In [1]:
```
import pandas as pd
import math
import numpy as np
from scipy import stats
import scipy.optimize as opt
# ファイルを読み込む
pd_reader = pd.read_csv("金融工学_第11回_スマートベータデータ.csv", encoding="ANSI")
df = pd_reader
display(df)
```

```
C:\Users\apple\AppData\Local\Programs\Python\Python39\lib\site-packages\scipy\__init__.py:138: UserWarning: A NumPy version >=
1.16.5 and <1.23.0 is required for this version of SciPy (detected version 1.23.4)
  warnings.warn(f"A NumPy version >={np_minversion} and <{np_maxversion} is required for this version of "
```

	yyyymm	等ウェイト	高配当	最小分散	クオリティ	企業価値	市場指数
0	200001	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1	200002	-4.326403	-7.506763	-2.580708	5.451383	-3.507194	-0.025701
2	200003	6.431353	5.873751	3.001612	-2.968766	5.069897	1.072972
3	200004	-0.590110	3.522099	0.107569	-1.200467	-0.816037	-2.541618
4	200005	1.626499	2.168112	-3.809710	-10.021505	-2.298337	-5.430798
...	...	...	...	...	...	...	...
247	202008	9.403594	10.961215	6.892987	3.240581	10.404669	7.936409
248	202009	0.771339	-1.601116	-0.309241	3.860360	-1.731106	0.618640
249	202010	-3.804058	-0.241031	-3.954824	-1.749322	-2.690068	-2.519181
250	202011	11.116687	8.799679	8.668490	13.346730	10.694101	12.212388
251	202012	2.091258	4.243682	1.527003	1.750070	3.983469	3.117455

252 rows × 7 columns

In [34]:
```
from scipy.optimize import minimize
#ポートフォリオ最適化関数
def optimize_portfolio(Mean, Cov, risk_tolerance):
    num_assets = len(Mean)
    cov_matrix = Cov
    expected_returns = Mean
    risk_tolerance = risk_tolerance

    def objective(weights):
        return weights.dot(cov_matrix).dot(weights) - risk_tolerance * expected_returns.dot(weights)

    def constraint(weights):
        return weights.sum() - 1

    bounds = tuple((0, 1) for _ in range(num_assets))
    constraints = ({'type': 'eq', 'fun': constraint})
    initial_weights = np.ones(num_assets) / num_assets

    result = minimize(objective, initial_weights, bounds=bounds, constraints=constraints)
    return result.x
def nextym(yyyymm):
    yyyymm = yyyymm + 1
    if yyyymm % 100 == 13:
        yyyymm = yyyymm + 88
    return yyyymm
```

In [59]:
```
def backtest(risk_tolerance):
    np.set_printoptions(precision=3)
    yyyymm_start = 201501
    yyyymm_end = 201801 #バックテスト期間は201501から201801まで

    n = 0
    acc_rtn = 0
    ACC_RTN = []


    while yyyymm_end <= 202011:

        print(yyyymm_end)
