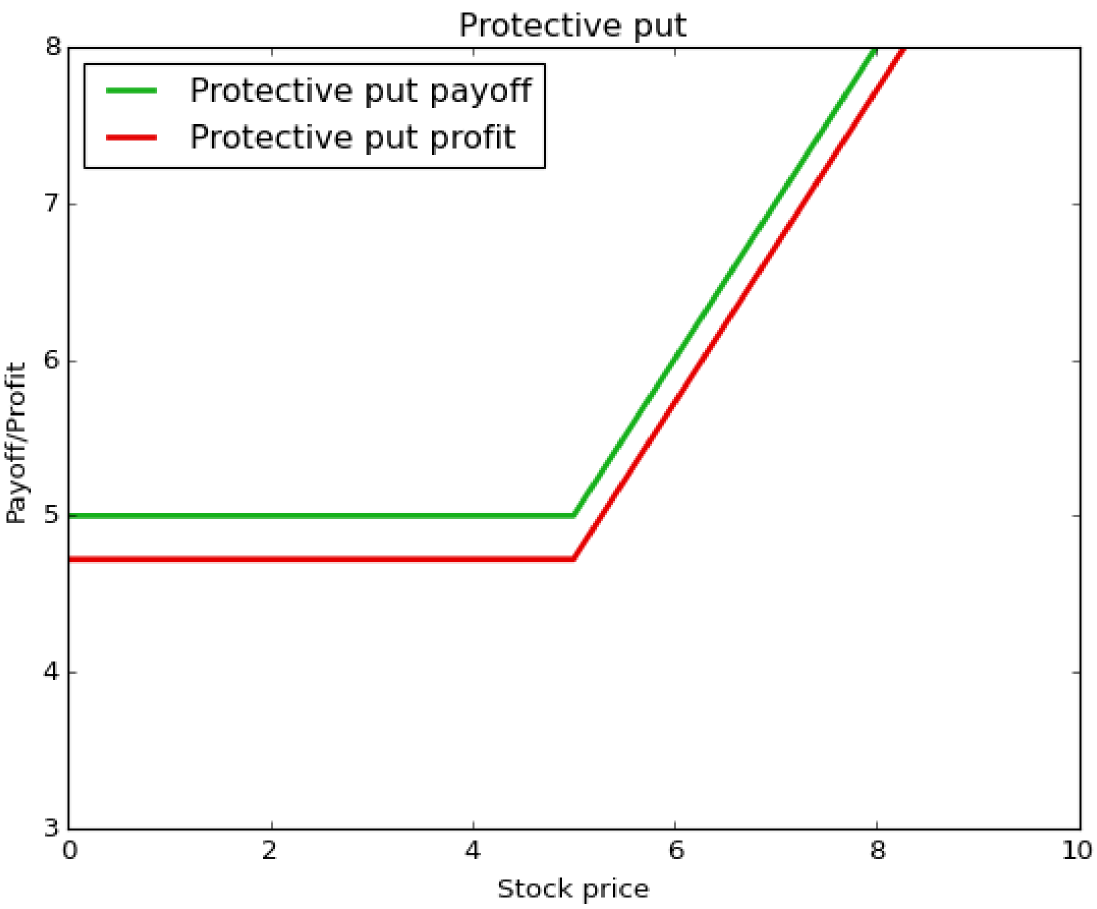
```
t = 1
Sigma = 0.2

Cost = -BS_call(S_t, 5, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(0,8)
plt.legend(['Covered call payoff', 'Covered call profit'], loc='best')
#plt.savefig('Covered_call.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.7 Protective puts

[9]:

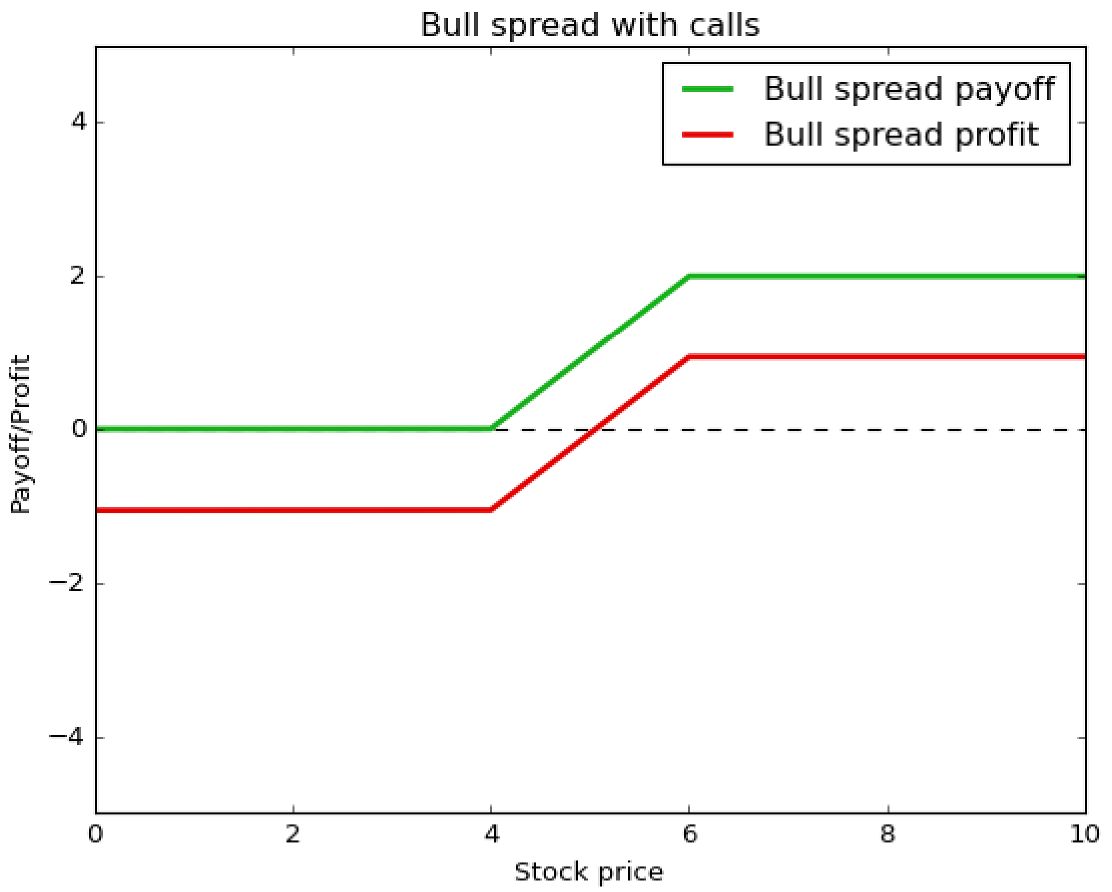
```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Protective put')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = S + put_payoff(S, 5)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 1
Sigma = 0.2

Cost = BS_put(S_t, 5, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(3,8)
plt.legend(['Protective put payoff', 'Protective put profit'], loc='best')
#plt.savefig('Protective_put.png', bbox_inches="tight", dpi=600)
plt.show()
```


Protective put
Protective put payoff
Protective put profit
Payoff/Profit
3
4
5
6
7
8
0
2
4
6
8
10
Stock price

1.8 Bull spread with calls

[10]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Bull spread with calls')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 4) - call_payoff(S, 6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_call(S_t, 4, r, t, Sigma) - BS_call(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Bull spread payoff', 'Bull spread profit'], loc='best')
#plt.savefig('Bull_spread_call.png', bbox_inches="tight", dpi=600)
plt.show()
```

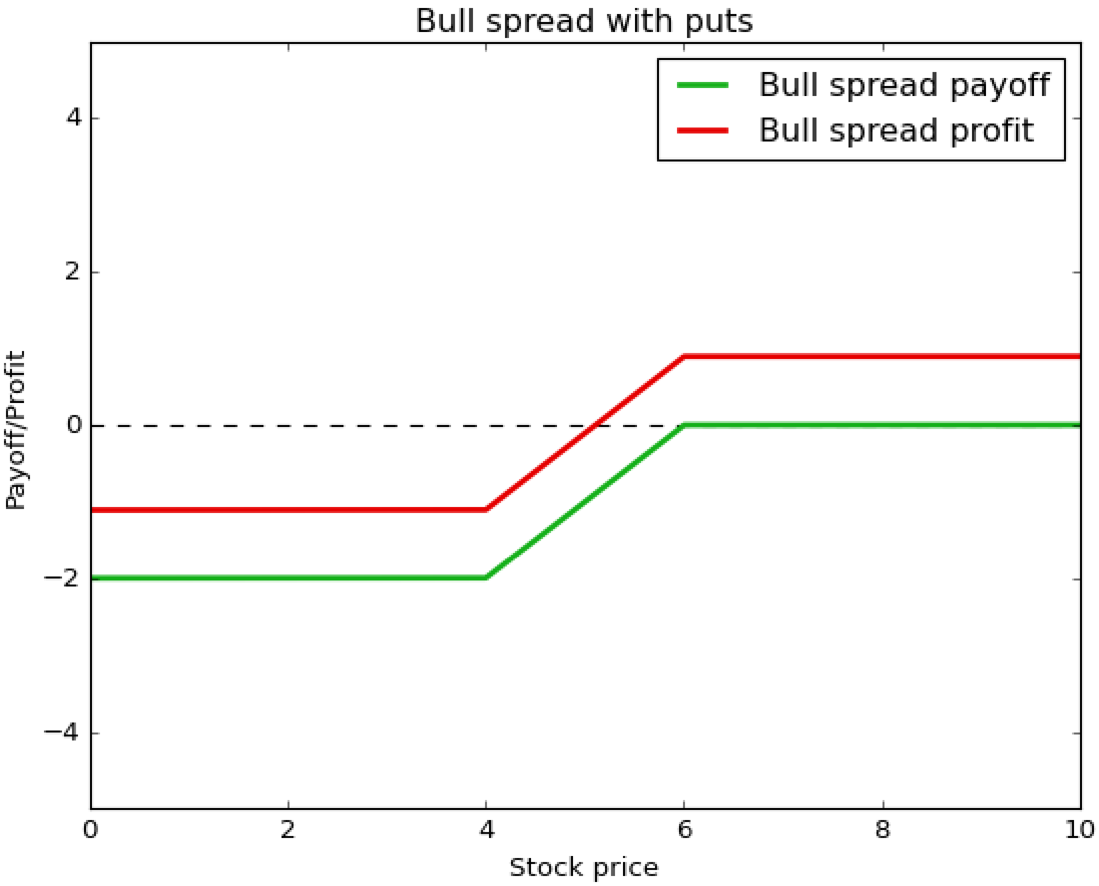


1.9 Bull spread with puts

[11]:

```
plt.style.use('classic')

S = 5

S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Bull spread with puts')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = put_payoff(S, 4) - put_payoff(S, 6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)
```

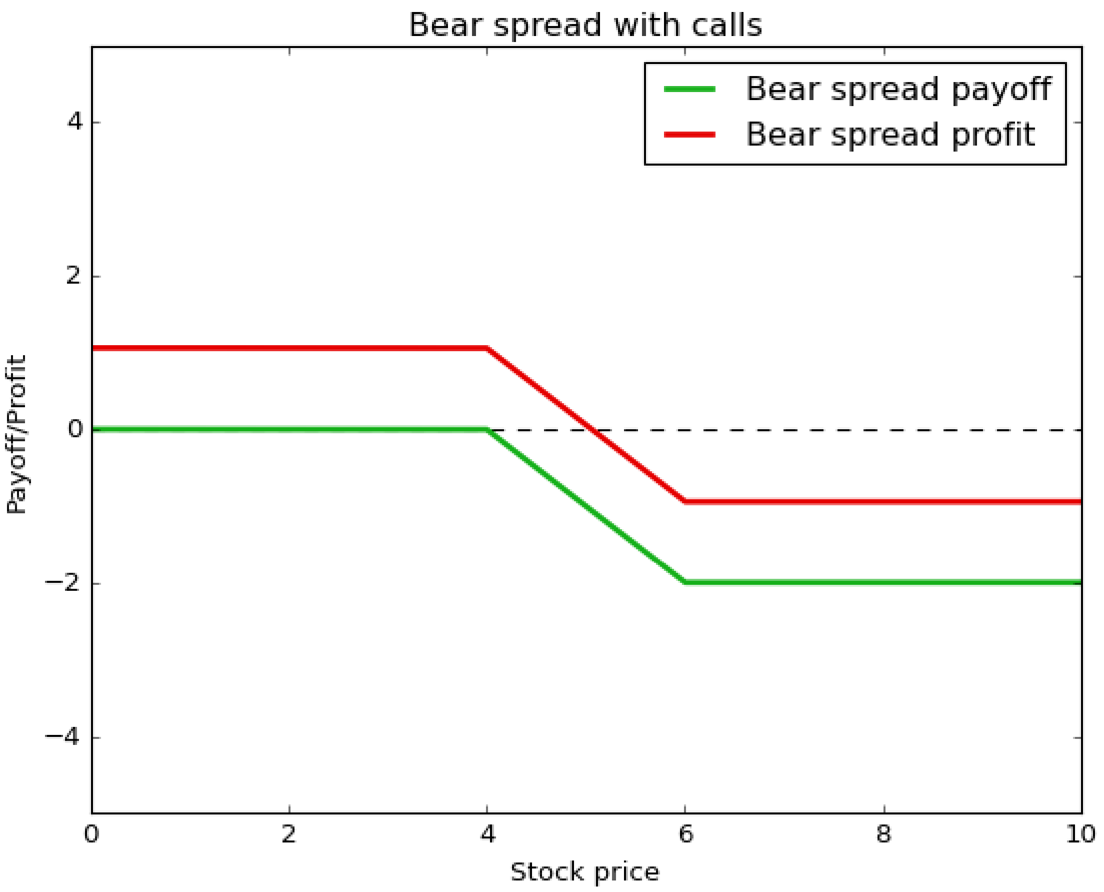
```
S_t = 5
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_put(S_t, 4, r, t, Sigma) - BS_put(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Bull spread payoff', 'Bull spread profit'], loc='best')
#plt.savefig('Bull_spread_put.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.10 Bear spread with calls

[12]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Bear spread with calls')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 6) - call_payoff(S, 4)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_call(S_t, 6, r, t, Sigma) - BS_call(S_t, 4, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Bear spread payoff', 'Bear spread profit'], loc='best')
#plt.savefig('Bear_spread_call.png', bbox_inches="tight", dpi=600)
plt.show()
```