        #T時点の前36月分の歴史データを抽出する
```

```
        tmp = df[(df.yyyymm >= yyyymm_start) & (df.yyyymm < yyyymm_end)]
        tmp = tmp.drop('yyyymm',axis=1)
        Mean = tmp.mean().values
        #print(Mean)
        tmp = tmp.values.T
        Cov = np.cov(tmp)
        #print(Cov)

        optimized_weights = optimize_portfolio(Mean, Cov, risk_tolerance)

        yyyymm_start = nextym(yyyymm_start)
        yyyymm_end = nextym(yyyymm_end)
        n = n + 1
        next_rtn = df[df.yyyymm == yyyymm_end]
        next_rtn = next_rtn.drop('yyyymm',axis=1).values
        rtn = next_rtn.dot(optimized_weights)
        print('allocation:',optimized_weights)
        print('potforlio return:',rtn,'\n')
        acc_rtn = acc_rtn + rtn + 0
        ACC_RTN.append(acc_rtn)
    return ACC_RTN
high_risk = backtest(100)
mid_risk = backtest(0)
low_risk = backtest(-100)
```

```
201801
allocation: [6.968e-13 1.000e+00 3.271e-13 0.000e+00 0.000e+00 0.000e+00]
potforlio return: [-4.383]

201802
allocation: [3.939e-14 1.000e+00 7.050e-15 3.811e-14 4.358e-15 9.687e-15]
potforlio return: [-1.729]

201803
allocation: [2.394e-13 1.000e+00 9.368e-14 0.000e+00 0.000e+00 0.000e+00]
potforlio return: [3.712]

201804
allocation: [0.000e+00 1.000e+00 0.000e+00 1.549e-13 9.898e-13 8.086e-13]
potforlio return: [-3.914]

201805
allocation: [1.689e-13 1.000e+00 1.689e-13 3.292e-14 0.000e+00 0.000e+00]
potforlio return: [-1.483]

201806
allocation: [0.000e+00 0.000e+00 1.000e+00 0.000e+00 1.266e-13 9.104e-14]
potforlio return: [0.545]

201807
allocation: [0.000e+00 0.000e+00 1.000e+00 0.000e+00 2.363e-12 1.331e-12]
potforlio return: [-2.038]

201808
allocation: [6.443e-01 0.000e+00 1.114e-02 3.446e-01 8.640e-14 6.508e-14]
potforlio return: [4.955]

201809
allocation: [3.794e-13 0.000e+00 7.269e-14 1.000e+00 0.000e+00 0.000e+00]
potforlio return: [-11.673]

201810
allocation: [0.000e+00 0.000e+00 1.324e-14 1.000e+00 3.292e-14 1.160e-14]
potforlio return: [0.823]
```

```
201811
allocation: [5.079e-14 4.097e-14 1.000e+00 0.000e+00 0.000e+00 0.000e+00]
potforlio return: [-6.65]

201812
allocation: [0.000e+00 0.000e+00 1.000e+00 3.241e-13 2.344e-13 1.749e-13]
potforlio return: [3.355]

201901
allocation: [4.901e-13 0.000e+00 1.000e+00 0.000e+00 0.000e+00 0.000e+00]
potforlio return: [2.228]

201902
allocation: [4.656e-01 1.866e-13 3.991e-01 9.084e-13 1.353e-01 1.364e-13]
potforlio return: [-0.054]