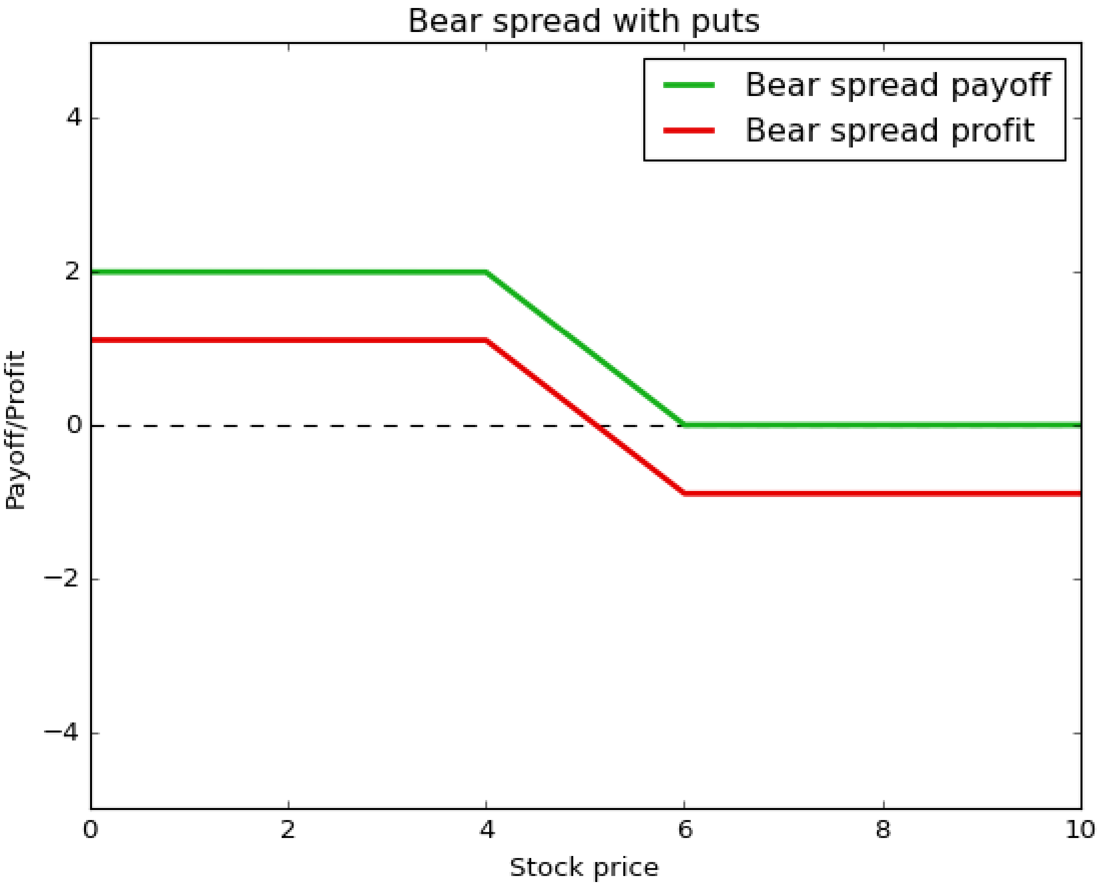


1.11 Bear spread with puts

[13]:

```
plt.style.use('classic')

S = 5

S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Bear spread with puts')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = put_payoff(S, 6) - put_payoff(S, 4)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)
```

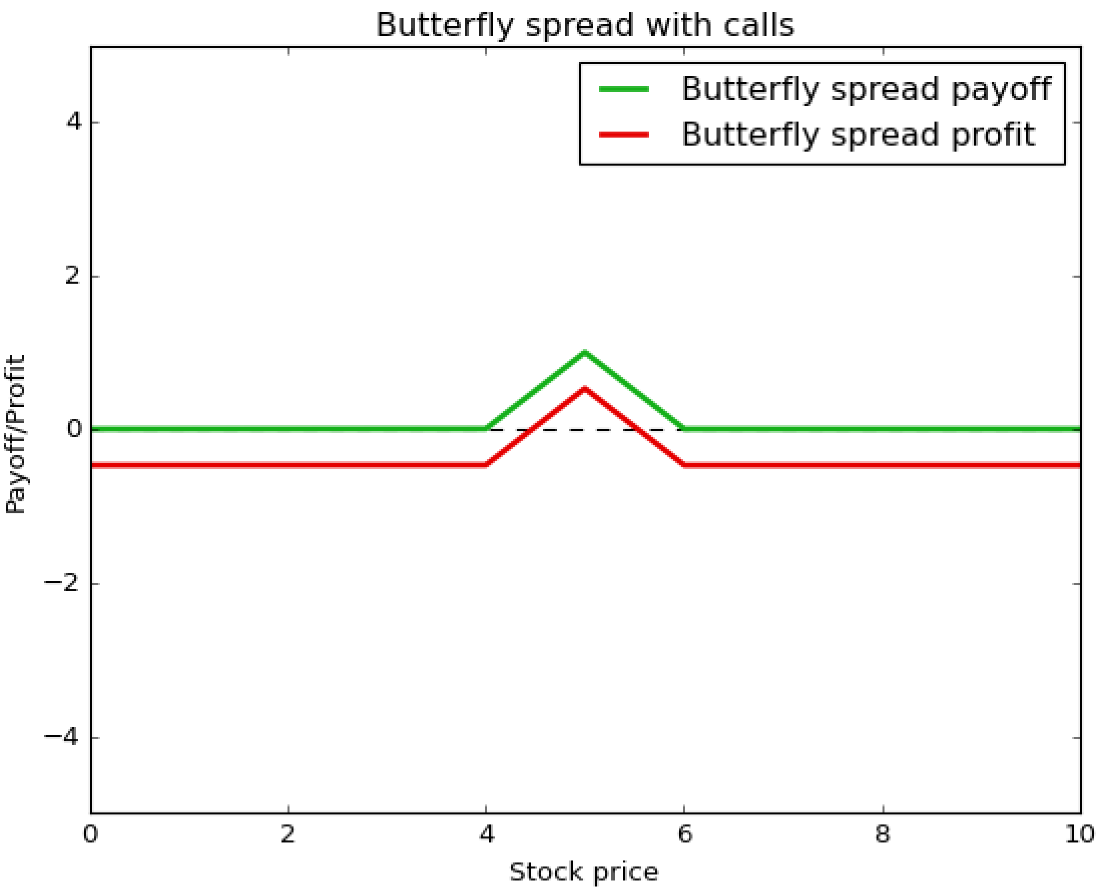
```
S_t = 5
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_put(S_t, 6, r, t, Sigma) - BS_put(S_t, 4, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Bear spread payoff', 'Bear spread profit'], loc='best')
#plt.savefig('Bear_spread_put.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.12 Butterfly spread with calls

[14]:

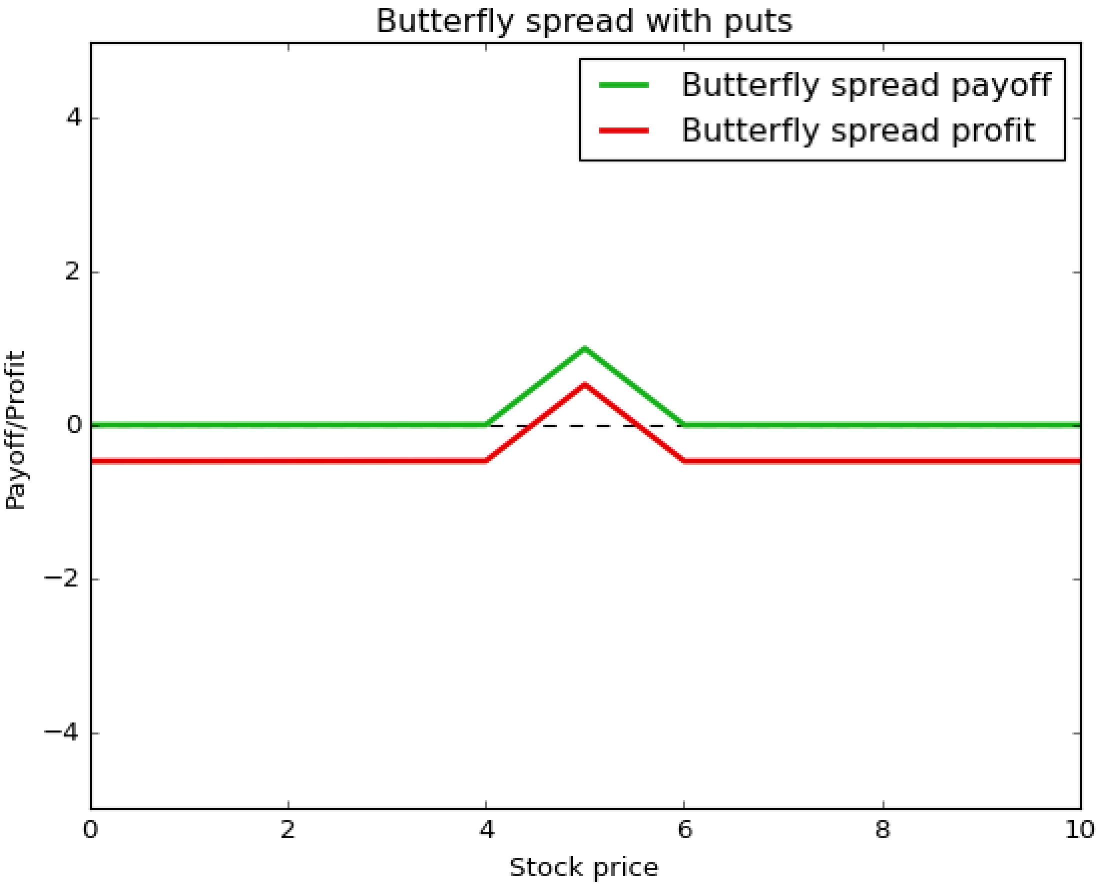
```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Butterfly spread with calls')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 4) - 2*call_payoff(S, 5) + call_payoff(S,6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_call(S_t, 4, r, t, Sigma) - 2*BS_call(S_t, 5, r, t, Sigma) +␣
 ↪BS_call(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Butterfly spread payoff', 'Butterfly spread profit'], loc='best')
#plt.savefig('Butterfly_spread_call.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.13 Butterfly spread with puts