201903
allocation: [0.000e+00 6.772e-13 1.762e-14 3.965e-13 1.000e+00 0.000e+00]
potforlio return: [1.739]

201904
allocation: [3.639e-01 0.000e+00 7.562e-13 1.442e-14 6.361e-01 0.000e+00]
potforlio return: [-7.143]

201905
allocation: [7.679e-14 0.000e+00 0.000e+00 1.818e-13 8.751e-01 1.249e-01]
potforlio return: [3.029]

201906
allocation: [0.000e+00 0.000e+00 1.447e-01 3.045e-13 4.732e-12 8.553e-01]
potforlio return: [0.838]

201907
allocation: [0.000e+00 2.098e-13 1.440e-13 8.449e-14 1.000e+00 0.000e+00]
potforlio return: [-4.143]

201908
allocation: [0.000e+00 0.000e+00 0.000e+00 8.689e-13 9.309e-01 6.913e-02]
potforlio return: [6.782]
```

```
201909
allocation: [2.809e-13 0.000e+00 1.662e-01 8.338e-01 1.906e-13 3.372e-13]
potforlio return: [6.325]

201910
allocation: [0.000e+00 3.249e-12 0.000e+00 4.112e-01 0.000e+00 5.888e-01]
potforlio return: [1.482]

201911
allocation: [5.610e-13 0.000e+00 1.209e-12 1.000e+00 0.000e+00 7.742e-13]
potforlio return: [2.546]

201912
allocation: [0.000e+00 1.116e-12 0.000e+00 1.000e+00 2.363e-13 0.000e+00]
potforlio return: [-0.242]

202001
allocation: [0.000e+00 3.924e-12 0.000e+00 1.000e+00 2.110e-12 0.000e+00]
potforlio return: [-8.989]

202002
allocation: [0.000e+00 0.000e+00 8.771e-15 1.000e+00 0.000e+00 1.957e-14]
potforlio return: [-1.295]

202003
allocation: [1.018e-12 2.199e-12 0.000e+00 1.000e+00 1.890e-12 0.000e+00]
potforlio return: [5.427]

202004
allocation: [6.940e-12 1.829e-11 0.000e+00 1.000e+00 1.836e-11 0.000e+00]
potforlio return: [6.817]

202005
allocation: [1.200e-12 4.142e-12 0.000e+00 1.000e+00 3.247e-12 0.000e+00]
potforlio return: [2.536]

202006
allocation: [0.000e+00 0.000e+00 1.227e-12 1.000e+00 0.000e+00 1.555e-12]
potforlio return: [-2.514]
```

```
202007
allocation: [9.291e-12 5.077e-11 0.000e+00 1.000e+00 3.452e-11 0.000e+00]
potforlio return: [3.241]

202008
allocation: [0.000e+00 0.000e+00 4.827e-13 1.000e+00 0.000e+00 8.887e-13]
potforlio return: [3.86]

202009
allocation: [0.000e+00 0.000e+00 1.685e-14 1.000e+00 0.000e+00 2.996e-12]
potforlio return: [-1.749]

202010
allocation: [2.946e-12 5.123e-11 0.000e+00 1.000e+00 3.294e-11 0.000e+00]
potforlio return: [13.347]

202011
allocation: [1.319e-11 6.446e-11 0.000e+00 1.000e+00 5.082e-11 0.000e+00]
potforlio return: [1.75]

201801
allocation: [1.585e-14 1.033e-14 1.000e+00 0.000e+00 2.400e-13 9.123e-14]