[15]:
```
plt.style.use('classic')

S = 5

S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Butterfly spread with puts')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = put_payoff(S, 4) - 2*put_payoff(S, 5) +  put_payoff(S, 6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)
```

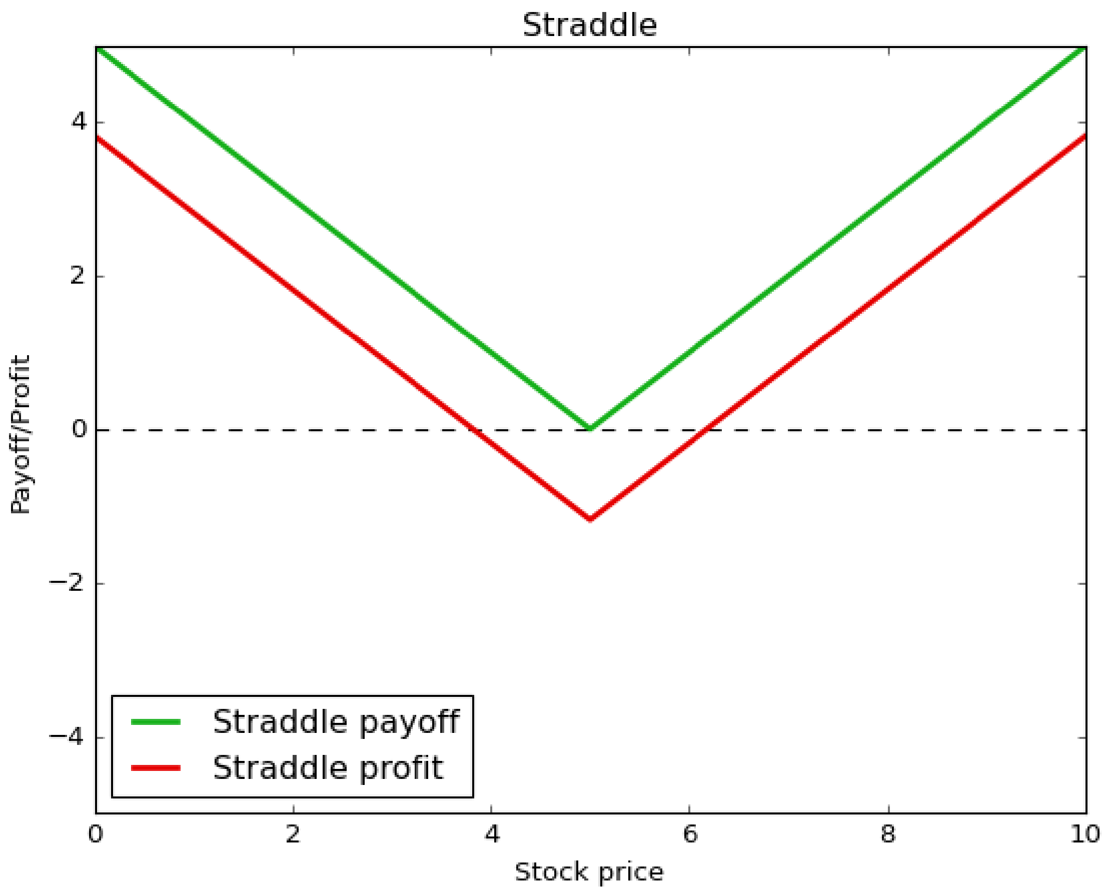
```
S_t = 5
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_put(S_t, 4, r, t, Sigma) - 2*BS_put(S_t, 5, r, t, Sigma) + BS_put(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Butterfly spread payoff', 'Butterfly spread profit'], loc='best')
#plt.savefig('Butterfly_spread_put.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.14 Straddles

[16]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Straddle')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 5) + put_payoff(S, 5)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 1
Sigma = 0.3

Cost = BS_call(S_t, 5, r, t, Sigma) + BS_put(S_t, 5, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Straddle payoff', 'Straddle profit'], loc='best')
#plt.savefig('Straddle.png', bbox_inches="tight", dpi=600)
plt.show()
```

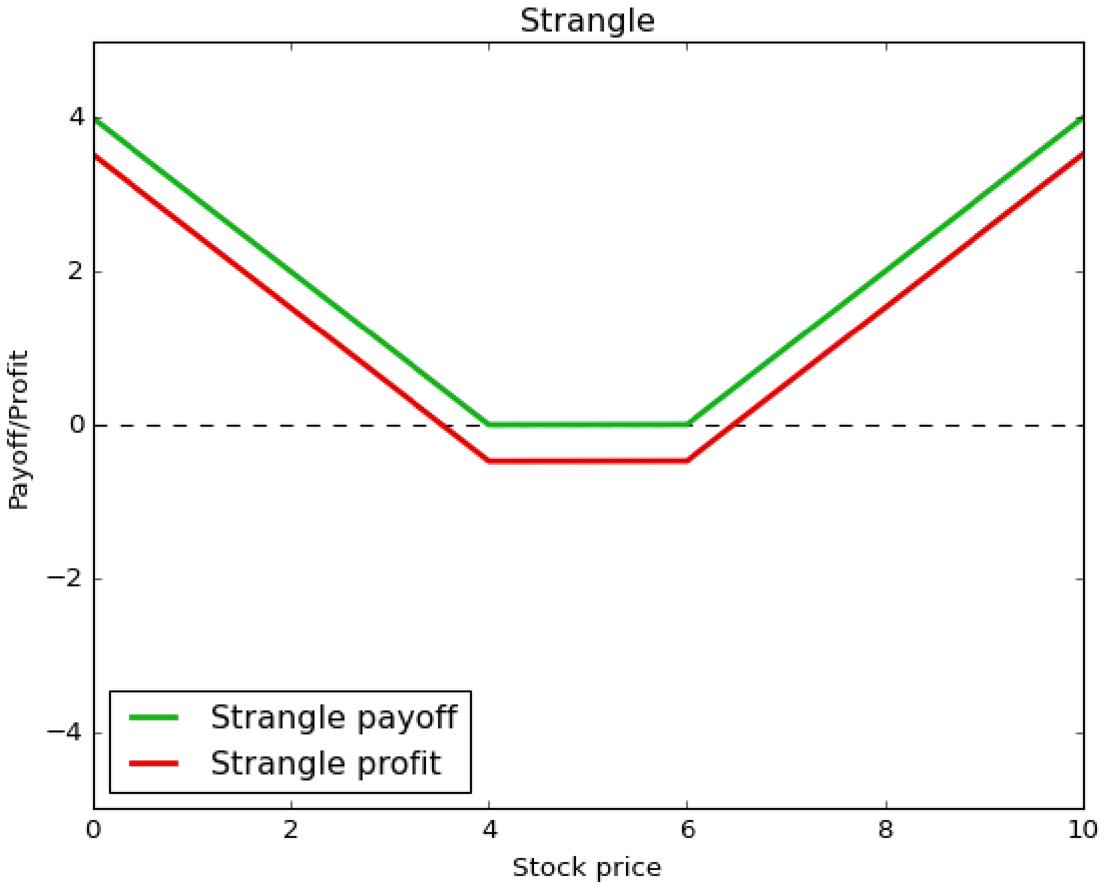


1.15 Strangles

[17]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Strangle')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 6) + put_payoff(S, 4)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
```

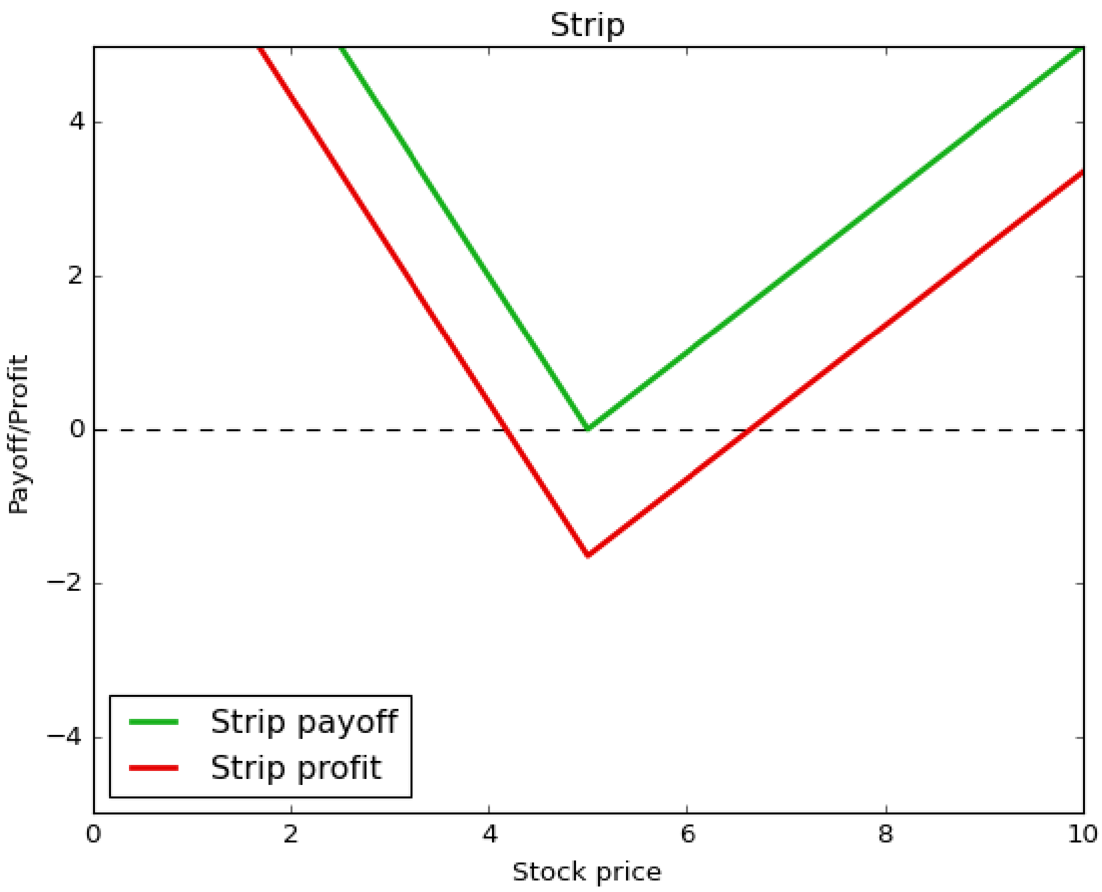
```
r = 0.05
t = 1
Sigma = 0.3

Cost = BS_call(S_t, 6, r, t, Sigma) + BS_put(S_t, 4, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Strangle payoff', 'Strangle profit'], loc='best')
#plt.savefig('Strangle.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.16 Strips

[18]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Strip')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 5) + 2*put_payoff(S, 5)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 1
Sigma = 0.3