potforlio return: [-2.44]

201802
allocation: [2.595e-14 1.646e-14 1.000e+00 0.000e+00 2.971e-13 1.159e-13]
potforlio return: [0.122]

201803
allocation: [0.000e+00 0.000e+00 1.000e+00 4.394e-14 0.000e+00 0.000e+00]
potforlio return: [3.515]

201804
allocation: [1.560e-14 1.965e-14 1.000e+00 0.000e+00 1.236e-13 5.029e-14]
potforlio return: [-1.058]

201805
allocation: [1.640e-14 0.000e+00 1.000e+00 0.000e+00 7.852e-14 3.189e-14]
potforlio return: [0.223]
```

```
201806
allocation: [0.000e+00 0.000e+00 1.000e+00 6.159e-14 0.000e+00 0.000e+00]
potforlio return: [0.545]

201807
allocation: [0.000e+00 2.137e-15 1.000e+00 1.496e-14 0.000e+00 0.000e+00]
potforlio return: [-2.038]

201808
allocation: [7.577e-15 1.943e-16 1.000e+00 0.000e+00 1.202e-14 7.577e-15]
potforlio return: [5.518]

201809
allocation: [3.580e-15 1.152e-14 1.000e+00 0.000e+00 5.881e-14 2.062e-14]
potforlio return: [-6.681]

201810
allocation: [2.237e-14 6.939e-16 1.000e+00 0.000e+00 1.211e-13 4.871e-14]
potforlio return: [2.949]

201811
allocation: [2.065e-14 0.000e+00 1.000e+00 0.000e+00 6.375e-14 2.379e-14]
potforlio return: [-6.65]

201812
allocation: [0.000e+00 9.270e-15 1.000e+00 6.836e-14 0.000e+00 0.000e+00]
potforlio return: [3.355]

201901
allocation: [6.106e-15 5.579e-15 1.000e+00 0.000e+00 1.957e-14 9.354e-15]
potforlio return: [2.228]

201902
allocation: [0.000e+00 0.000e+00 1.000e+00 7.508e-14 0.000e+00 0.000e+00]
potforlio return: [-0.238]

201903
allocation: [3.275e-15 0.000e+00 1.000e+00 0.000e+00 2.140e-14 6.301e-15]
potforlio return: [-1.664]
```

```
201904
allocation: [0.000e+00 0.000e+00 1.000e+00 1.651e-14 0.000e+00 0.000e+00]
potforlio return: [-3.194]

201905
allocation: [0.000e+00 0.000e+00 1.000e+00 5.293e-14 0.000e+00 0.000e+00]
potforlio return: [1.13]

201906
allocation: [0.000e+00 0.000e+00 1.000e+00 6.939e-15 0.000e+00 0.000e+00]
potforlio return: [0.417]

201907
allocation: [0.000e+00 0.000e+00 1.000e+00 1.538e-14 0.000e+00 0.000e+00]
potforlio return: [-0.715]

201908
allocation: [0.000e+00 0.000e+00 1.000e+00 3.580e-15 2.776e-17 2.914e-15]
potforlio return: [5.308]

201909
allocation: [0.000e+00 0.000e+00 1.000e+00 1.613e-14 0.000e+00 0.000e+00]
potforlio return: [3.698]

201910
allocation: [0.000e+00 0.000e+00 1.000e+00 1.732e-14 0.000e+00 0.000e+00]
potforlio return: [0.985]

201911
allocation: [1.418e-14 1.862e-14 1.000e+00 0.000e+00 2.545e-14 1.368e-14]