Cost = BS_call(S_t, 5, r, t, Sigma) + 2*BS_put(S_t, 5, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Strip payoff', 'Strip profit'], loc='best')
#plt.savefig('Strip.png', bbox_inches="tight", dpi=600)
plt.show()
```

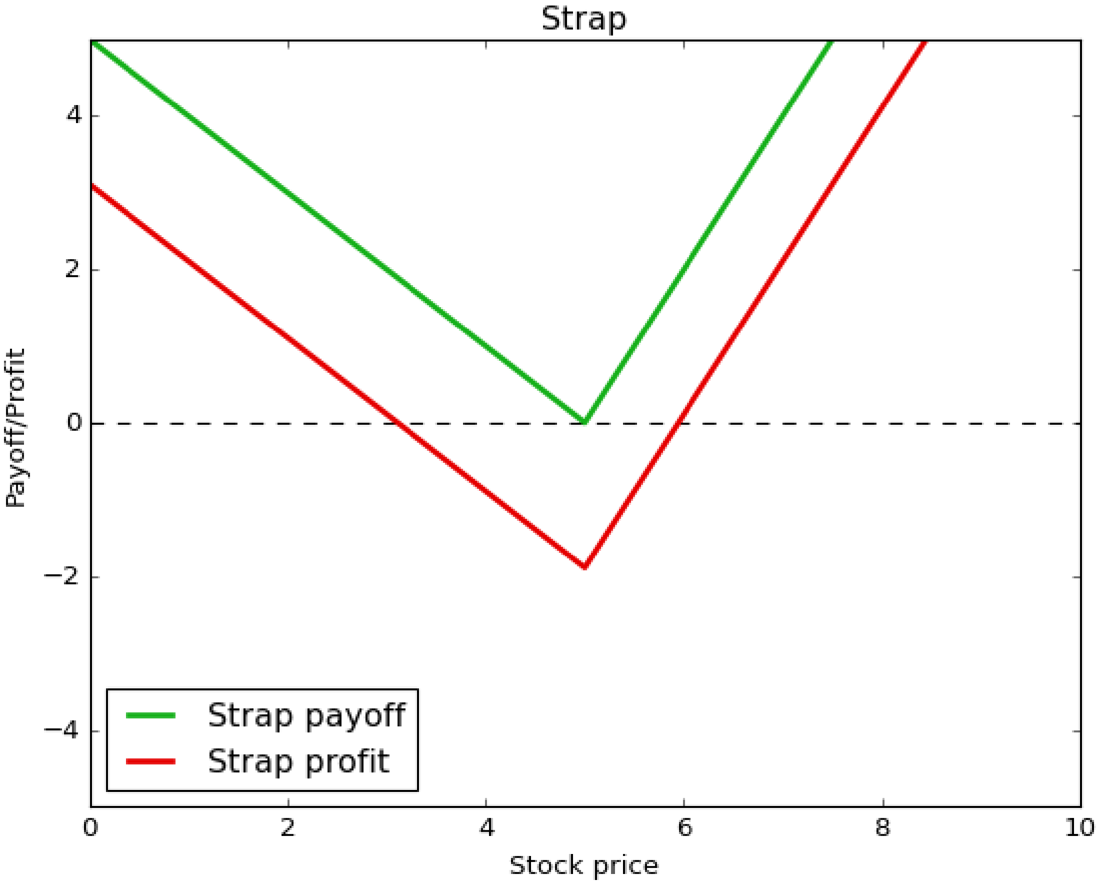


1.17 Straps

[19]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Strap')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = 2*call_payoff(S, 5) + put_payoff(S, 5)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
```

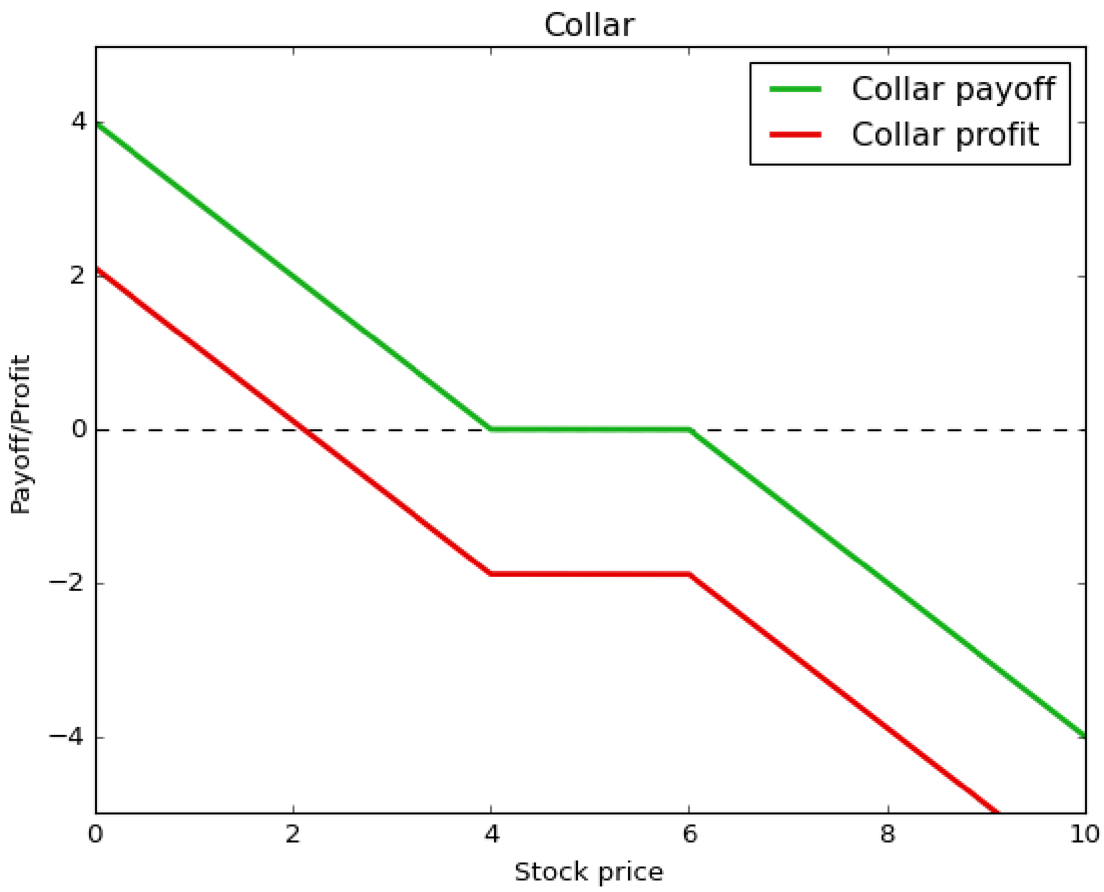
```
r = 0.05
t = 1
Sigma = 0.3

Cost = 2*BS_call(S_t, 5, r, t, Sigma) + BS_put(S_t, 5, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Strap payoff', 'Strap profit'], loc='best')
#plt.savefig('Strip.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.18 Collars

[20]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Collar')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = -call_payoff(S, 6) + put_payoff(S, 4)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 1
Sigma = 0.3

Cost = 2*BS_call(S_t, 5, r, t, Sigma) + BS_put(S_t, 5, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Collar payoff', 'Collar profit'], loc='best')
#plt.savefig('Collar.png', bbox_inches="tight", dpi=600)
plt.show()
```

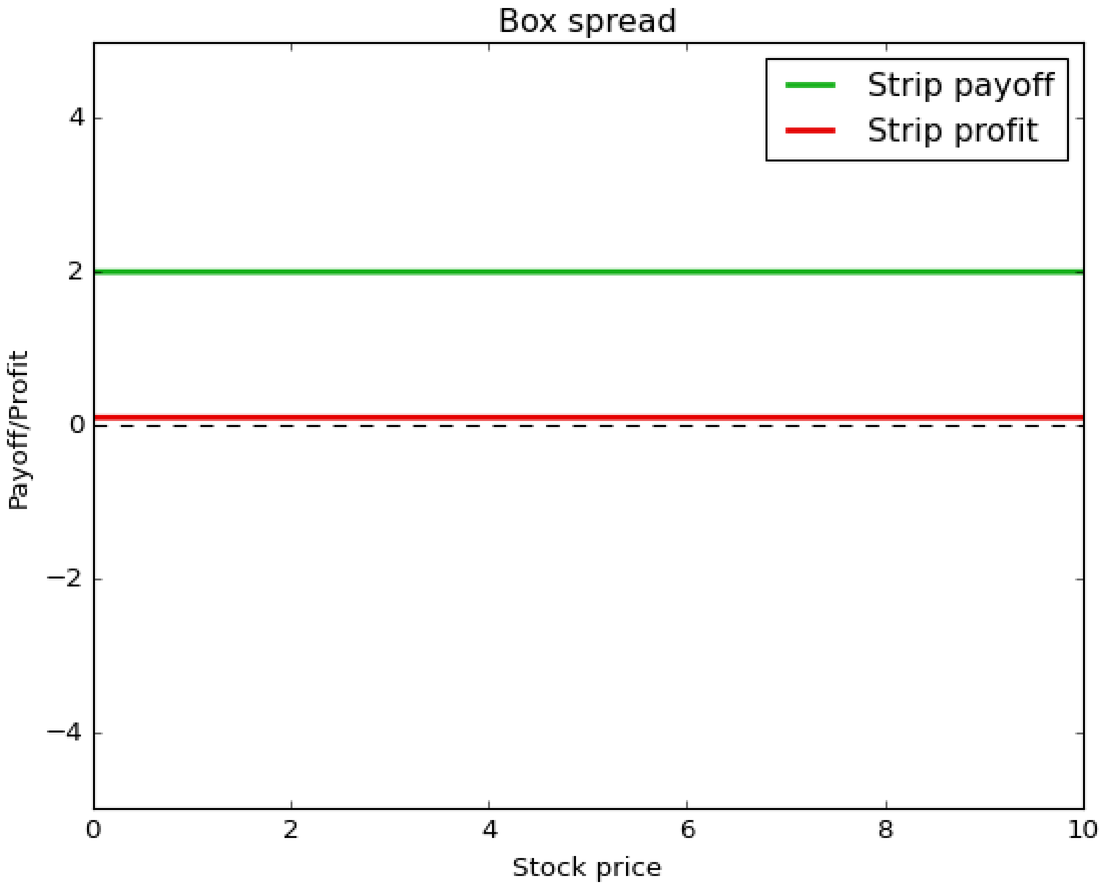


1.19 Box spread

[21]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Box spread')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 4) - put_payoff(S, 4) + put_payoff(S,6) -␣
 ↪call_payoff(S,6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)
```

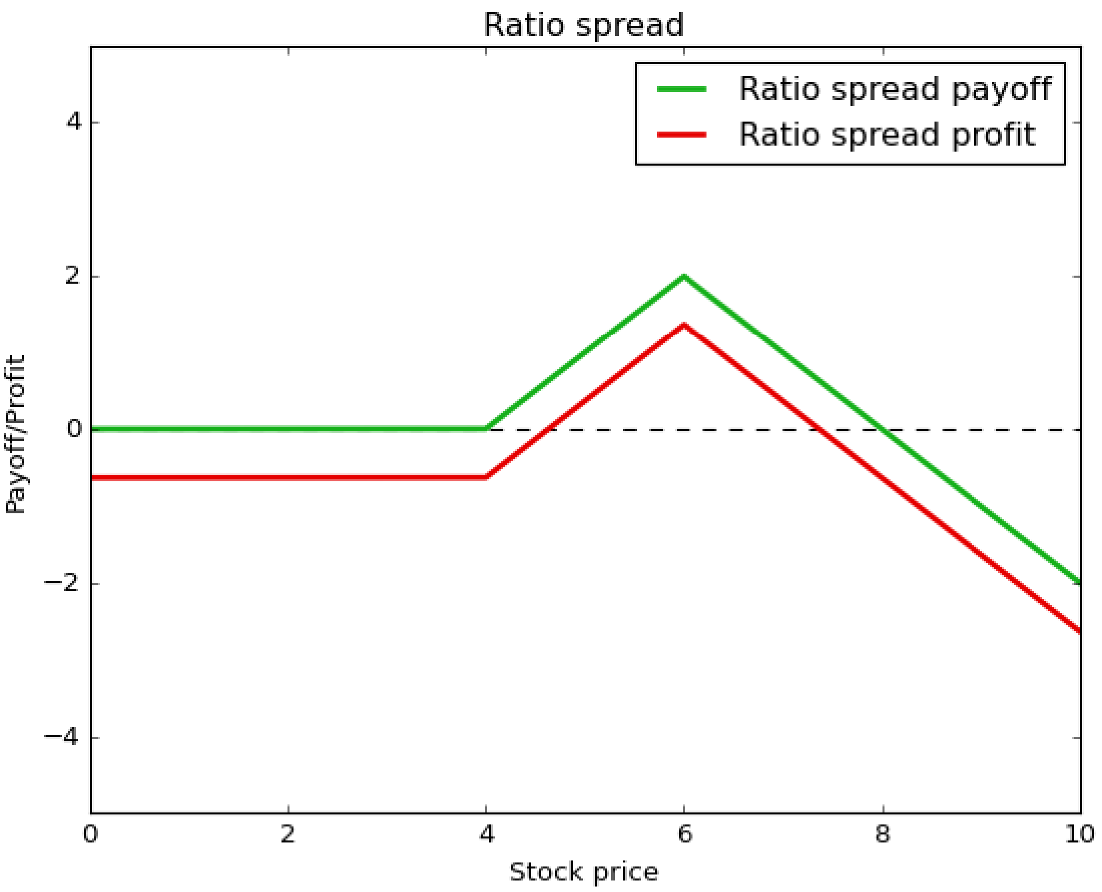
```
S_t = 5
r = 0.05
t = 1
Sigma = 0.3

Cost = BS_call(S_t, 4, r, t, Sigma) - BS_put(S_t, 4, r, t, Sigma) + BS_put(S_t,␣
 ↪6, r, t, Sigma) - BS_call(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Strip payoff', 'Strip profit'], loc='best')
#plt.savefig('Strip.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.20 Ratio spreads

[22]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Ratio spread')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 4) - 2*call_payoff(S, 6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
r = 0.05
t = 1
Sigma = 0.3

Cost = BS_call(S_t, 4, r, t, Sigma) - 2*BS_call(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Ratio spread payoff', 'Ratio spread profit'], loc='best')
#plt.savefig('Ratio_spread.png', bbox_inches="tight", dpi=600)
plt.show()
```

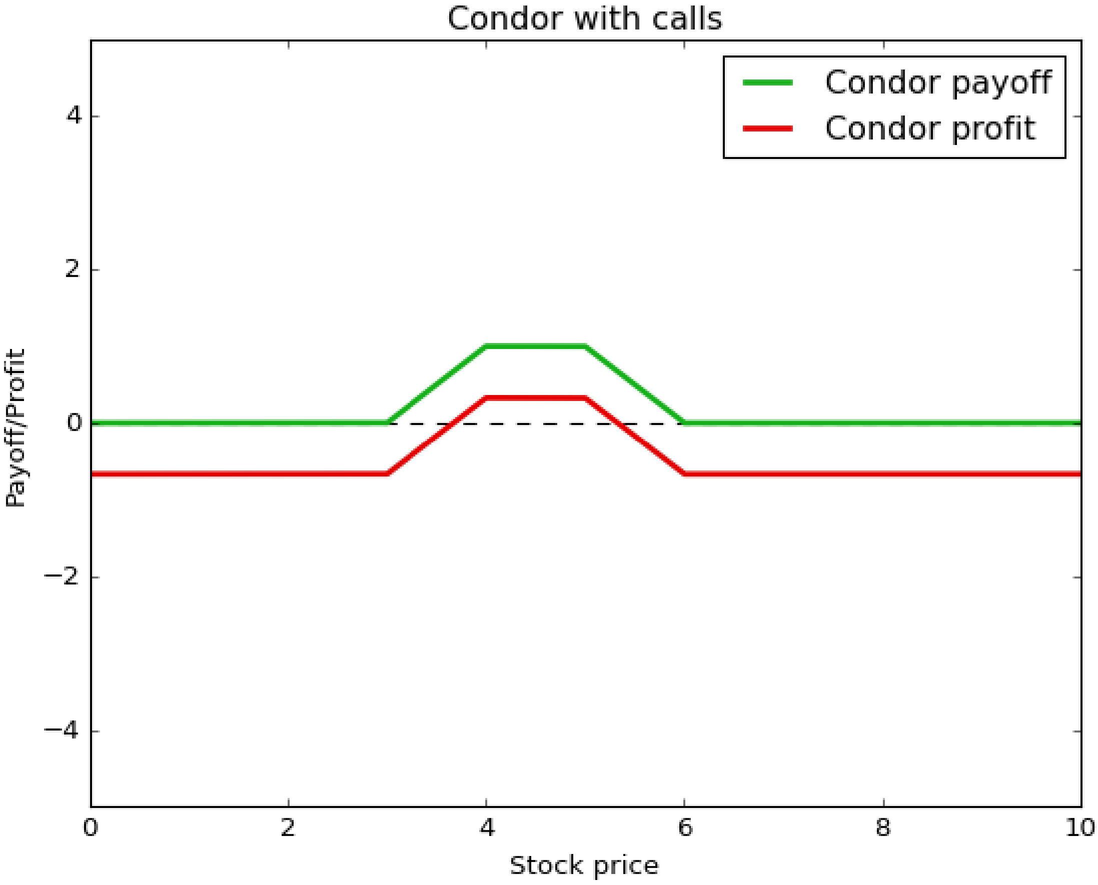


1.21 Condors

[23]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Condor with calls')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

Payoff = call_payoff(S, 3) - call_payoff(S, 4) - call_payoff(S, 5) +␣
 ↪call_payoff(S, 6)
plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

S_t = 5
```