potforlio return: [-0.234]

201912
allocation: [1.957e-14 1.008e-14 1.000e+00 0.000e+00 2.012e-14 1.324e-14]
potforlio return: [-0.889]

202001
allocation: [3.386e-15 7.244e-15 1.000e+00 0.000e+00 4.580e-15 3.469e-15]
potforlio return: [-9.91]
```

```
202002
allocation: [1.107e-14 1.088e-14 1.000e+00 0.000e+00 1.213e-14 1.035e-14]
potforlio return: [-3.204]

202003
allocation: [2.609e-15 0.000e+00 1.000e+00 0.000e+00 0.000e+00 1.027e-15]
potforlio return: [0.596]

202004
allocation: [1.135e-14 7.022e-15 1.000e+00 0.000e+00 1.532e-14 9.215e-15]
potforlio return: [5.801]

202005
allocation: [0.000e+00 6.245e-15 1.000e+00 0.000e+00 0.000e+00 0.000e+00]
potforlio return: [-1.182]

202006
allocation: [6.634e-15 9.076e-15 1.000e+00 0.000e+00 8.632e-15 6.189e-15]
potforlio return: [-5.458]

202007
allocation: [0.000e+00 2.970e-15 1.000e+00 1.718e-14 0.000e+00 0.000e+00]
potforlio return: [6.893]

202008
allocation: [0.000e+00 0.000e+00 1.000e+00 4.088e-14 0.000e+00 0.000e+00]
potforlio return: [-0.309]

202009
allocation: [2.340e-15 0.000e+00 8.638e-01 1.362e-01 7.490e-16 4.065e-17]
potforlio return: [-3.654]

202010
allocation: [7.941e-14 3.046e-14 8.563e-01 1.437e-01 8.488e-14 3.032e-14]
potforlio return: [9.341]

202011
allocation: [0.000e+00 6.300e-15 8.404e-01 1.596e-01 0.000e+00 3.386e-16]
potforlio return: [1.563]
```

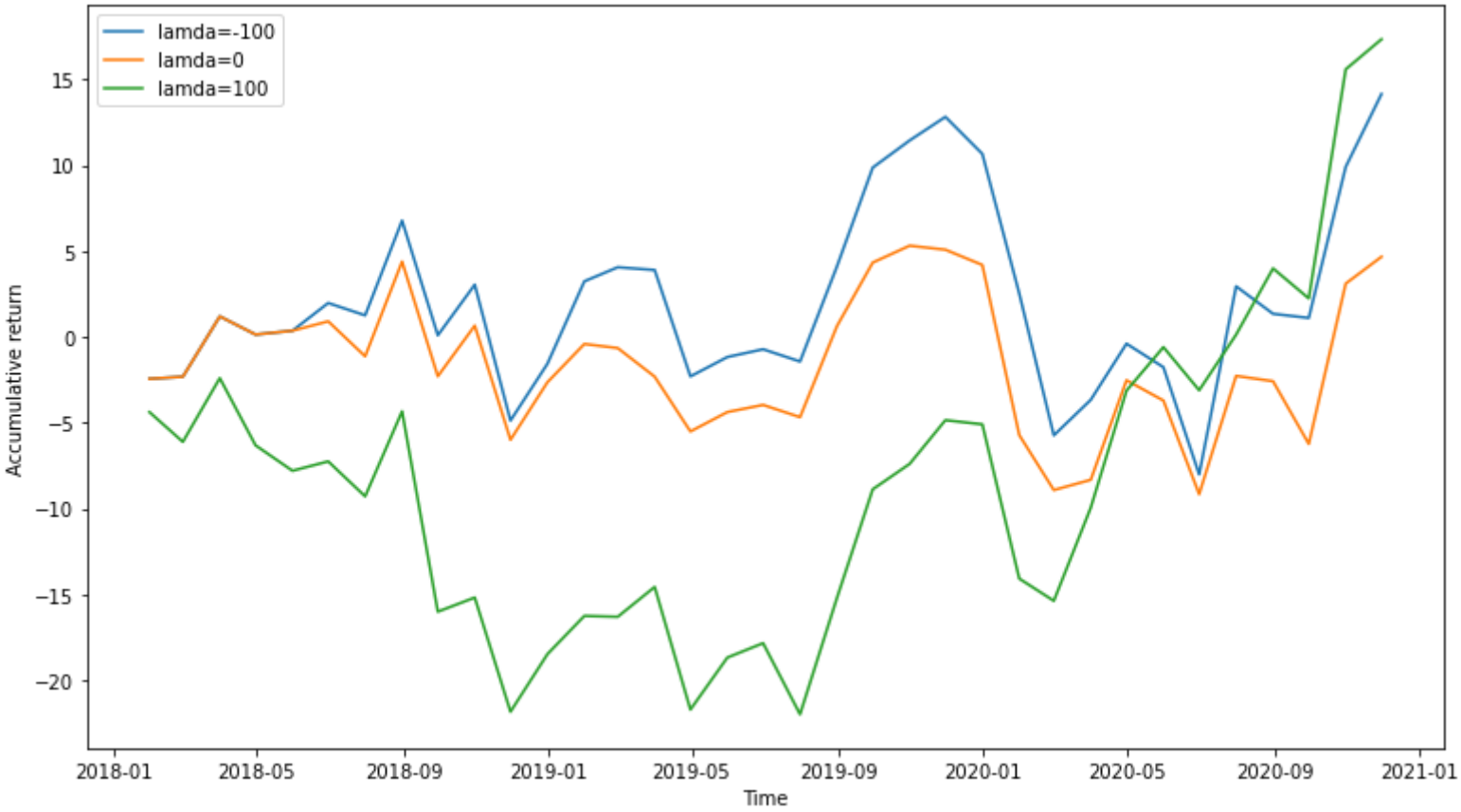
```
201801
allocation: [0.000e+00 0.000e+00 1.000e+00 1.176e-13 0.000e+00 6.786e-14]
potforlio return: [-2.44]

201802
allocation: [0.000e+00 0.000e+00 1.000e+00 5.883e-13 0.000e+00 0.000e+00]
potforlio return: [0.122]

201803
allocation: [0.000e+00 0.000e+00 1.000e+00 1.131e-12 0.000e+00 4.505e-14]
potforlio return: [3.515]

201804
allocation: [8.885e-13 1.917e-12 1.000e+00 0.000e+00 2.810e-13 0.000e+00]
potforlio return: [-1.058]

201805
allocation: [0.000e+00 0.000e+00 1.000e+00 8.605e-13 0.000e+00 7.077e-13]
potforlio return: [0.223]

201806
allocation: [0.000e+00 0.000e+00 4.871e-13 2.903e-14 1.643e-01 8.357e-01]
potforlio return: [1.613]

201807
allocation: [0.000e+00 0.000e+00 1.466e-13 4.867e-14 2.409e-13 1.000e+00]
potforlio return: [-0.718]

201808
allocation: [0.000e+00 0.000e+00 1.000e+00 4.191e-15 2.592e-14 1.116e-13]
potforlio return: [5.518]

201809
allocation: [0.000e+00 0.000e+00 1.000e+00 0.000e+00 0.000e+00 4.635e-15]
potforlio return: [-6.681]

201810
allocation: [0. 0. 1. 0. 0. 0.]