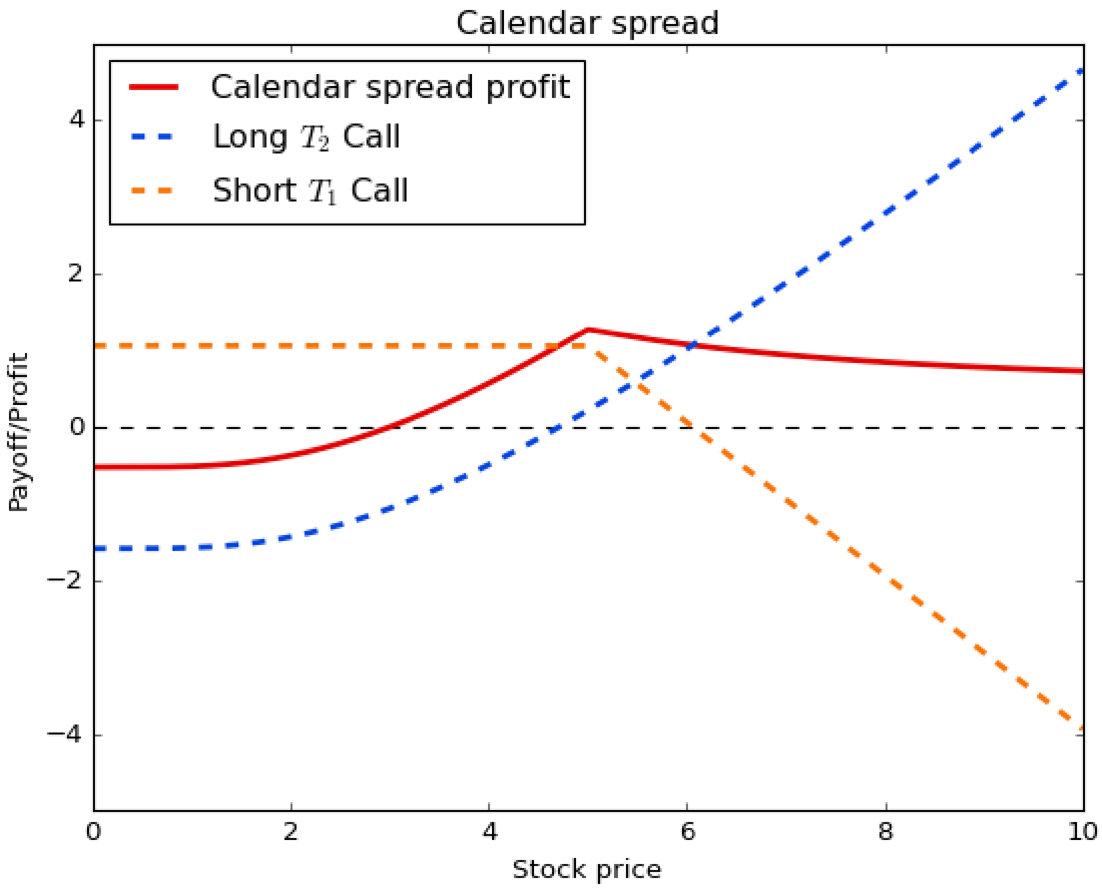
```
r = 0.05
t = 0.5
Sigma = 0.2

Cost = BS_call(S_t, 3, r, t, Sigma) - BS_call(S_t, 4, r, t, Sigma) -␣
 ↪BS_call(S_t, 5, r, t, Sigma) + BS_call(S_t, 6, r, t, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Condor payoff', 'Condor profit'], loc='best')
#plt.savefig('Condor_call.png', bbox_inches="tight", dpi=600)
plt.show()
```



1.22 Calendar spreads

[24]:

```
plt.style.use('classic')

S = 5
S = np.linspace(0.0001, S*2, 10000, endpoint=True)

fig, ax = plt.subplots()
fig.patch.set_facecolor('white')
plt.axhline(y=0, linestyle='--', color='black', label='_nolegend_')
plt.title('Calendar spread')
plt.ylabel('Payoff/Profit')
plt.xlabel('Stock price')

S_t = 5
r = 0.05
t_1 = 0.0001
t_2 = 5
Sigma = 0.3

#Payoff = BS_call(S, 5, r, t_1, Sigma) - BS_call(S, 5, r, t_2, Sigma)
#plt.plot(S, Payoff, color='xkcd:green', linewidth=2.5)

Payoff = BS_call(S, 5, r, t_2, Sigma) - BS_call(S, 5, r, t_1, Sigma)
Cost = BS_call(S_t, 5, r, 4, Sigma) - BS_call(S_t, 5, r, 2, Sigma)
plt.plot(S, Payoff - Cost, color='xkcd:red', linewidth=2.5)

Payoff = BS_call(S, 5, r, t_2, Sigma) - BS_call(S_t, 5, r, 4, Sigma)
plt.plot(S, Payoff, '--', color='xkcd:blue', linewidth=2.5)

Payoff = -BS_call(S, 5, r, t_1, Sigma) + BS_call(S_t, 5, r, 2, Sigma)
plt.plot(S, Payoff, '--', color='xkcd:orange', linewidth=2.5)

plt.xlim(0,10)
plt.ylim(-5,5)
plt.legend(['Calendar spread profit', 'Long $T_2$ Call', 'Short $T_1$ Call'],␣
 ↪loc='best')
#plt.savefig('Calendar_spread.png', bbox_inches="tight", dpi=600)
plt.show()
```


Calendar spread
Calendar spread profit
Long T_2 Call
Short T_1 Call
Payoff/Profit
Stock price
4
2
0
−2
−4
0
2
4
6
8
10