potforlio return: [2.949]
```

```
201811
allocation: [7.585e-14 0.000e+00 1.465e-01 8.535e-01 0.000e+00 0.000e+00]
potforlio return: [-7.917]

201812
allocation: [0.000e+00 8.618e-14 7.910e-15 1.000e+00 0.000e+00 0.000e+00]
potforlio return: [3.311]

201901
allocation: [2.693e-13 0.000e+00 4.946e-14 1.000e+00 2.504e-13 1.174e-14]
potforlio return: [4.802]

201902
allocation: [0.000e+00 4.213e-14 3.618e-13 1.000e+00 0.000e+00 0.000e+00]
potforlio return: [0.82]

201903
allocation: [8.401e-13 6.267e-02 3.874e-01 5.499e-01 8.684e-13 5.452e-13]
potforlio return: [-0.161]

201904
allocation: [0.000e+00 7.523e-01 1.893e-12 2.477e-01 0.000e+00 0.000e+00]
potforlio return: [-6.2]

201905
allocation: [0.000e+00 2.184e-12 1.000e+00 1.786e-12 0.000e+00 0.000e+00]
potforlio return: [1.13]

201906
allocation: [0.000e+00 8.042e-01 1.958e-01 2.454e-12 0.000e+00 0.000e+00]
potforlio return: [0.454]

201907
allocation: [0.000e+00 3.483e-12 1.000e+00 4.037e-12 0.000e+00 0.000e+00]
potforlio return: [-0.715]

201908
allocation: [0.    0.162 0.838 0.    0.    0.   ]
potforlio return: [5.544]
```

```
201909
allocation: [0.000e+00 1.000e+00 7.602e-14 0.000e+00 0.000e+00 0.000e+00]
potforlio return: [5.753]

201910
allocation: [2.715e-13 1.000e+00 0.000e+00 1.016e-14 3.372e-13 2.963e-13]
potforlio return: [1.582]

201911
allocation: [2.524e-13 1.000e+00 0.000e+00 1.643e-13 1.469e-13 2.704e-13]
potforlio return: [1.372]

201912
allocation: [7.019e-14 1.000e+00 0.000e+00 9.501e-14 2.659e-14 4.435e-14]
potforlio return: [-2.157]

202001
allocation: [0.000e+00 1.000e+00 8.575e-13 0.000e+00 6.585e-13 0.000e+00]
potforlio return: [-8.136]

202002
allocation: [4.448e-13 1.000e+00 0.000e+00 3.991e-12 0.000e+00 1.045e-12]
potforlio return: [-8.261]

202003
allocation: [0.000e+00 1.000e+00 0.000e+00 6.100e-12 0.000e+00 1.457e-12]
potforlio return: [2.07]

202004
allocation: [3.713e-13 1.000e+00 0.000e+00 0.000e+00 3.334e-12 0.000e+00]
potforlio return: [3.271]

202005
allocation: [9.081e-13 1.000e+00 6.771e-12 0.000e+00 1.587e-11 0.000e+00]
potforlio return: [-1.37]

202006
allocation: [0.000e+00 1.000e+00 3.494e-12 0.000e+00 4.325e-12 0.000e+00]
potforlio return: [-6.248]
```

```
202007
allocation: [3.429e-13 1.000e+00 0.000e+00 3.757e-11 0.000e+00 9.816e-12]
potforlio return: [10.961]

202008
allocation: [4.038e-13 1.000e+00 6.855e-12 0.000e+00 1.251e-11 0.000e+00]
potforlio return: [-1.601]

202009
allocation: [5.274e-12 1.000e+00 0.000e+00 3.791e-11 0.000e+00 1.717e-11]
potforlio return: [-0.241]

202010
allocation: [3.011e-12 1.000e+00 0.000e+00 2.152e-11 0.000e+00 6.898e-12]
potforlio return: [8.8]

202011
allocation: [1.083e-12 1.000e+00 0.000e+00 3.266e-11 0.000e+00 7.821e-12]
potforlio return: [4.244]
```

In [61]:
```
import matplotlib.pyplot as plt
plt.rcParams['figure.figsize']=(12.8, 7.2)

x=pd.date_range('2018-01-01','2020-12-01',freq='M')
y1 = low_risk
plt.plot(x,y1)
y2 = mid_risk
plt.plot(x,y2)
y3 = high_risk
plt.plot(x,y3)
plt.xlabel("Time")
plt.ylabel("Accumulative return")
plt.legend(["lamda=-100","lamda=0","lamda=100"],shadow=False,fancybox="blue")
plt.show()
```


lamda=-100
lamda=0
lamda=100
Accumulative return
Time
15
10
5
0
−5
−10
−15
−20
2018-01
2018-05
2018-09
2019-01
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2021-01

In [ ]: